THE BEGINNING OF THE LONG DASH

MASTER COPY

Amendment: Index under Q, add Quebec ... 44

Beginning of the Long Dash sent to:

Alberta - 12845 - 102 Ave, Edmonton T5N 0M6

B.C. Pub Archives - Parliament Bldgs Victoria V8V 1X4

Manitoba - 200 Vaughan St. Winnipeg R3C 0P8

N.B. Historical Resources Admin - Box 6000,
Fredericton, N.B. E3B 5H1

Prov'l Archives, Colonial Bld St Johns Nfld A1C 2C9

Pub Arch of N.S. 6016 University Ave, Halifax B3H 1W4

Archives of Ont Ministry of Culture & Rec
77 Grenville St, Toronto Ont M7A 2R9

Pub Arch of PEI Box 1000 Charlottetown C1A 7M4

Legislative Library, Govt Bldgs, Que City G1A 1A5

Sask Arch Board, University of Regina, Sask S4S 0A2

Yukon Archives and Records Services, Dept of Info Resources
2071 Second Ave Whitehorse Y1A 2C6

Prince of Wales Northern Heritage Centre, Govt of N.W.T.
Yellowknife X1A 2L9

16-6-1985

Dear Malcolm:

How kind of you to send me a copy of your book; quite unexpected.

For someone who doesn't wear a watch, a turnip or a sundial, it was a revelation. The last time I had reason to consider time really accurately was during the War when, as a navigator, I was involved in what we called astro navigation. Today I count time in years they pass so quickly.

What is next? I look forward to your next contribution to Can Hist.

Sincerely

Ken Roberts

Co-author of "Canoe"

Public Archives Canada | Archives publiques Canada

Archives Branch | Direction des Archives

395 Wellington Street
Ottawa, Ontario
K1A 0N3

395, rue Wellington
Ottawa (Ontario)
K1A 0N3

Your file Votre référence

Our file Notre référence

6 January 1985

8921/85

Mr. M.M. Thomson
209 Dovercourt Avenue
Ottawa, Ontario
K1Z 7H3

Dear Mr. Thomson:

Thank you very much for donating your work diaries for the period 1932-1975. These combined with Mr. Henderson's will provide almost unbroken coverage of the Dominion Observatory from 1919 to 1972. That is quite a stretch!

I am enclosing a Deed of Gift form covering the diaries. Please sign and return it to me.

Once again, thanks for donating this interesting material.

Yours sincerely,

Larry McNally

Larry McNally
Acting/Science and Engineering Archivist
Economic/Scientific Archives
Manuscript Division

/tcl.

Encl.

Canada

THE BEGINNING OF THE LONG DASH

by

MALCOLM M. THOMSON

Public Archives Canada | Archives publiques Canada

Archives Branch | Direction des Archives

395 Wellington Street
Ottawa, Ontario
K1A 0N3

395, rue Wellington
Ottawa (Ontario)
K1A 0N3

Your file Votre référence

3 June 1985

Our file Notre référence
85—3607

Mr. Malcolm M. Thomson
209 Dovercourt Avenue
OTTAWA, Ontario
K1Z 7H3

Dear Mr. Thomson:

I wish to thank you for having donated your manuscript and research notes for The Beginning of the Long Dash to the Public Archives of Canada. For anyone studying timekeeping in Canada, your papers will be invaluable.

Enclosed is a Deed of Gift form for your signature. This form officially transfers ownership of the material to the Public Archives. Please note that the signature of one witness is required. After signing the form, please return it to me.

Once again, thank you for having donated these useful papers.

Yours sincerely,

Larry McNally

996-~~6576~~
-0769

Larry McNally
Acting Science & Engineering Archivist
Economic/Scientific Archives
Manuscript Division

Encl/dm

Canada

Public Archives Canada
Archives Branch
395 Wellington Street
Ottawa, Ontario
K1A 0N3

Archives publiques Canada
Direction des Archives
395, rue Wellington
Ottawa (Ontario)
K1A 0N3

17 July 1985

Your file Votre référence

Our file Notre référence
85/8320-T—4189

Mr. Malcolm M. Thomson
209 Dovercourt Avenue
OTTAWA, Ontario
K1Z 7H3

Dear Mr. Thomson:

Thank you very much for returning the signed Deed of Gift form. A photocopy for your files is enclosed. In accordance with your wishes, a tax credit appraisal will be prepared for the papers you donated to the P.A.C.

Thank you for your cooperation.

Yours sincerely,

Larry McNally

Larry McNally
Acting Science & Engineering Archivist
Economic/Scientific Archives
Manuscript Division

Encl/dm

Canada

APPENDIX "A"

Malcolm M. Thomson Papers
MG 31 J 22 (35 cm)
(for donation of material, 29 March 1985)

Contains the unedited manuscript of Thomson's The Beginning of the Long Dash: A History of Timekeeping in Canada including illustrations and reviews. Also included are research files on timekeeping in major Canadian cities, methods of timekeeping and individuals involved in the field (1935-1984).

MG 31 J 22

THOMSON, Malcolm M. (b. 1908). Astronomer.

Originals, n.d., 1934-1984. 35 cm.

M.M. Thomson was born January 3, 1908 in Nelson, B.C. He attended public school in Alberta and Manitoba. He obtained his B.A. from St. John's College, Winnipeg in 1929, and later, his MSc. from Yale in 1954. Thomson joined the Positional Astronomy Division of the Dominion Observatory, Ottawa, in May 1930, and became head of the division in 1957. In 1970, with the transfer of the Dominion Observatory to the National Research Council, Thomson assumed charge of the Time and Frequency section of the Applied Physics Division, where he remained until his retirement in December 1972.

In his retirement, he wrote a history of timekeeping in Canada. This was published in 1978 as The Beginning of the Long Dash, by the University of Toronto Press.

Presented in 1985 by Malcolm M. Thomson, Ottawa, Ont.

"The Beginning of the Long Dash", n.d., 1978-1981. 10 cm (volume 1).
Contains the unedited manuscript of Thomson's book, including illustrations and photos. The published version contains only about two-thirds of this manuscript. Also included are reviews of the book from newspapers and journals, mostly Canadian.

Timekeeping, n.d., 1934-1984. 16 cm (volumes 1-2).
Thomson's research on the history of timekeeping, with files on timekeeping in major Canadian cities. In addition, there are articles on longitudes at various observatories, and information on methods of timekeeping, particularly the atomic clock. The files also include offprints, photocopied articles, notes and correspondence.

Reference Files, n.d., 1970-1972. 9 cm (volume 2).
Notes, correspondence and articles about, and by, Charles F. Dowd, Sandford Fleming, and Prof. W.B. Jack & Dr. J.B. Toldervy. Also contains photocopies of sessional papers regarding the Dept. of the Interior and the Dept. of Marine & Fisheries from 1869-1919, and photocopied articles from the Journal of the Royal Astronomical Society of Canada.

May 1985 | 7-9896
L. McFarlane | Economic/Scientific

INTRODUCTORY NOTE

The preparation of this brief historical sketch of timekeeping in Canada was inspired by three facts. Seated one day beside Andrew Thomson, former Director of the Meteorological Service, it was perhaps in 1967, I was informed by him that the Department of Marine and Fisheries had made a considerable contribution to timekeeping in Canada. I had just contributed an historical review called Astronomy of Time and Position for the special issue of the Journal of the Royal Astronomical Society of Canada, published in Canada's centennial year. Almost apologetically the final sentence reads "In this review, no mention has been made of the contributions to timekeeping in Canada by the Meteorological Service". I determined then to find out more about this contribution.

The second fact was that having joined the time service of the Dominion Observatory in 1930, and was facing retirement at the end of 1972, I felt some responsibility for assembling some of the events that I had witnessed over 4 decades.

The third fact was that J.P. Henderson, my mentor and coach during my first decade at the Observatory, had kept a fairly careful diary throughout his 37 years at the Observatory. A few years have been lost, but all that could be found were placed at my disposal.

Then began the long and patient search for information surrounding the development of time services to meet the needs of a growing community. What was the origin of the observatories at Fredericton, Toronto, Quebec, Montreal, Saint John, N.B., Kingston, Ottawa and Victoria? Why was Halifax, a year round port, not equipped with a federal timeball observatory back in 1870 when Saint John, N.B. was? Why did the Dominion Observatory finally become the official timekeeper? Perhaps some of these questions have been answered.

Malcolm M. Thomson

HISTORY OF TIMEKEEPING IN CANADA

CONTENTS

Transit of Venus (1882) observations were organized. In 1936 responsibility for time was relinquished and Toronto became fully absorbed with the Meteorological Service of Canada.

6. Montreal. The McGill Observatory, founded in 1862, provided time
Pg 82
for the local business community, harbor, and railway, and collaborated with Toronto in meteorological observations. McLeod re-determined the longitude of Montreal with respect to Harvard and later with respect to Greenwich. McGill time continued to serve the telegraph companies until the duty was transferred to the Dominion Observatory in 1947.

7. Saint John, N.B. A time ball observatory was built in Saint John
Pg.109
in 1870. G. Hutchinson and his son D.L. Hutchinson provided time and weather information for the maritimes for nearly six decades. Francis M. Barnes maintained the service 1927-1949, and in 1951 the observatory was closed.

8. Halifax. William Crawford, followed by R.H. Cogswell, clock makers,
Pg.127
provided correct time for Halifax and the Citadel, commencing 1832, for which $100 per annum was paid. In 1904 a time ball was installed at the Citadel and controlled from Saint John.

9. Kingston. Timekeeping at Kingston benefited by the sounding of bells
Pg.136
in the adjacent military dockyard. In 1860 an observatory was built, and through the efforts of J. Williamson and N.F. Dupuis of Queen's University, a time service was developed. By the end of the century the McGill signal began to serve the community.

10. Victoria and Vancouver. Victoria benefited by time signals from
Pg.146
ships in the harbor and later by the firing of a time gun by the military garrison. With the completion of the telegraph line, Vancouver and Victoria received the McGill time signal. In 1915 F. Napier Denison established a time service for Victoria, but by 1930 both he and Shearman of Vancouver were using radio time signals.

11. Sir Sandford Fleming. Fleming was noted as a railway surveyor and
Pg.166
builder, and as a promoter of standard time. At the International Conference held in Washington in 1884, time zones were approved together with the recognition of Greenwich as the prime meridian.

12. The Cliff Street Observatory. It was a small wooden structure
Pg.179
perched on the bank overlooking the Ottawa River. Built in 1890, it served as the Canadian prime meridian from 1896 to 1905. E.G. Deville, W.F. King, and O.J. Klotz were the prime promoters. King explains limitations of astronomy to surveying. Klotz extends longitude chain across Pacific to Australia.

13. The Dominion Observatory. Completed in 1905, it succeeded Cliff
Pg.194
Street as the site of the prime meridian for the survey of Canada. Provision was made for a fully modern time service with R.M. Stewart in charge.

14. Clocks of the Time Service. The finest pendulum clocks, two Rieflers
Pg.204
and one Shortt Synchronome, were acquired, and by 1927 an efficient clock vault was built. The downtown time service expanded to a maximum of about 750 dials, but after World War

II they gave way to frequency dials which required no attention from the Observatory.

15. The Time Signal Machine. R. Meldrum Steward devised a mechanism
Pg 217 which was controlled by a sidereal pendulum and had an output of mean time seconds pulses. From 1938 to 1950 it controlled the time signals from the Observatory, to be replaced by a crystal controlled signal generator by Muirhead.

16. Astronomical Equipment of the Time Service. The meridian circle
Pg.227 transit was used for five decades on international programs to improve the fundamental star catalogue. An experiment with a mirror transit telescope was unsuccessful. For timekeeping the meridian circle was replaced in 1935 by the broken type Cooke transit, and the transit in turn was succeeded in 1952 by the photographic zenith tube (PZT). A second PZT is located at Calgary. A Markowitz moon camera was used for a few years, commencing with the International Geophysical Year, 1958.

17. The Quartz Crystal Frequency Standard. Quartz crystal frequency
Pg.265 standards acquired by other government departments in the 1930's demonstrated a performance superior to the primary pendulum, and led to electronic timekeepers at the Dominion Observatory.

18. Radio Time Signals. Radio permitted the extension of surveys into
Pg.287 remote frontier areas where no telegraph line existed. A regular program of time signal reception permitted comparison of astronomical time determinations and measurement of long

geographical arcs. Two stations, Ottawa and Vancouver, formed Canada's participation in the World Longitude Campaigns of 1926 and 1933.

19. Time Distribution from the Dominion Observatory. Distribution of
Pg.314 time pulses by wire was augmented by radio time signals commencing in the 1920's. By 1938 they were designated CHU with the present frequencies, 3330, 7335, and 14670 kHz. Observatory time became official by Order-in-Council in 1941. In 1947 CHU was moved to the Greenbank Road. It is now cesium controlled with a bilingual voice announcement of time each minute. New methods of time distribution and synchronization are being studied.

20. Atomic Timekeepers. The National Research Council has been to the
Pg.345 forefront in the development of the cesium atomic standard and the hydrogen maser. International comparison of laboratory standards involves a portable cesium standard, and precise radio signals such as Loran C and the T.V. synchronizing pulse. Amalgamation of NRC and Dominion Observatory facilities in 1970 resulted in the formation of the Time and Frequency Section of the Physics Division of NRC.

Time

A General Statement

on Timekeeping in Canada

TIME

General

Ever since people have gathered themselves into communities they have contrived some method for marking the passage of time. The first settlers found the Indians capable of measuring time from moon to moon, and season to season. And in turn they mystified the Indians with the family clock or watch which they brought among their treasured possessions.

According to Anne Langton in her book, Gentlewoman in Upper Canada, (Clarke Irwin, 1950) the household with a watch or clock in 1840 maintained considerable prestige among the neighbours. By contrast, the community with neither watch nor clock nor village bell had difficulty in the regular conduct of Sunday church services and weekday school.

Certain traditions were brought from the rural background of Europe which demonstrated that people can manage without a clock. Dr. A.P. Baerg, a physicist at the National Research Council, Ottawa, recalls that as a boy on a prairie farm he would be told to return from the field for supper at 7 p.m. Toward the end of the afternoon he would determine the height of the sun above the horizon as so many handwidths, measured by extending the arm full length and bending the wrist at right angles. One handwidth represented half an hour. So without benefit of a mechanical timekeeper the young lad headed back across the field at the required hour.

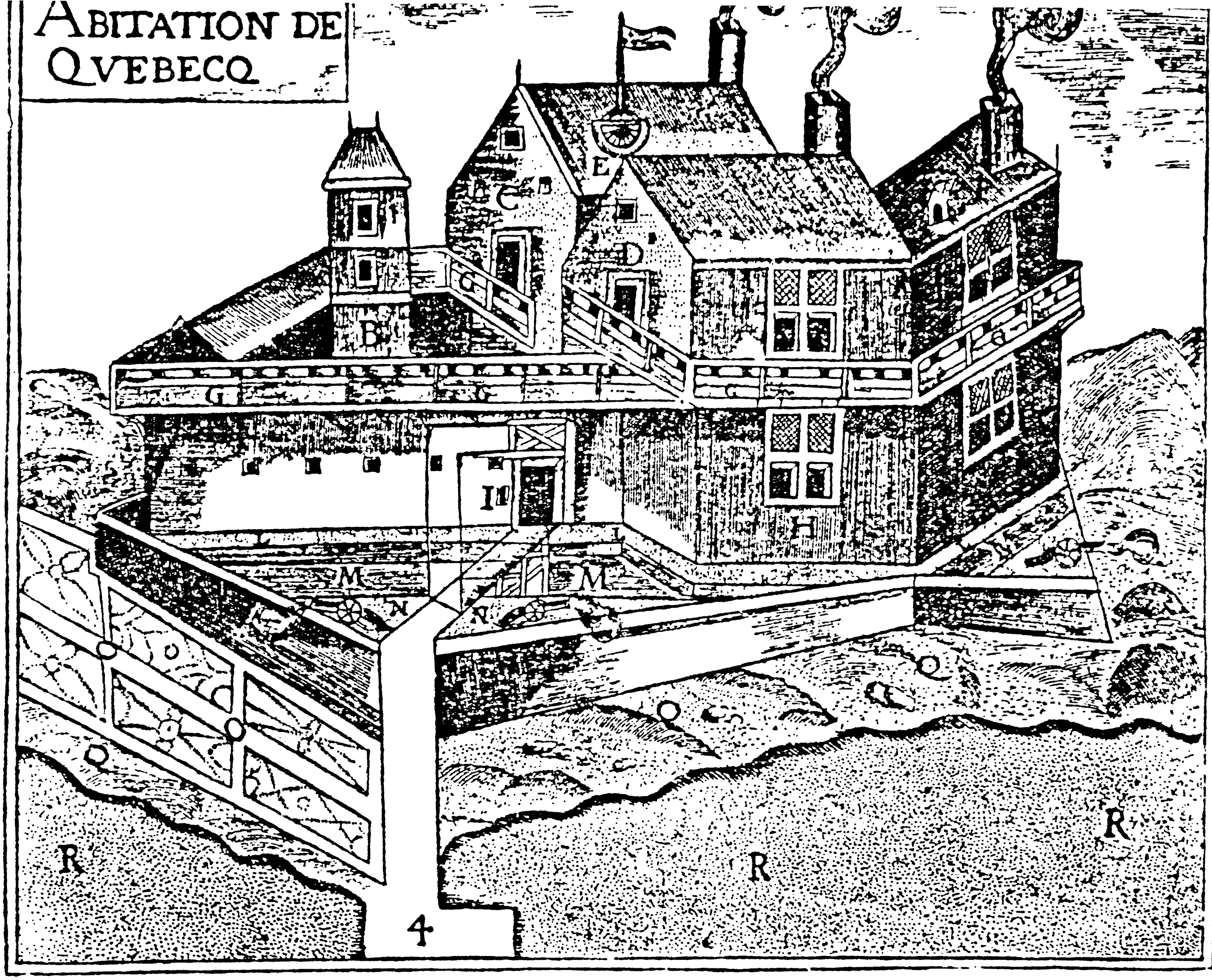
By contrast, Professor W.L. Morton, the historian, recalling his boyhood days on the farm at Gladstone, Manitoba, confided, "My father was always concerned that our dollar watches should be correct so that we would stop work on time. His reason was that the horses should not be overworked!"

There were familiar "sun marks". One person recalled that her grandmother used to start preparing the noon meal when the sun reached a certain board in the summer kitchen. Presumably her "biological clock" took over on days that were overcast.

Because the early communities had few clocks, and those few that did exist could well be many minutes apart, some synchronizing device was necessary. The church bell served this purpose to a degree. In New France, from the earliest days, it was the custom for the Angelus to be sounded in the church centered communities three times a day, morning, noon and evening. Across the wide expanse of the prairies the regular passing of the train, sometimes many miles away, provided a means of checking the clock in the farm kitchen.

In urban communities, a uniform time was provided by the sounding of fire alarm bells. For instance, Dr. Charles Smallwood, founder of McGill College Observatory, provided a signal to ring the city fire alarm bells at 7 a.m., noon, and 6 p.m. for the benefit of shops and factories. The signal from the Toronto observatory sounded the fire alarm bells at 11:55 a.m.

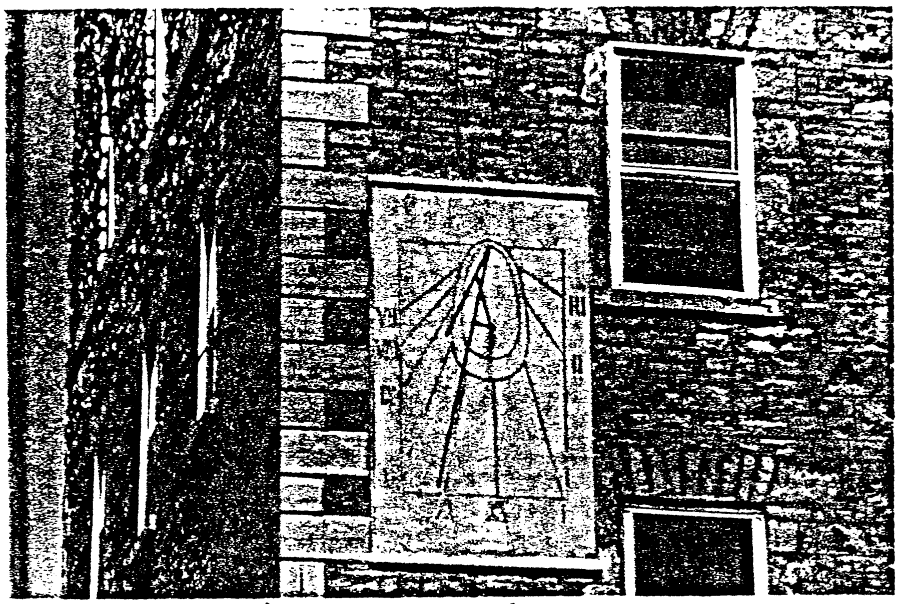
Individual factories in Canadian cities followed the practice of sounding a harsh penetrating whistle which could be heard above the noise within the plant and throughout the surrounding community. Even in post World War II years, the steam whistle of the E.B. Eddy Company, on the Ottawa River between Ottawa and Hull, sounded a whistle four



A Le magazin.
B Colombier.
C Corps de logis où ſont nos armes, & pour loger les ouuriers.
D Autre corps de logis pour les ouuriers.
E Cadran.
F Autre corps de logis où eſt la forge, & artiſans logés.
G Galleries tout au tour des logemens.
H Logis du ſieur de Champlain.
I La porte de l'habitation, où il y a pont-leuis.
L Promenoir autour de l'habitation contenant 10. pieds de large iuſques ſur le bort du foſſé.
M Foſſés tout autour de l'habitation.
N Plattes formes, en façon de tenailles pour mettre le canon.
O Iardin du ſieur de Champlain.
P La cuiſine.
Q Place deuant l'habitation ſur le bort de la riuiere.
R La grande riuiere de ſainct Lorens.

p. 303.

Fig. 1 Pg. 3 Abitation de Quebecq, built in 1608 by Champlain. In Laverdière, C.-H. ed Ouvres de Champlain Quebec, 1870, Torne III, facing p. 155. Courtesy Public Archives of Canada.



Sundial - Sussex St Ottawa April 1973

Fig. 2
Pg. 3

Vertical sundial facing south-east at the corner of Sussex Drive and Bruyère Street, Ottawa, was placed in position soon after the building was erected in 1850.

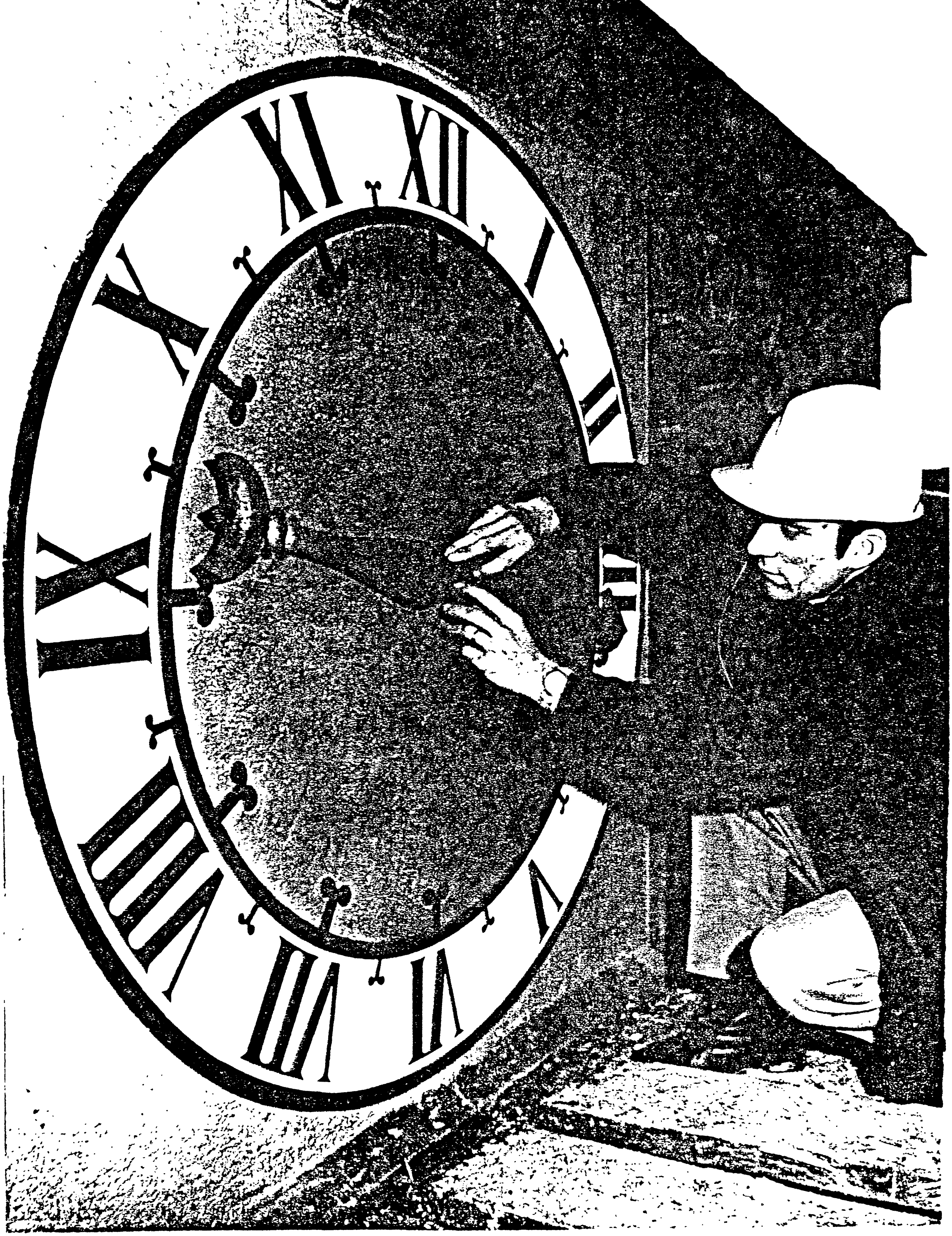


Fig. 3
Fig. 3

Tower Clock, Fortress of Louisbourg, Cape Breton. The clock has been restored according to the design of its original, and so has no minute hand. Courtesy National Parks Branch, Indian and Northern Affairs Department.

times a day as follows: 8 a.m. to start work; 11:57 a.m. to provide 3 minutes for wash up; 1 p.m. to return to work; 4:57 p.m. for a 3 minute clean up before going home for supper. Today this whistle is silent.

There were other whistles in Ottawa which would form a chorus with Eddy's. In the midst of them could be heard, even from the distance of the Dominion Observatory at the Experimental Farm, the firing of the Noonday Gun at Parliament Hill. Fig. 51 That, of course, was during the 1930's, before the city population explosion, before the proliferation of the motor car, and before the construction of enormous buildings in downtown Ottawa.

The sundial, one of the earliest devices used at the dawn of history for subdividing the day, played an important part in early Canadian communities.

When Champlain built the Habitation at Quebec City in 1608, he mounted the flag of France and also a sundial on one of the roofs. Fig. 1 Mechanical clocks had been under development since the 14th century. But in addition to their expense, they were not very accurate. The sundial was therefore invaluable as a means of checking the time of the mechanical clocks. So the sundial is to be found, in some instances, gracing the wall of a church or a school, where it is in plain view and out of reach of souvenir hunters. Fig. 2

The Fortress of Louisbourg, built by the French on Cape Breton Island as a guardian of New France, was equipped with a tower clock. It was one of the earliest on the North American continent, and according Fig. 3 to John Lunn, Superintendent of the park which today shelters the reconstruction of the Fortress, it was equipped with an hour hand only.

Recovered from the excavations is a sundial made of slate, some of the fragments of which have not been found. The date 1722, clearly engraved on it, indicates that it was a part of the early community. Fig. 4

Scientifically, the sundial also played an important role in Canada during the second half of the 19th century. Little was known of the weather pattern which governed the shipping route through the Hudson Straits to the Hudson Bay ports. The private ships of the Hudson Bay Company ventured along the route during the brief season that navigation was assured, and for the rest of the year it was left to the scattered native settlements. Lieut. Edward Chappel of the British Admiralty, who was involved in the hydrographic survey of Hudson Bay in 1814, commented on the incorrectness of existing charts, due to "reluctance of officers of the Hudson's Bay Company to divulge to any outsiders, navigational information in their possession relating to the Bay or its entranceways" (Men and Meridians by Don Thomson, Vol. 1, pg. 185, Queen's Printer, 1966).

The Hudson Bay Expeditions conducted by the Department of Marine and Fisheries in 1884 to 1886 were organized to study the weather pattern throughout the year, and to ascertain for what period of the year the straits were navigable. There was no telegraph into this territory either to carry messages or to transmit a time signal. Each of the scientific parties had to carry some means of recording the time of day, and also of coordinating the time with that carried by other parties. To do this they were provided with a timepiece and a sundial. On favourable days, the timepiece was to be corrected by the sundial at local noon. At each station the correction card for reducing from apparent

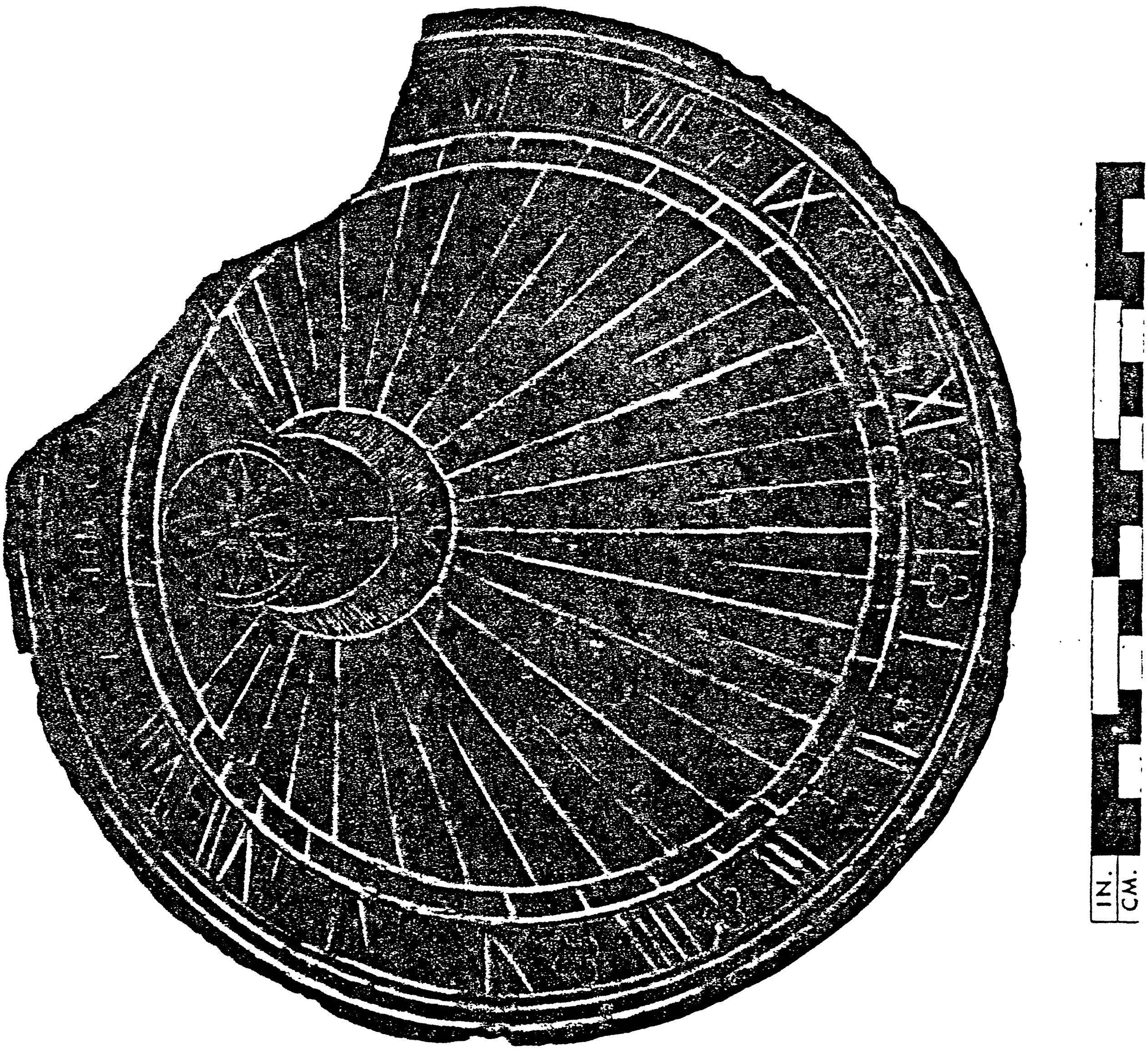


Fig. 4
Pg. 4

The fragments of a slate sundial were recovered during excavations associated with the restoration of the Fortress of Louisbourg. The date is 1722. The latin inscription may be reconstructed to read, "Sum sine sol(e nihil)" meaning "Without the sun I am nothing". Courtesy National Parks Branch, Indian and Northern Affairs Department.

Fig. 5
Pg. 5

Sundial at Fort Providence, Northwest Territories. At latitude 61° 21' N the gnomon appears to be close to the vertical. (Photograph by J.P. Henderson, Aug. 29, 1921) solar to mean solar time also gave the correction to the 75th meridian. So within the limits of accuracy, this primitive method assured that a synoptic chart could be drawn from the observations.

In his report of 1902, H.V. Payne, an inspector for the Meteorological Service, mentioned that it was necessary to make sundry adjustments to sundials located in some observing stations in Newfoundland. They were required to regulate the clocks used in making the daily weather observations.

When a party from the Dominion Observatory travelled down the Fig. 5
Mackenzie River during the 1921 and 1922 seasons, providing astronomical control points for a survey line from the existing survey at the 60th parallel right down to the oil fields of Norman Wells and also to Arctic Red River, they found some of the local communities with no time indicator. So, a few sundials were designed and mounted on the cement piers which the party had built for gravity studies.

Doubtless there are many other instances, hidden in the history of Canadian communities, which would indicate the important role that the sundial has played.

When Captain James Cooke made his great voyages of exploration in the 1770's, he had the advantage of a reliable chronometer recently developed by Harrison. He also had a crew member who was an astronomer. Relying on the excellent performance of the chronometer, the astronomer was able to determine the longitude at each land fall, and navigation on the open sea was no longer guess work.

The ordinary mariner of the time was able to follow a similar pattern. Using a ship's chronometer set, for example, to the local time of Liverpool, he would take observations of the sun or other celestial objects to determine local time. The difference between the observed local time and the chronometer time would then be a direct indication of the longitude difference east or west of Liverpool (and hence Greenwich). The method was scientifically correct. It was, however, only as reliable as the chronometer which was keeping the local time of the home port. Since few ships could be equipped with a chronometer of Harrison excellence, navigation was far from perfect. The longer he was away from home port, the less reliance could the mariner place on his chronometer. It was necessary to check the time and the rate of the chronometer at every opportunity, and particularly after the long Atlantic crossing. So there was a great need to establish a source of correct time at key locations on the North American continent. This gave rise to the establishment of an observatory in the Citadel at Quebec City in 1855, and to another in Saint John, N.B., in 1869, and to the financial support of the McGill Observatory, which was built in 1862. The true position of each of these ports was determined with respect to Harvard College Observatory, the best determined spot on the North American continent. Local time was derived from transit observations, and this was indicated to the shipping in the harbour by the dropping of a time ball at 1:00 p.m. local time each day.

Equally important to the mariner, and important alike to the farmer and others who are land-based, was a foreknowledge of weather disturbances. Meteorology as a science was recognized by the government Magnetic Observatory at Toronto in the 1840's and McGill in the 1860's. In each case it was realized that observations should be timed with the greatest possible accuracy. Also the directors of the Toronto Observatory, commencing with Captain Lefroy in 1841, recognized the importance of collecting data on temperature, wind, clouds, etc., from as many locations as possible. Because of this initiative, Toronto became the coordinating centre, both for the processing of weather data, and for the regulating of the time used in making the observations.

As long as people were limited to the sailing vessel and to the horse and buggy, and as long as communication was limited to the speed of a letter delivered by stage coach, it mattered little that each town kept its own time. But when the sail gave way to steam, and the stage coach gave way to the railway train, and communications over great distances became almost instantaneous as a result of the telegraph, then it became a source of confusion that adjacent towns differed by several minutes. The confusion of times was particularly noticeable on the American transcontinental railway lines which were the first to span three hours of local time. So they were among the first to give thought to some orderly arrangement, Charles F. Dowd being a leading proponent of time zones. Sandford Fleming of Canada, noted railway engineer and builder, brought the question to international attention, and was largely instrumental in having the international convention convened in Washington in 1884, at which Greenwich was selected as the zero meridian, and time zones of 15 degrees to the east (ahead) and to the west (behind) Greenwich at the rate of one hour per zone were proposed. Today one has to remember that our transcontinental phone system can cause embarrassment to the unwary. There is a three-hour time difference between Ottawa and Vancouver, and a phone call placed at 9 a.m. in Ottawa can rouse a protesting and sleepy voice in Vancouver at 6 a.m.!

In 1883, about the same time that local mean time was abandoned in favor of standard or zone time, the time ball observatories of Quebec and Saint John, N.B., were officially placed under the supervision of the Director of the Toronto Observatory, Charles Carpmael. He inaugurated a system of time exchange by telegraph once every two weeks to insure uniformity. C.H. McLeod, Director of McGill Observatory, voluntarily joined the exercise. His predecessor, Charles Smallwood, had inaugurated a time service to the local telegraph office in the 1860's because the observatory had been sponsored by the railway for that purpose. In 1869, at the request of the Postmaster General, his daily time signal was relayed to Ottawa to provide a time for the noonday gun.

It was a straightforward operation for the McGill time signal to advance across the country with the advance of the railway and telegraph to the Pacific coast. Montreal, therefore, became the time centre for the whole eastern, prairie, and western network, retaining this distinction until June 1944, when the Dominion Observatory took over.

The maritime provinces came under the influence of Saint John, N.B. Charles Carpmael of Toronto had delegated to Hutchinson, the director of the time ball observatory, the authority to coordinate the meteorological observations submitted each day by observers throughout the maritimes, and to publish the daily forecasts prepared at Toronto.

In 1901, Hutchinson reported that a daily time signal from the observatory was being sent by telegraph throughout the maritimes and was being used by the railways, the telephone company, and the business community. A time ball had been operating in Saint John Harbour for the benefit of shipping since June 1870. In 1904 a second time ball was installed at the Citadel in Halifax and operated directly from Saint John. Hutchinson and his successor, Francis Barnes, continued to provide correct time for the business, transportation, communication and shipping interests of the maritimes until about 1950, when the observatory was dismantled. It was not without regrets and protests by the local community that this service was discontinued.

At the west coast, F. Napier Denison inaugurated a time service in connection with Gonzales Meteorological Observatory, Victoria, in 1915. For more than two decades, the time was made available by land line, by telephone, and by radio from the observatory. A time ball was operated for the benefit of the shipping and business enterprises of Victoria harbour until 1931, and the firing of the noon and 9 p.m. gun was controlled until the time service folded after 1937. Time from the Dominion Observatory at Ottawa had by now gained official recognition.

The time as distributed by the several meteorological observatories, namely, Toronto, Quebec, Saint John, and Victoria, and by the McGill Observatory at Montreal, was derived initially from star observations at each observatory. By 1920 it became evident that a convenient check on the local clock at each location could be made by radio reception of time signals from Washington, D.C., or from San Francisco. By the early 1930's, transit observations for time at all meteorological observatories except Saint John, N.B., were discontinued in favor of the more readily available radio time signals.

Confederation occurred in 1867 and two years later, in 1869, the Hudson Bay Company yielded its control over the enormous expanse of western Canada, extending from Ontario to the Pacific. The details of the exchange do not form part of this discussion. What does concern us is that one of the terms of union by B.C. was that a trans-Canada Railway be built to form a line of communication. This railway was completed in 1885. Newcomers flowed into the country from all over Europe, and farm holdings and towns sprang up along the right of way as well as along the old trade routes.

"It was realized", writes John Vicars in his History of the Surveys Made Under the Dominion Lands System, 1869 to 1889, "that one of the first duties of the Federal Government was to devise and adopt a comprehensive scheme or system upon which to conduct the surveys of the country, and to proceed with the survey of such portions as were likely to be required for immediate settlement".

The actual survey commenced in 1869 with Pembina, North Dakota, at the U.S.-Canadian border, as the starting point. While much of the survey work depended upon direct measures along the ground, both north-south and east-west, the final location of each key position was determined astronomically.

Latitude, the distance from the equator, is readily determined by measuring the altitude of the Pole Star, or by measuring the altitude at meridian passage of any of a number of stars whose positions are well known.

Longitude presents a more complicated problem. It is well known that a star which crosses the meridian of, say, Winnipeg will in a little more than an hour cross the meridian of Calgary, and about 35 minutes later will be on the meridian of Vancouver. It is a result of the earth turning on its axis. After a complete rotation of the earth, the star will again appear on the Winnipeg meridian, and 24 hours of sidereal or star time will have elapsed.

Hence, if at two observing locations the same star is seen to drift across the field of each transit instrument, the difference in the observed time of transit is an exact measure of the difference in longitude. Each location must have a reliable timepiece, and in addition there must be direct communication in order to make an accurate comparison between the two clocks. The telegraph line, once it was installed, provided this link.

By 1888, Winnipeg had become the base station. W.F. King, Chief Inspector of Surveys, occupied Winnipeg, and O.J. Klotz the field stations to the west.

For more than a year, both King and Klotz had urged the establishment of an observatory in Ottawa to serve as a Canadian base station. King, in 1887, had built a temporary observatory in his own garden in Ottawa. This was followed three years later by the erection of a small wooden building on a government lot on Cliff Street, overlooking the Ottawa River, which served to house the astronomical instruments until 1905. It was tied via McGill Observatory to Greenwich in 1896, thereby becoming the reference meridian for the survey of Canada. When the new Observatory on the Experimental Farm in Ottawa was occupied in 1905, the reference meridian was relocated there. The time service was based on the most modern astronomical clocks, transit instrument, and recording equipment. A few years later a large meridian circle telescope was added. A telegraph line into the time room, looping into both the CN and CP telegraph offices, made it possible to send a time signal to any part of the country served by telegraph.

The new observatory expanded its time service within the local government offices. An observing program was commenced which was designed to improve the catalogue positions of stars used for the determination of latitudes in Canada. The greater part of the Canada-USA boundary was defined in terms of latitude. Subsequently Canada participated in various observing programs aimed at improving the fundamental star catalogue which is used internationally as the stellar framework for celestial positions.

Radio had become an accepted vehicle for the dissemination of time prior to World War I. Following the war, daily reception of all available wireless time signals was instituted at Ottawa. Locally observed time was thereby compared directly with the time as determined at Washington, Paris, Hamburg and Greenwich, and later at Rio de Janeiro and Buenos Aires.

A team from the observatory occupied an observing site in Stanley Park, Vancouver, in 1926, and again in 1933, as part of an international effort to establish exact longitudes and to detect continental drift, if such existed. On each occasion local time was determined from star transits and compared with the time of reception of a number of radio time signals. The results were inconclusive.

The broadcast of radio time signals from the Dominion Observatory commenced during the 1920's, using the short wave part of the spectrum. During the 1930's the call sign CHU, and the frequencies 3330, 7335, and 14670 kHz were assigned. Following World War II the transmitters were removed from the Observatory to Department of Transport facilities on the Greenbank Road , where they are at present. The power, efficiency and precision of CHU have increased until today its output is monitored world wide, and is particularly useful throughout the eastern half of the North American continent.

R.M. Stewart, the scientist who was the first chief of the time service, and who later became the third director of the observatory, designed an ingenious Time Machine during the 1930's. It was a mechanical device, controlled by a master sidereal pendulum. Incorporated in the gearing was the ratio of sidereal to mean time, approximately 366¼ to 365¼, as well as the observed error of the sidereal pendulum which was a few hundredths of a second a day. The output, then, was mean solar time. For over a decade this time machine was used to generate the signals that were transmitted by radio and by direct wire from the Observatory. It was superseded about 1950 by a quartz crystal clock.

In December, 1936, there was a reorganization of government departments which involved the consolidation within the Observatory of federal responsibility of timekeeping, magnetic survey, and seismic research. The Meteorological Branch was thereby free to devote all its energies to the rapidly increasing demands of the Meteorological Service. This was followed in 1941 by an Order-in-Council which declared Observatory time to be official for federal purposes.

The first quartz crystal frequency standard to be acquired by the observatory arrived in 1941, the second in 1949. They paved the way for Canada's entry into the electronic period of timekeeping, though it was not without grave misgivings that the older astronomers saw the pendulum clock become a museum piece. The quartz clock had the advantage of subdividing the second into thousandths, whereas the pendulum has a basic period of two seconds. The early quartz clocks were uniform to a few thousandths of a second per day, which was almost an order of precision better than the pendulum. And the rapid improvement in quartz oscillators during the 1950's resulted in a clock with a precision of better than a ten-thousandth of a second per day. The pendulum, of course, was bolted solidly to a pier which was anchored firmly to the ground, and hence was subjected to the continuous vibration which is known to seismologists as microseisms. By contrast the quartz oscillator is carefully shock-mounted.

The small transit instrument was replaced by a photographic zenith tube (PZT) in Ottawa about the same time that the pendulum was abandoned. The PZT had the potential of measuring astronomical time with ten times the accuracy of the transit instrument, and from the same photographic plate one can measure the astronomical latitude with the same precision. From 1952 onward, when the Ottawa PZT became operational, Ottawa's contribution to international timekeeping was greatly improved. Also for the first time, Canada was able to contribute information on variation in earth rotation and polar wander, the two components of geophysical as well as timekeeping interest. With the installation in 1968 of a second PZT just south of Calgary, Alberta, on the same latitude as the PZT at the Royal Greenwich Observatory of Herstmonceux, earth dynamics studies were extended to include a long term observational program of continental drift.

The transition from the pendulum to the electronic (quartz) clock was accompanied by a subtle change in outlook by astronomers. The master clock had always been a sidereal pendulum whose rate was delicately adjusted to keep pace with earth rotation as measured by the stars. And when once set in motion the sidereal pendulum was left undisturbed. It was a simple matter to translate from sidereal to mean (solar) time.

The quartz clock was a product of the physics lab, and was designed to measure the official international second, which was 1/86400 of the mean solar day. So the precise quartz clocks and atomic frequency standards have, with rare exceptions, been built to give mean time, (now atomic time), and sidereal time has become a derivative.

During the 1930's astronomers and other scientists became aware that the earth was not a perfect timekeeper. Astronomers therefore proposed changing the unit of time to the mean solar year, and it was accepted by the International Committee of Weights and Measures. Accordingly in 1956 the second was defined as "the fraction 1/31 556 925.9747 of the tropical year 1900, January 0, 12 hours Ephemeris Time". It was adopted by the International Astronomical Union in 1958. Ephemeris time (E.T.) takes its name from the fact that it is based on the ephemeris (i.e. the equations) that describe the motions of the members of the solar system, and it is determined by measuring the motion of the moon around the earth.

The lunar clock, however, has its limitations. It can be likened to the old style clock with only an hour hand, except that in this case the hour hand requires 27½ days to make a circuit of the celestial dial. It cannot be read with precision. For long range astronomical work this presents no problem, but for the laboratory scientist who requires time discrimination to the microsecond or better, another solution was required.

The solution came in the development of the atomic clock in the 1950's. Initially it had a precision of a few parts in 10^9, but subsequent advances now make it possible to determine the second of atomic time to about a part in 10^{12} in the laboratory, and the end is not in sight. Commercially available units have only slightly less precision than the laboratory standards. Because of this the General Conference on Weights and Measures (CGPM) redefined the ephemeris second in the International System of Units as 9 192 631 770 periods of the radiation emitted between two hyperfine states of cesium 133 in the ground state.

Intercomparison of atomic standards now involves not only the monitoring of precision broadcasts such as the Loran-C navigation signal, but also the transportation of a portable cesium standard from one laboratory to another. This has been done on a fairly regular basis by the U.S. Naval Observatory in the course of monitoring their Loran-C stations.

The transmission of the Canadian time signals, via CHU, initially dependent upon a pendulum clock, is today controlled by a cesium clock, and monitored by T.V. link with the NRC standard. Furthermore, since the second is now a physical and not an astronomical constant, it was logical that in 1970 the facilities of the Dominion Observatory and the National Research Council be amalgamated to form the Time and Frequency Section of the Physics Division of NRC.

Because of the rapidity with which advancements are being made, it is unwise to make any predictions concerning the future. At the moment the NRC long beam cesium atomic standard, known as CS III, provides a means of determining the atomic second with an accuracy of about a part in ten to the twelfth. Cs V, which is being built on the same principle as Cs III but with improved technology, is in an advanced stage of construction. Accompanying the improvements on the cesium standard at NRC is an intensive study of the hydrogen maser which provides the best source of uniform frequency which, in turn, is so necessary to the development and testing of the cesium standard.

The search for perfection is not an end in itself. The demands of other branches of science, including space research, are pushing hard on the heels of the timekeeper.

The Unit of Time

THE UNIT OF TIME

There are three natural units of time: the tropical year marked by the return of the seasons, the lunar month marked by the return of the new moon, and the day marked by passage of the sun causing daylight and darkness to follow in regular progression. All other units, such as the hour, minute and second, are man-made to meet the needs of our complex society.

It might be noted in passing that the three natural units are not even multiples of each other. The tropical year contains 365.2422 days, the return of the new moon occurs on the average in 29.53 days, and there are 12.368 lunar months in the year. The ancients tried unsuccessfully to discover simple relationships. But the struggle with the calendar does not form part of this discussion.

What time is, of course, nobody knows. One man's guess is as good as another's. The present moment has been likened to the neck of a sand glass through which the sands of time are passing in quick succession and dropping into the great reservoir of the past. Fortunately this lack of a satisfactory definition of time is, for most purposes, no great handicap. All that is necessary is to be able to measure time. How many days before this did that event happen - or how many days after? These are for the most part the only questions concerning time that need to be answered, the former affording the time order for writing the history of things that are past, the latter assisting in planning or predicting the things that are to come. One attendant problem, of course, is the choice of a suitable unit of time. The unit has been based progressively on the day, the tropical year, and a natural transition period of the cesium atom.

For the measurement of time there was supplied, when the earth was created, an almost perfect clock. The earth was sent into space spinning on its axis, and has since continued to travel in an orbit, almost circular, about the sun. Since the easiest way to count the days is to note each time that the rotation brings the sun overhead, a solar day has been used as the ordinary unit of time. The introduction of clocks forced the adoption of a mean solar day, because apparent solar time, as displayed by a sundial, showed variations of as much as a quarter of an hour fast and slow in the course of a year.

The second, defined as 1/86400 of the mean solar day, became the fundamental unit of time. Earth rotation is measured by noting the passage of stars across the meridian, and the resulting sidereal time is translated into mean solar time by a simple formula. The primary pendulum timekeepers were thus sidereal. When properly adjusted they were sealed in air tight containers and left to run undisturbed in a thermally controlled vault. Any residual rate and resulting clock error was determined from the transit observations. The mean time pendulum time-keepers assumed a secondary role, and were adjusted as necessary each day.

In 1939, H. Spencer Jones, the Astronomer Royal, confirmed a growing suspicion by showing from astronomical evidence that earth rotation was not uniform (M.N. of the R.A.S. <u>99</u> 541 (1939)). His argument was to the effect that either the members of the solar system had conspired to change their predicted positions by amounts proportional to their orbital speeds, or else the earth had changed its period of rotation. Hence the unit of time, one of the funadmental constants, was not a constant. So long as timekeeping to an accuracy of better than a part in 10^8 (about a millisecond a day) was still academic, the problem was not too serious. By 1950, the problem could no longer be ignored. Crystal clocks had been developed to the point where they could be used to detect departures from uniformity.

Universal time (UT), which is mean solar time referred to the Greenwich meridian, is not uniform because of the following irregularities:

(1) A shift in the earth's crust relative to the direction in space of the earth's axis of rotation, known as polar wander and measured as a variation of latitude.

(2) A seasonal change, detected with the use of modern timekeepers, which is assumed to be periodic and hence is predictable. It is recognized as a slowing down of earth rotation in the spring near the time of the vernal equinox, followed by a speeding up in the autumn, and is perhaps due to meteorological causes.

(3) A gradual secular slowing down, amounting to about a millisecond per century, which has little impact on the present discussion.

(4) A random unpredictable variation in earth rotation which may be due to interaction between the core and the mantle of the earth. At present the period of earth rotation is about 3 millisecond longer than its average period during the 18th and 19th centuries. There is no way of predicting when this slowing trend will reverse.

Polar wander had been recognized since the turn of the century. About 1905, five small observatories were established as uniformly as possible about the world at 39°08' north latitude. Using the same catalogue of stars and visual zenith telescopes of the same design, they recorded the cyclical variation of latitude of each station, thereby indicating the irregular motion of the pole of rotation with respect to its mean position. The principal period is 14 months. Accompanying the motion of the pole is an east west shift of the meridian of each place, with a value of zero at the equator, and becoming maximum for places at the north and south poles. The displacement is small, amounting at Ottawa to a maximum error ±30 milliseconds.

Modern observation of earth rotation on any one night can be made with an uncertainty of 3 or 4 milliseconds, and by averaging over a few nights can be reduced to a millisecond or less. The mean solar time derived from this is called UT0. The Bureau International de l'Heur provides corrections for polar wander and seasonal variation which result in the following:

UT0 plus correction for polar wander = UT1

UT1 plus correction for seasonal variation = UT2

UT2 is reasonably uniform from day to day, but the inherent irregularities due, in particular, to (4) above make it quite inadequate for the definition of the unit of time, the second. However, it must be noted that an accurate knowledge of UT is essential in all modern endeavours which require a knowledge of the attitude of the earth in space. Surveying, celestial navigation, and the launching and control of space vehicles are examples of such endeavours.

In 1952, Ottawa Photographic Zenith Tube (PZT) observations began to contribute direct evidence of polar wander. By 1955 the Bureau International de l'Heure was providing information on polar wander and seasonal variation to each of the national time services so that corrections to the time broadcasts could be published in terms of UT2.

Responding to the general need for a revision in the unit of time, the Conference of Fundamental Constants held in Paris in 1950 under the Chairmanship of André Danjon, Director of the Paris Observatory, proposed that the second be defined in terms of the year instead of the day, in particular the year 1900. The International Astronomical Union (IAU) at the General Assembly in Rome, 1952, gave its approval.

A resolution of the International Committee of Weights and Measures, Paris in 1956, states that:

"The second is the fraction 1/31 556 925.9747 of the tropical year 1900, January 0, 12 hours Ephemeris Time."

The reason for stating the year in this manner is that it defines the second as a constant. The tropical year is decreasing at the rate of 0.530 ephemeris second per century. It is thus easy to relate any particular year to the tropical year for 1900.

Ephemeris Time (ET) is the independent variable in the equations which describe the motions of the sun, moon, and planets. It is essential to astronomy because it forms the continuous link between observations of the remote past and predictions into the future. Furthermore it can be observed directly by observing the position of any member of the solar system against the background of stars, and it is independent of earth rotation. The usual practice is to observe the moon as the time indicator and the background of stars as the celestial clock. Its position can be determined by the use of transit instruments, and moon cameras, and by the observation of lunar occultations.

Formal approval of the resolution by the IAU was given at the General Assembly in Moscow in 1958.

The obvious practical problem is that ephemeris time is not readily available. The moon does move faster than the sun or any of the planets against the star background. Even so it requires 27½ days to complete one circuit. The position of the moon in its orbit is predicted according to ephemeris time, but the observations are recorded in UT. The discrepancy in the apparent position, both in right ascension and declination, may be translated into an increment of time required for the moon to travel this small distance along its orbit. It is the ΔT between ephemeris time and UT, and is expressed in the form

$$ET = UT + \Delta T$$

Observations must be averaged over a period of about a year to obtain a determination of ephemeris time with a precision approaching a part in 10^9. As the time base is expanded to a century the relative precision, according to Jean Kovalevsky (Metrologia, 1, 169, (1965)), approaches about 3 parts in 10^{10}. While this is invaluable to the astronomer in relating events of the past and projecting forecasts into the future, it fails as a readily available time scale of short term high precision for laboratory purposes.

The first cesium atomic reasonator was built by L. Essen and J.V.L.Parry at the National Physical Laboratory, Teddington, England, and placed in operation in 1955. It was calibrated with respect to the value of the second of UT2 at the time. After a three-year experiment conducted jointly with the U.S. Naval Observatory, the value of the ephemeris second was derived as

9 192 631 770 ± 20 cycles of a transition of the cesium atom, and this was also adopted by the International Astronomical Union in Moscow in 1958. But the proposal to adopt it as an alternative to the ephemeris second was rejected. Promising research with other elements, principally hydrogen and thallium, raised the question as to which one would ultimately show the greatest precision and be readily reproduced at each repetition of the experiment.

Further research into the cesium resonator resulted in a greatly improved accuracy and reproducibility of laboratory standards, and also led to the introduction in quantity of commercially designed atomic clocks of high precision. Time could be intercompared between laboratories to the microsecond or better, and frequency to a part in 10^{11}. From the standpoint of the physicist all the requirements of high accuracy and of long term continuity were being demonstrated by the cesium atomic clock. The passage of years confirmed the original value, and in October, 1967, the General Conference on Weights and Measures (CGPM) defined the second in the International System of Units as 9 192 631 770 periods of the radiation emitted by the transition between two hyperfine states of the cesium 133 atom in the ground state.

At the same time the CGPM recognized the continuing use of the ephemeris second in all astronomical computations.

There was a continuing requirement for mean solar time in civil activities such as surveying, celestial navigation, and space exploration. Initially this was met by offsetting the output of the cesium standard to produce UT2. The offset was established on January 1st for the ensuing year, and any departure due to a change in earth rotation was accommodated by a step adjustment of a fraction of a second at the beginning of a month. The time and frequency produced in this manner was coordinated through the Bureau International de l'Heure and called Universal Time Coordinated (UTC).

As the table indicates, the offset in frequency commenced in 1961, and continued for 11 years. The system was inadequate because, while it indicated UT with but small error, it did not make the unit of time readily available.

Offsets and Step Adjustments of UTC, Until 1973 Dec. 31

Date (at 0h UT)			Offsets	Steps
1961	Jan.	1	-150×10^{-10}	
	Aug.	1	"	$+0.050^s$
1962	Jan.	1	-130×10^{-10}	
1963	Nov.	1	"	-0.100^s
1964	Jan.	1	-150×10^{-10}	
	April	1	"	-0.100^s
	Sept.	1	"	-0.100^s
1965	Jan.	1	"	-0.100^s
	March	1	"	-0.100^s
	July	1	"	-0.100^s
	Sept.	1	"	-0.100^s
1966	Jan.	1	-300×10^{-10}	
1968	Feb.	1	"	$+0.100^s$
1972	Jan.	1	0	$-0.107\ 7580^s$
	July	1	"	-1^s
1973	Jan.	1	"	-1^s

On January 1, 1972, the offset was removed from UTC, and the atomic second became the practical unit of time. The UTC clock now runs fast with respect to UT1, gaining about 3 milliseconds a day, or a little more than a second a year. Should the rate of earth rotation accelerate, it is quite possible for the UTC clock to lose with respect to UT1. In any case, provision has been made to adjust UTC by the addition or subtraction of a "leap" second at appropriate intervals so that at no time will UT1-UTC exceed seven tenths of a second. The dates for applying the leap second are July 1 or January 1 at zero hours UT. Since UT1 is running slow, leap seconds must be inserted so that UTC will be retarded. This was done July 1, 1972, and January 1, 1973.

A paper value of atomic time called International Atomic Time (IAT) was extended back to January 1, zero hours, 1958. At the end of December, 1971, UTC was just a little less than 10 seconds slow at IAT. In order to make it ten seconds exactly, an increment of 0.107758 second was added to UTC. Each successive leap second has therefore resulted in the difference IAT-UTC being an integral number of seconds.

The difference, DUTI = UT1-UTC is indicated to the nearest tenth of a second by emphasizing certain seconds pulses on the radio time signals. On the signal emitted by the National Research Council of Canada time transmission, CHU, the emphasis is achieved by removing the central third of a pulse which is normally 0.3 second long, so that it sounds like a double pulse. If UT1 is fast, appropriate pulses between 1 and 7 are emphasized, and if UT1 is slow, seconds 9 to 15 are used. For instance, if UT1 is ahead of UTC by 2 tenths of a second, then pulses 1 and 2 will sound like double pulses, while if UT1 is slow by

3 tenths of a second, then pulses 9, 10 and 11 will be emphasized. The zero pulse of each minute is always lengthened and is never used for this program. Its leading edge marks the beginning of the minute.

The present system for the radio transmission of time signals makes the official unit of time instantly available. For some types of field work this is a close enough approximation to mean solar time (UT1). The correction, DUT1, can be applied, yielding UT1 to the nearest tenth of a second. Some time transmissions have a further incoded correction which can be applied to yield UT1 to 0.02 second. Frequently precision of this degree or better can await the published corrections to the signals.

Finally, then, the unit of time is known with greater precision than any of the other primary units, and it is available to all who wish to utilize it.

Ottawa Citizen
July 15, 1975.

How Canada keeps in time

The Beginning of the Long Dash, by Malcolm M. Thomson; University of Toronto Press; 190 pages; $17.50

By Don W. Thomson

Time, like space, is a human concept and the true nature of both conditions remains mysterious to our minds. "What time is, nobody knows," this author states in his landmark history of timekeeping in Canada.

But both time and space are measurable, time more precisely than, say, outer space. In fact, time can now be measured with the utmost exactitude. Such precision developed because it was and is a basic service to marine navigators, land surveyors and research workers.

Nowadays this service is made available to the Canadian public by television, radio, telephone, by second impulses, bilingual voice announcements and special code. But the most widely known is the CBC signal of 1 p.m. "at the beginning of the long dash."

From 1840 to 1973

The title is inspired yet natural. The volume is handsomely printed and well illustrated. The writer' makes no pretence at any literary style. His sentences convey facts with clarity and objectivity, the result testifying to Thomson's exhaustive research.

His story of Canadian timekeeping, 1840-1973, portrays the progress from primitive equipment to the most sophisticated devices now in any laboratory anywhere. He gives much of the credit for improvements to such scientific organizations as the National Research Council of Canada. The Dominion Observatory, Ottawa, was a pioneer, pressed by the needs of the early prairie land surveys and of the CPR construction.

It would be misleading to suggest that Thomson's scholarly, conscientious writing is packed with human interest. Yet he summarizes with skill the careers and contributions of men of vision, dedication and ability, trail blazers in more than one discipline.

These include Sandford Fleming, one of the foremost advocates of standard time zones, E. G. Deville, O. J. Klotz, W. F. King, W. S. McClenahan, R. M. Stewart and C. S. Beals, nearly all of whom worked in Ottawa. The author, another Ottawan, in modesty makes no claim for entry to this Hall of Fame but undoubtedly belongs there.

The author points out that by the 1920s radio began revolutionizing time distribution as electrical simultaneity over great distances, without relaying devices, became possible.

During the period covered by Thomson's book the astronomical pendulum achieved its finest performance as a timekeeping mechanism. In the years following its introduction it would be displaced first by the quartz oscillator, then by th atomic resonator. The unit of time known as the second, is now defined in terms of the cesium atom.

Daylight Saving Time

It was not until the beginning of World War I that the adoption of daylight saving time was seriously considered, although propaganda had been carried on for some years previously. In 1916 an Act of Parliament legalized its use in Great Britain, and since that time it has been maintained there. The United States adopted daylight saving over the entire country in 1918, and in 1919 its use there was fairly general. Now, by the Uniform Time Act of 1966, the entire U.S.A., with the exception of any State which exempts itself, observes daylight saving time each year from the last Sunday in April to the last Sunday in October.

In Canada, the Dominion Government, by the Daylight saving Act of 1918, required the adoption of daylight during the summer of that year. After 1918, the act lapsed.

During World War II there were three Orders-in-Council passed under the War Measurers Act dealing with the observance of daylight saving time:

(i) PC4494, 20 September 1940,directed "that Daylight Saving Time, so called, (being one hour in advance of Standard Time) observed during the past summer months, shall continue to be observed until such time as the Governor-in-Council may otherwise order in the Province of Quebec and in the Province of Ontario by all persons, firms and corporations resident or carrying on business therein except transportation companies and telegraph companies."

(ii) PC547, 26 January 1942, ordered that "as of and from 2:00 A.M. Standard Time, Monday, February 9th, 1942, until otherwise ordered, the time for all purposes in Canada shall be one hour in advance of accepted Standard Time, and that Daylight Saving Time shall be observed by all persons, firms, corporations and public authorities, without exception, situate, resident or carrying on business in Canada."

(iii) PC6102, 14 September 1945, revoked the above.

Several provinces have legislation controlling provincial or municipal adoption of daylight saving. In recent years, due mainly to the impact of radio and television, and perhaps influenced by legislation within the U. S. A., it has beome an established custom in Canada, where daylight saving is observed, to advance the clocks for the six month interval from the last Sunday in April to the last Sunday in October.

William Brydone Jack and the Maritime Surveys

U.S. Congress approves 3-week extension of daylight-saving time

WASHINGTON (AP) — Congress has passed legislation to lengthen daylight-saving time by three weeks.

In a voice vote Tuesday, the House of Representatives sent the proposal, which has the support of the administration, to President Ronald Reagan's desk.

Under the plan, beginning next year people would set their clocks ahead an hour on the first Sunday in April. Since 1966, daylight-saving time has begun on the last Sunday in April. The date for reverting to standard time, the last Sunday in October, would not change.

In Canada, daylight-saving time begins and ends the same time as it is in the United States now. Officials have said they would consider matching any U.S. changes.

O i

Fal

I f

Lot

Newfie clock may go extra 1/2-hour ahead

By JULIAN BELTRAME
Southam News

HALIFAX — The time may soon be a-changing in Newfoundland.

A government green paper offers Newfoundlanders several compelling reasons to question the wisdom of continuing to observe their idiosyncratic half-hour time zone.

Newfoundland Standard Time dates back to 1875, when St. John's adopted a time three hours and 30 minutes behind Greenwich mean time, half an hour ahead of Atlantic Standard Time and 90 minutes ahead of Toronto and Montreal.

Today, it is the only jurisdiction in North America stuck between time zones.

In 1963, Premier Joey Smallwood attempted to change time by adopting Atlantic Standard, but so great was the protest that even the dictatorial Smallwood relented. A second attempt in 1967 fared no better.

The problem with Smallwood's proposal, said Bill Frost, assistant deputy minister of culture, was that he wanted to set time 30 minutes back to conform with Atlantic Standard, thereby compounding the problem that the half-hour zone was intended to address.

Newfoundlanders' main complaint is not so much with being stuck between time as being stuck in the dark most of the time.

During December, Newfoundlanders watch the sun set just a few minutes past 4 p.m. In June, they can spy the first light in the east as early as 4:08 a.m.

The green paper lays out five proposals. They range from advancing standard time by half an hour to extending and/or doubling Daylight Saving Time, along with different combinations of the three.

Besides stressing the obvious advantages of increased time for leisure activities in daylight and holding out the possibility of reduced traffic accidents, the paper argues that in this case, time advanced is money saved.

According to the National Research Council, consumers would save between \$1.20 and \$1.50 in energy costs for each month time is advanced one hour. In addition, the province could save up to \$400,000 in electrical and heating bills.

MONTREAL GAZETTE
6 FEB 1987

ROTAR ... ary 1985

Canada

everything.

Ontario aims to advance Daylight Saving Time

By Jack Aubry
Citizen staff writer

It should be a little brighter in Ontario and Quebec this spring.

The Quebec government tabled legislation Wednesday to introduce Daylight Saving Time three weeks earlier than usual, starting this April, and Ontario is preparing to follow suit.

Allan
Law by spring

Quebec becomes one of the first provinces to follow the lead of the U.S., where Congress has already changed the start of Daylight Saving Time. Governments have al-

Duncan Allan, Ontario's deputy minister of energy, said today his government is preparing similar legislation, which should be law by spring. While he did not know when a bill would be tabled, he predicted that it would be done soon because Ontario municipalities will have to be given advance notice of the change.

"The overwhelming reality is that it would be enormously disruptive if we didn't follow suit. Just airline, television and radio schedules alone would be greatly affected if we didn't," he said.

Quebec Justice Minister Herbert Marx tabled Bill 148 Wednesday at the National Assembly in Quebec City.

Canadian governments have been interested in extending Daylight Saving Time by a month or even two for 10 years, but were waiting for the Americans to take

...of the measure say ...energy, reduce traf... ...provide more recre... ...d benefit the sport... ...barbecue industries.

d,

xpand!

y matched:

Enlightened April

An earlier start to Daylight Saving Time has long made sense to Canadians. The National Research Council has documented the potential energy savings. And anyone who has tried to sleep in these latitudes in April knows the delights of 4 a.m. sunrises.

But changes here had to await enlightenment in the United States. The consequences of being out of sync with the great empire to the south (buses and planes arriving an hour late; the Cosby Show at 9 p.m. instead of 8) were just too horrendous.

The U.S. Congress has finally seen the light and shifted the start of Daylight Saving Time from the last Sunday in April to the first Sunday of the month. Canadian provinces are now scurrying to do the same thing.

It's about time Congress did something nice for Canada, if only by inadvertence. It almost makes up for shakes and shingles.

Citizen
Editorial pg
18 Nov 1986

Table I. Time Districts Legislated in Canada

Legislative Jurisdiction	UTC Offset Standard	DST	Time Zone	DST Start Sun in Apr	DST End Sun in Oct	Ref for 1987
Yukon	-8h	-7h	Pacific	first[0]	last	announcement[0]
British Columbia	-8h	-7h	Pacific	first	last	Reg 284 (86)
	-7h	-6h	Mountain	first	last	Reg 284 (86)
Alberta	-7h	-6h	Mountain	first[1]	last	announcement[1]
Saskatchewan	-7h	-6h	Mountain	last	last	definite
	-7h	no	Mountain Standard Time year-round (option)			
	-6h	no	Central Standard Time year-round			
Northwest	-7h	-6h[2]	Mountain	first[2]	last	announcement[2]
Territories	-6h	-5h[2]	Central	first[2]	last	announcement[2]
	-5h	-4h[2]	Eastern	first[2]	last	announcement[2]
	-4h	-3h[2]	Atlantic	first[2]	last	announcement[2]
Manitoba	-6h	-5h	Central	first[3]	last	announcement[3]
Ontario	-6h	-5h	Central	first	last	Bill 58
	-5h	-4h	Eastern	first	last	Bill 58
Quebec	-5h	-4h	Eastern	first	last	Bill 148
	-4h	-3h	Atlantic	first	last	Bill 148
New Brunswick	-4h	-3h	Atlantic	first	last	OIC 86-985
Prince Edward Island	-4h	-3h	Atlantic	first	last	EC 710/86
Nova Scotia	-4h	-3h	Atlantic	first	last	OIC 87-66
Newfoundland	-3.5h	-2.5h	Newfoundland	first[4]	last	announcement[4]

[0] Yukon - decision at cabinet meeting 87-07. Public memorandum to follow.

[1] Alberta - announced intention (Attorney General Feb. 13, 1987).

[2] NWT - DST except for Southampton Island(s) - announced intention (Mar. 2, 1987).

[3] Manitoba - announced intention, Bill 2. First reading Mar. 2, 1987.

[4] Newfoundland - announced intention (Minister of Culture Feb. 13, 1987).

(Prepared by Rob Douglas, NRC, 9 Feb, 1987)

Fig. 6 The Wm Brydone Jack Observatory built in 1851 on the campus of
Pp. 28 the University of New Brunswick. Courtesy University of New

WILLIAM BRYDON JACK AND THE MARITIME SURVEYS

William Brydon Jack (1819-1896) was born in the Parish of Linwald, Dunfries-shire, in Scotland, on the 23rd of November 1819. The son of a stone mason and master builder, he attended the local parish school, and later Halton Hall Academy at Caerlaverock. In 1835 he entered the University of St. Andrews in Fifeshire, where he distinguished himself for proficiency in mathematics and physics, carrying off top honors in both these subjects. He graduated with the degree of M.A. in 1840. Shortly thereafter two opportunities presented themselves. One was the chair of physics in Manchester New College, as successor to the celebrated Dr. Dalton, and the other was the position of Professor of Mathematics, Natural Philosophy and Astronomy in King's College (later University of New Brunswick), Fredericton. He was advised by Sir David Brewster, Principal of the University, and by other friends, to take the latter, since the Manchester posting was considered too arduous for one who had not yet attained his twenty-first birthday. The advice was followed. Jack considered it as a temporary posting of a year or two, to be followed by a more important appointment elsewhere. Fortunately for Fredericton and the Maritimes he remained, and contributed forty-five years to the institution he had come to hold in high regard, twenty-five of them as President of the University of New Brunswick.

Professor Jack's chief concern was to improve the educational facilities afforded the young people of the province. Sir Edmond Head, Lieutenant Governor of New Brunswick from 1847 to 1854, and himself a scholar, gave him every encouragement. In 1851 Jack supervised the construction of a small observatory. It was designed with economy in Fig. 6

mind, in the hope that it would serve as a useful pattern for any amateur astronomer wishing to build one for himself. Jack was pleased with its efficiency. The College purchased from Merz and Son of Munich a 6-inch equatorial that was for some time considered to be the best in British North America. A transit and chronometer were obtained on loan from the Commissioners of the Boundary Survey between Canada and New Brunswick. Many hundreds of careful observations made by Jack marked him as an enthusiastic scientist who enjoyed the practical as well as the theoretical nature of his work.[1] His was the first astronomical observatory to be built in Canada.

Prior to 1835 there was no fixed astronomical observatory on the North American continent, and hence no place where a standard meridian could be drawn. This is not to say that positions were not determined. Men of the Royal Navy who carried on extensive surveys on both the inland and coastal waters of Canada attempted to measure the coordinates of key positions. When Captain (later Admiral) H.W. Bayfield, R.N., commenced his survey of the St. Lawrence River and Gulf in 1827 he had already spent nine years on the inland waters of the Great Lakes.[2] Quebec City became his headquarters for the next fourteen years. From his temporary observatory on the Plains of Abraham he exercised the utmost care in extending the surveys along to Anticosti, the Magdalen Islands, Prince Edward Island, Cape Breton and the coast of Nova Scotia as far as Halifax. It was all by triangulation, supplemented by astronomical observations. This was before the days of the cable across the Atlantic. Hence there was no direct link with Greenwich by means of which local time could be compared and differences of longitude determined. There was, however,

(1) The Genesis of the University of New Brunswick, by Archdeacon W. O. Raymond (1918), Harriet Irving Library, UNB, Fredericton, N.B.

(2) Men & Meridians, by Don Thomson, Vol 1, 1968, page 168.

a link through the stars in the form of special astronomical tables which gave the position of the moon against the background of stars for every hour of the day in Greenwich time. Lunar distances, as the method was called, was a way by which one could determine Greenwich time from any location around the world. Transit observation of the stars, on the other hand, yielded local time, and the difference between local and Greenwich time was a measure of the difference in longitude from Greenwich. The instant that a star disappears behind the advancing limb of the moon, or emerges from the opposite limb, called an occulation, is the most precise method of reading the lunar clock. Occulations were (and still are) predicted. Other phenomena which were also used to determine Greenwich time, and hence local longitude, were the disappearance of Jupiter's satellites, a transit of Venus or Mercury across the disc of the sun, and a solar eclipse. But these methods were cumbersome even for a land-based observer, and were not at all suited for marine navigation.

In 1839, Harvard College Observatory was founded with W.C. Bond as Director. Bond was not only a skilled technician, being a clock maker by family tradition, he was also an ardent and painstaking observer. He gathered the observations of the longitude of Harvard dating back to 1743. They involved all the techniques referred to above. In addition observations made at other U.S.A. locations were ultimately linked to Harvard by telegraph. The most advanced technique employed by Bond was the transport of chronometers across the Atlantic. The same observer would check the time and rate of each chronometer at each end of the run, Liverpool and Boston, and derive a value for the difference in local time between these two centres. Great care was taken of the chronometers during the trans Atlantic voyage. By 1855 a total of 988 exchanges had been accumulated, and this resulted in the longitude of Harvard College Observatory being established with greater evidence than any other location in the western hemisphere. It, therefore, became the fundamental reference point for all coastal and inland surveys of the United States, and ultimately of Canada.

In the early 1850's when Captain Bayfield and Commander Shortland were advancing their surveys of the Gulf of St. Lawrence and the Bay of Fundy, respectively, the need to adopt a reference meridian for the longitudes of their maps and charts was recognized. Should it be Quebec City or Harvard College? The former had been adopted by the British surveyors, and the latter by the Americans, leading to a discrepancy along the Maine-New Brunswick Boundary of upwards of a mile and a half. In order to preserve uniformity, Airy, the Astronomer Royal, agreed with Admiral Beaufort, Chief of the U.S. Hydrographical Bureau, that Harvard College be used in preference to Quebec City. There was greater evidence in support of its adopted longitude.

W.C. Bond was most receptive to their request for a telegraphic exchange of time, and was able to secure financial and instrumental assistance to equip a temporary observatory which was established by Shortland near the Government House at Halifax. In 1852 the three stations, Halifax, Bangor Maine and Cambridge (Harvard College) were connected by Eastern Telegraph line; a total distance of about 770 miles. Bond described the operation in the following manner. "The touch of the observer on the break circuit key at Halifax, at the instant of the passage of a star over the wire of his transit instrument, was recorded by the armature magnets at each place; and subsequently the passage of the same star was in like manner recorded for Bangor and Cambridge. A single operation of this kind determined the difference in longitude of these points within half a second of time." (Report of the Harvard College Director for the year 1852.)(3) The exercise continued with several such star transits so that the longitude of Halifax was defined to the hundredth of a second with respect to Cambridge.

In due course the report of P.F. Shortland's work came to the attention of W. Brydone Jack. In 1854 he wrote to W.C. Bond, whose acquaintance he had made some years previously and with whose work he was familiar, requesting his cooperation in determining the longitude of Fredericton with respect to Cambridge, using the electric telegraph method. "The mean of a vast number of observations which I have made, give, from the calculations in the Nautical Almanac, the longitude of this place 20 seconds of time less than that usually received as correct. ... I have depended upon a clock made and regulated to sidereal time by Dr. Toldervy, here, and his transit, which is steadier than mine, has been used in all observations of lunar culminations. ... The Telegraph Office here is close by Dr. Toldervy's observatory so that there would be no difficulty in making a connection with Boston." (Jack to Bond July 10, 1854.)(4)

Dr. James B. Toldervy, a graduate of London and Glasgow, had applied to King's College in 1837 for the position of Lecturer in Chemistry and other branches of Natural Philosophy, but the position as been granted to Dr. James Robb. It would appear that Toldervy was

(3) Harvard University Archives.
(4) Harriet Irving Library, University of New Brunswick, Fredericton, N.B.

held captive by the atmosphere of the university and by the friendship of men such as W. Brydone Jack.

The two men collaborated in the time exchange with W.C. Bond in January and February of 1855, and found the correction to the adopted longitude of Fredericton to be of the same sign but considerably smaller in size, i.e., approximately 2 seconds of time instead of the 20 seconds Jack had observed. The measured longitude of Fredericton was 66° 38' 21".5 W, (4^h 26^m $33^s.43$ W).

Jack reported the results of this work to the Honourable John Henry Thomas Manners Sutton, successor to Sir Edmond Head as Lieutenant Governor of the Province of New Brunswick in a letter dated March 5, 1855:

"May it please your Excellency,

"Encouraged by your Excellency's predecessor (Sir Edmond Head), we, the undersigned, undertook to verify the Longitude of Fredericton by means of the Electric Telegraph leading therefrom to Boston; and having now accomplished that object, we beg to report to your Excellency the result of our operations.

"The Government of the United States has spared neither pains nor money in determining by the most approved astronomical methods, and by interchanges of upwards of one thousand chronometers, the difference of longitude between Greenwich and Harvard College Observatory, in order that the latter might serve as a point of reference in conducting the operations of the coast Survey. By our telegraphic communications with Boston, and through the kind cooperation of Professor Bond and his assistants, we have, at a comparatively insignificant amount of trouble and expenditure, been enabled to avail ourselves of the labours undertaken for the above mentioned purpose, and thus to ascertain the longitude of Fredericton with probably an equal degree of precision.

"It was originally intended to have an unbroken telegraphic communication between the Fredericton Observatory and that of Harvard University; but in consequence of the wires from the latter to the office in Boston being out of repair, Professor Bond found it necessary to trust the two excellent sidereal chronometers for the interval, and remarks that "on examination, I am induced to believe that no greater error has arisen from this source than would have taken place had the communication been made from the room adjoining the Transit Instrument".

"Professor Bond's chronometers were carefully and repeatedly compared with his Transit Clock, and with each other, both before and after interchanging signals, so as to ascertain their error and rate; and at both Observatories, on each day of operations, the meridian passages of a number of stars were observed in order to obtain the error and rate of the Transit Clocks. But we need not trouble Your Excellency with the tedious details and long calculations connected with this part of the work.

"The longitude of Fredericton having been thus verified and ascertained with an exactness much greater than it could have been done by any other method, it might be used as a centre of operations for determining, with equal exactness, the longitudes of all the other places in the Province that are connected with it by Telegraph wires. To do this would be a matter of much importance to the geography of the country in general; and so far as the sea-ports are concerned, it would also be of great service to navigation.

"In conclusion, we would beg to observe to Your Excellency that we are much indebted to Professor Bond for his kindness and courtesy in cooperating with us, and for the gratuitous services which he has rendered. We are also under deep obligations to the different Telegraph Companies between Fredericton and Boston for the readiness with which they placed their lines at our disposal, and for the attention and liberality which we uniformly experienced at their hands."

With the encouragement of Sir Edmond Head, who in 1854 became Governor General of Canada, and with a letter of instruction dated August 3, 1855, from the Provincial Secretary, Jack and Toldervy commenced their task of determining the longitude of several places in the Maritimes so that the geography of the province might be more accurately known. Their first effort was directed to the important port of Saint John. Here they had the enthusiastic cooperation of William Mills, a well respected teacher in the Commercial Mathematical School, who had a private observatory on Garden Street near the Roman Catholic Cathedral.

Toldervy in Fredericton and Jack in Saint John determined the corrections of their individual clocks from star transits both before and after an exchange of time. The exchange took the following form. Dr. Toldervy commenced tapping seconds in synchronism with his chronometer at 20 seconds after the minute, his telegraph key operating a break circuit. The beats continued until the 50th second, followed by a 10-second gap, then a single sharp tap on zero of the minute. The sequence was then repeated, the single tap on zero defining the signal, while the succession of taps from 20 to 50 permitted Jack to determine the tenth of a second by which the signal differed from the local chronometer. The sequence was then reversed with Jack tapping out pulses in synchronism with his clock, from which Toldervy judged time on his local clock to the nearest tenth of a second. It should be noted that when exchanges were made with Cambridge, the impulses could be recorded on the spring governor (drum chronograph), an invention by Bond which improved the accuracy of transit observations.

The longitude of Saint John proved to differ but little from the value determined by Admiral Owen. Later, Jack learned that Owen had derived his value by transporting chronometers from Boston and back, and having them carefully rated by Bond. In effect, then, Jack was verifying the earlier work but with improved instrumentation. The August 1855 observations gave the position of W. Mills observatory as 45° 16' 42" N, 66° 03' 43".35 W ($4^h\ 24^m\ 14^s.89$ W).

The following year, during July and August, longitude determinations were extended to Grand Falls and Little Falls (later called Edmundston in honor of Sir Edmund Head). Two values had been recorded for these centres, one with Cambridge as reference, the other with the Admiralty value for Quebec City. Jack and Toldervy verified the American measurement. In the ensuing discussion, the Astronomer Royal, G.B. Airy, said that this result was to be expected, since they had used the American reference meridian. Ideally the observations for the Quebec longitude should have been combined with all the others that were used to define Harvard College Observatory and then the Quebec longitude adjusted. But since the adjustment could not be readily performed at this juncture, Airy felt that it was preferable for the sake of uniformity to use a single datum, namely, Harvard College Observatory, for the whole continent.

Prof. Brydone Jack would have liked very much to have become involved in the larger operation of extending the longitude network to other parts of Canada. In a letter addressed to the Astronomer Royal, 9 October 1857, he states in part: "I wish some systematic and uniform plan were adopted for obtaining by Telegraph differences of longitude in the British North American Provinces. In the construction of maps, great and almost irreconcilable discrepancies are now found to exist, as has been experienced by Sir W. Logan in Canada. I would like very much to be engaged in such work." Doubtless his meticulous attention to detail, his apparent lack of profit motive and his demonstrated scientific ability would have caused such an endeavour to remain as a monument to him. He was instrumental in determining the correct position of the time ball observatory at Quebec City, and his measurements were used when the time ball observatory was established in Saint John in 1870. It was Lieut. E.D. Ashe, R.N. of Quebec City, who was commissioned to extend the longitude network in Canada. This he proceeded to do with almost overbearing assurance but somewhat less devotion to scientific detail, his main course of instruction being the few weeks of collaboration with Jack in the November 1855 telegraphic exchange between Fredericton and Quebec. In 1860, W. Brydone Jack became President of his college, newly named the University of New Brunswick, and henceforth was more than ever completely involved with educational matters.

There is no evidence that the splendid equipment of the Observatory was ever engaged in the routine observations that would be required for the maintenance of a time service, either on campus or within the city of Fredericton.

Mr. Fred Phillips of the New Brunswick Provincial Archives has provided the information that Fredericton was a garrison town from about 1847 to 1869, and that an evening gun was fired daily from Artillery Park. No little annoyance was caused to some of the nearby residents by the window rattling noise. Much more pleasant have been the bells in the tower of Christ Church Cathedral from which, since 1853, the hours have been rung, while chimes have marked each quarter hour. A fire in 1911 caused an interruption while repairs were effected and a finer set of bells was installed. Bells have also tolled the hours from the clock tower of the city hall from 1878 till the 1950's, and since 1930 from the clock tower of Lady Beaverbrook Hall on the campus of the University of New Brunswick.

A relic perhaps of garrison days is the weathered remains of a sundial (described by J.E. Kennedy in J. RASC 66 311 (1972)) on the east end of the New Brunswick Liquor Control Warehouse. Barrack block is the alternate name applied to this old building, indicating that it may date back to pre-Confederation days and that the sundial may have played an important role as a timekeeper within the community. Sundials were generally accepted as a means of determining time. The correction from apparent to mean solar time, called equation of time, was published in almanacs of early colonial days, so that clocks could be regulated from a sundial with all the accuracy that was required.

By the late 1880's the time service of the Saint John Observatory was being extended throughout the province by the telegraph line, and sundials tended to become ornamental rather than functional.

Immersed as he was in the affairs of the University, Prof. Jack nonetheless found time to make regular meteorological observations, and to forward them to Toronto in support of the Canadian weather forecasting program initiated by Prof. G.T. Kingston. In 1882 he participated in the Canadian campaign, organized by Charles Carpmael of Toronto, to observe the transit of Venus.

"The transit of Venus in 1882 undoubtedly stimulated a considerable amount of interest in this country but the solid growth of astronomy in Canada owes its origin chiefly to problems associated with the surveying of large areas within our far-flung borders. A substantial debt of gratitude is owed also in this field of effort to trial-blazers such as Sir Edmund Head and Dr. Jack. Their foresight and bold action, despite formidable obstructive and discouraging forces, made it possible for Canadians in later years to meet in praiseworthy fashion a great challenge." (Don W. Thomson "Men and Meridians", Vol. 2, p. 260).

QUEBEC CITY

QUEBEC

An observatory at Quebec City, for the purpose of providing correct time for the benefit of the shipping of the port, had been advocated since the early 1840's. Captain Boxer, the Harbour Master of Quebec, Sir Richard Jackson, the Commander of the forces in Canada, the Council of the Board of Trade of Quebec City, and Professor G.B. Airy, the Astronomer Royal, had all spoken in its favour.

In a report which was made to Lord Stanley by Prof. Airy in 1844, it was stated that he fully endorsed Captain Boxer's reasons for the establishment of an observatory. "In every port which has the same amount of commerce as Quebec" wrote Airy, "there should be provided means for obtaining time with that security which can be given only by the sanction of official authority. But it is especially desirable in a port where physical circumstances make it so difficult for mariners to conduct successfully the ordinary operations of nautical astronomy for obtaining time."

The Admiralty approved the construction of an observatory at Quebec. Airy was requested by Benjamin Hawes, Secretary of the Colonial Office, to submit a report concerning communications from the Ordinance dated 1st of March 1847, and from the Commanding Royal Engineers in Canada dated 11 January 1847, also concerning two original plans relating to the observatory and time signal which was proposed for the "terreplein of Man's Bastin on Cape Diamond, Quebec." Airy made a full report for the consideration of Earl Grey, Colonial Secretary. Three of his seven suggestions have lasting relevance, while the others, dealing with details of the time ball machinery, may be considered to have little importance. They refer to the design of an installation that was not used. Airy's report included the following:

"1. For the visibility of the signal ball, it is necessary that as seen from the ships in the river and from their neighborhood the ball should be projected against the sky. And for the adjustment of the transit it is desirable but not necessary that some object should be commanded in the north or south direction at a distance not less than two miles. I merely call attention to these points presuming that they have been regarded in the selection of the site.

2. The terrepleine of the bastion is undoubtedly made ground. It will be highly desirable that the pier supporting the transit should be founded upon the natural ground or rock.

3. The general size and plan of the buildings appear to me well adapted to the object in view. (I presume that the person who has charge of the observations will reside at no great distance from it.) I would vaguely suggest for the consideration of the engineer officer, and entirely in submission to his judgment the following point. In constructing two temporary observatories I have found very great convenience in making the opening for observing along the length of the ridge of the roof instead of transverse to it. Less difficulty was found in excluding rain (by a simple hinged shutter) than in any other construction which I have seen. I think it probable also that the whole building might be made a little lower (preserving the same elevation of the transit) which appears to be brought in these plans as a desirable object. etc.

These are all the points which occur to me at present as requiring a remark. But I shall be happy at Earl Grey's request to answer any other questions upon this subject.

I am

Sir

Your obedient servant

(G.B. Airy)"

The next correspondence has to do with the appointment of an officer to be in charge of the observatory, and in this connection the following is quoted:

"Admiralty, 11 June 1850, to Herman Merivale, Colonial Office.

Having laid before my Lords Commissioners of the Admiralty your letter of the 30th ultimo, requesting by the desire of Earl Grey that a Lieutenant of the Royal Navy on half pay may be selected to be placed in charge of the Observatory at Quebec, who will receive an allowance of one hundred pounds (£100) per annum together with quarters, fuel, and candles, and rations for himself and servant, I am commanded to acquaint you for the information of Earl Grey that their Lordships recommend Lieut. Edward D. Ashe, R.N. as the officer to be appointed to the Observatory. Lieut. Ashe's address is:

15 Brampton Crescent,

I have the honor to be

Sir

Your most obedient humble servant,

(J.H. Hay.)"

A footnote to the letter states: "Governor General to be informed, - Lieut. Ashe to be directed to wait upon the Astronomer Royal and report his selection to him and to take his instructions as to the instruments to be sent out."

importance. They refer to the design of an installation that was not used. Airy's report included the following:

"1. For the visibility of the signal ball, it is necessary that as seen from the ships in the river and from their neighborhood the ball should be projected against the sky. And for the adjustment of the transit it is desirable but not necessary that some object should be commanded in the north or south direction at a distance not less than two miles. I merely call attention to these points presuming that they have been regarded in the selection of the site.

2. The terrepleine of the bastion is undoubtedly made ground. It will be highly desirable that the pier supporting the transit should be founded upon the natural ground or rock.

3. The general size and plan of the buildings appear to me well adapted to the object in view. (I presume that the person who has charge of the observations will reside at no great distance from it.) I would vaguely suggest for the consideration of the engineer officer, and entirely in submission to his judgment the following point. In constructing two temporary observatories I have found very great convenience in making the opening for observing along the length of the ridge of the roof instead of transverse to it. Less difficulty was found in excluding rain (by a simple hinged shutter) than in any other construction which I have seen. I think it probable also that the whole building might be made a little lower (preserving the same elevation of the transit) which appears to be brought in these plans as a desirable object. etc.

These are all the points which occur to me at present as requiring a remark. But I shall be happy at Earl Grey's request to

Lieut. Ashe had been injured at Valparaiso, Chile, and invalided home in 1849 with a fractured thigh.

"Admiralty, 5 October 1850 to Herman Merivale, Colonial Office.

Sir,

In reply to your letter of the 28th ultimo, I am commanded by my Lords commissioners of the Admiralty to acquaint you for the information of Earl Grey that Lieutenant Edward D. Ashe, R.N., the Officer appointed to take charge of the Observatory at Quebec, has been ordered to be allowed the expense of a passage to Quebec via New York.

I am

Your most obedient humble servant,

(J.H. Hay.)"

The footnote to this letter states: "This letter is written in answer to a requisition from Lord Grey for conveyance for the instruments which the Admiralty are sending to the Observatory at Quebec. It will be observed that the Admiralty have taken measure for defraying the expense of Lieut. Ashe's passage. This is liberal, and as the Naval Service will derive great benefit from Lieut. Ashe's service, it may be presumed that Lord Grey will acquiesce."

Ashe acknowledged his appointment, and reported to the Astronomer Royal, G.B. Airy. He then provided himself with several books which he considered essential to his new duties, among which were:

Pearson's Astronomy

Groombridge's Catalogue of Stars

Oxford Astronomical Observations

British Association Catalogue of Stars
(several other catalogues)

Babbage Logarithms (and others)

Barlows Tables of Squares

Hutton's Logarithms

These were approved by Airy, and approval was duly granted by the Admiralty for their purchase.

A plan of the observatory building was requested by Airy so that he could select those instruments best suited for the size. Col. Holloway, the Commanding Royal Engineer who had lately returned from Canada, was to be requested for a copy of the plan.

The following letter 1850 October 9 from Airy to Benjamin Hawes, Secretary of the Colonial Office describes the action taken.

"Sir,

Referring to your letter of May 30 and to my response of May 31 regarding the equipment of the Observatory at Quebec, I have the honor to report to you:

1. that having understood that Lt. Ashe R.N. has been selected to take charge of the Observatory, I have transferred to the Gentleman from the stores of the Royal Observatory the following instruments, viz,

   a 30 inch transit instrument complete

   a 42 inch telescope with stand complete

   a 6 inch sextant

   a shade for artificial horizon.

2. That I have had on trial the clocks, one furnished by E.J. Dent and marked Dent 1155, and one furnished by R. Molyneux and marked Molyneux 157, and that I am satisfied with the goodness of the clocks and that I have expressed to the makers respectively my approval of

the clocks, and have advised the makers to transfer the clocks to the charge of Lieut. Ashe and to present their account to you, amounting to £63 for each clock as packed for embarkation in the form prescribed in your letter of May 30.

I have the honor to be

Sir

Your obedient servant,

(G.B. Airy.)"

Thus, while the clocks became the property of the Canadian Government, the instruments remained the property of the Greenwich Observatory on indefinite loan. The Observatory was apparently built according to a plan presumed to be furnished by Col. Holloway, who for a time was Commanding Royal Engineer. And the instruments provided by Airy took account for the dimensions.

Lieut. Ashe proceeded to Quebec, and being now in command, he made representations that only the latest design of time ball, namely, the one recently constructed for the port of Liverpool, be considered. Airy's only concern was that the machinery should function satisfactorily even in the severe Canadian climate. Major Robinson of the Royal Engineers dispelled all fears in this direction by stating that the vessels all leave Quebec when winter sets in, and return in spring when winter is over. But even should it be necessary to operate the machinery all winter, the rare occasion that freezing rain or sleet might tend to clog the works can be dealt with on the spot. So the order was placed, and in due time Messrs. George Forrester & Co. of Liverpool received £169.4.11 from the Colonial Office. The time ball was shipped to Canada May 3rd 1852 on board the Intrepid.

The Imperial budget contained an appropriation of £526 16s 6d for the construction of the observatory. It was built during 1854 and 1855 and was within the citadel on Cape Diamond, between the pole of the "Pavillon" and the former French works, in a southwest direction. The building had a front of 26 feet. The main body of the building was 15 feet high, 15 feet deep and 24 feet long. The adjoining tower was 44 feet high.

By 1855 the Quebec Observatory was in readiness to provide correct time for the shipping in the harbour by dropping of the time ball on the Citadel. More than a decade earlier a temporary observatory had been located close to the Citadel at Quebec, and astronomical observations were made during the winter of 1844-45 in connection with the boundary problem between Maine and New Brunswick. From 1827 to 1841 Admiral H.W. Bayfield had made Quebec his headquarters, and the Citadel his reference meridian in connection with the coastal survey. The longitude west of Greenwich was determined by moon occultations and eclipses of Jupiter's satellites. Ashe, however, had heard of the connection by electric telegraph made between Boston and Fredericton, and of the greater weight that was accorded Boston over Quebec as a reference meridian on the continent. So he wrote to Prof. Jack of King's College, and arranged for an exchange of time by telegraph between Fredericton and Quebec, which was effected in November 1855. Permission for this and for the more extensive operation of making telegraph contact with the most important places in Canada was obtained in the following communication:

"Secretary's Office,
Quebec, 18th August, 1855.

Lieut. Ashe, R.N
"Observatory", Quebec.

Sir,

His excellency, the Governor General in Council having had under consideration your letter of the 2nd inst., I have the honor, by command of His Excellency, to convey to you in reply His authority for your incurring the expense of taking a wire to the Observatory in connexion with the line of the British North American Telegraph Company; and further to authorize you to procure an apparatus at an expense not exceeding £30, to enable you to determine the longitude of the Observatory by telegraphic signals to and from Fredericton, and the longitude of the most important places in Canada by the same means.

I have the honor to be,

Sir,

Your most obedient servant,

(Geo. W. Cartier, Secretary.)"

Prof. Jack, in writing Lieut. Ashe said, "It is somewhat singular that the present Governor General of Canada, Sir E. Head, when in this province, [as Lieut.-Govenor] first encouraged me to attempt the determination of the longitude of Fredericton by telegraphic communication with Boston."

The first trial between Fredericton and Quebec was not very satisfactory either to Ashe or to Jack, and it was recommended that another attempt be made by direct connection with Boston. This was done later.

Sir Wm. E. Logan, the geologist, was the one most desirous of accurate positions because of a map he was preparing of the geology of Canada. Accordingly, in a cooperative effort between Ashe and Prof. G.T. Kingston, the position of the Toronto Magnetic Observatory, relative to Quebec, was measured in January 1857. In Kingston, in February, Ashe was molested at his work by mischievous boys. His temporary observatory was situated in a cross street between Earl and Barrie streets. In March, Ashe set up his portable transit at the gardener's tool-house in Viger Square, Montreal.

The position of Chicago on different maps varied by as much as 40 miles. So in May, with the cooperation of Lieut. Col. Graham U.S.A., a telegraphic connection was made between the city and Quebec. "The electric current was transmitted via Toledo, Cleveland, Buffalo, Toronto and Montreal, a distance of 1210 miles, by one entire connection between the two extreme stations, and without any intermediate repetition, and yet all the signals were heard distinctly at either end of the line; the signal occupied only .08 of a second in passing along the distance." Telegraphic exchanges were subsequently made with Windsor, Collingwood and Ottawa, and in October an exchange was effected with W.C. Bond of Harvard College Observatory in Boston, Thomas Heatley was the assistant at Quebec. With both a sidereal and a meantime chronometer at Quebec, Ashe was able to employ one or the other, depending on the facility at the field station, so that a sidereal timepiece at one end of the line would be compared with a mean solar timepiece at the other. The relative rates yielded a coincidence every six minutes, and hence a comparison to the hundredth of a second. However no attempt was made now or later in Ashe's longitude work to exchange observers in order to eliminate or reduce personal equation. The results of his work in 1857 are summarized as follows:

Longitude of Harvard College Observatory (W.C. Bond)	4^h	44^m	$30^s.70$
Quebec Observatory west of H.C.O.	0	00	18.32
Longitude of Quebec Observatory	4	44	49.02
Toronto Magnetic Observatory west of Quebec Observatory	0	32	44.41
Longitude of Toronto Magnetic Observatory	5	17	33.43
New Court House at Kingston west of Quebec Observatory	0	21	05.50
Longitude of Kingston	5	05	54.52
Viger Square west of Quebec Observatory	0	09	22.70
Longitude of Montreal	4	54	11.72
Chicago observing site west of Quebec Observatory	1	05	41.52
Longitude of Chicago	5	50	30.54

In the Dominion Annual Register for 1883 it is stated that it was Mr. Robert Barlow, chief draughtsman for the Canadian Geological Survey, who proposed that the service of Capt. Ashe, R.N. be "secured in 1854-57 to determine by telegraph the relative longitudes of several widely separated points in Canada, by which means he determined for the first time, with singular accuracy, the position of the Great Lakes."

Timekeeping duties involved observations of stars and the sun to check the time and rate of his clocks. Each day, except Sunday, during the navigation season, the time ball was released at the Citadel for the benefit of ships in the harbour. At 12:45 it was raised to the half-way point, at 12:55 to the top, and at 1 p.m. local mean time it was dropped. From the adopted longitude of the Citadel, 1 p.m. corresponded to 5^h 44^m 49^s Greenwich time.

Plans were submitted in 1855 for an astronomical observatory to be located outside the Citadel, but they were not accepted. Ashe had taken up residence at the farm house known as "The Bonner Property" situated on the Plains of Abraham about two miles to the west of the Citadel. In his report for 1857, Ashe refers to his longitude work, and suggests that with a properly equipped observatory he could increase greatly the Canadian contribution to astronomical research. A letter from the Astronomer Royal was quoted as supporting evidence: "To make the inhabitants acquainted in a practical way with the most attractive and noblest of sciences, to promote education in the accurate habit of using instruments which belong so peculiarly to astronomy, and generally to serve as an engine of instruction. I conceive that it is mainly in this way that such an institution would be useful at Quebec." (Signed G.B. Airy). Support also came from the Canadian Institute of Toronto in the form of a petition to Parliament to erect and endow a "National Canadian Astronomical Observatory as requested by Lieut. E.D. Ashe at Quebec." The names supporting it were the three Vice-Presidents, Edward J. Chapman, De Rottenberg, and John Simpson, together with the secretary, J. George Hodgins.

The request was partially realized when, in 1864, $2500 of public funds were made available for the acquisition of an 8-inch refracting telescope of 9 feet focal length built by Alvin Clark and Sons of Boston. Public Works provided a tower for it alongside the house. Ashe became quite interested in solar photography, and was soon propounding his theory to explain the formation of sun spots. From their apparent motion across the disc he derived a period of solar rotation.

In 1869 he was authorized to organize a Canadian eclipse party and observe the total solar eclipse of August 7 from a site at Jefferson City, Iowa. Here he secured four photographs which he thought revealed some entirely new features. And he was deeply hurt when official opinion in the February 1871 issue of Monthly Notices of the Royal Astronomical Society expressed the view that his telescope had moved during the exposure. The American effort, on the contrary, was credited with great success. He was somewhat mollified by the request of Dr. Balfour Stewart, Director of Kew Observatory, for copies of Quebec solar plates on a regular basis to supplement his own which he used for sun spot counts.

Prior to Confederation, Ashe reported through the Auditor of Public Accounts directly to Parliament. By Order in Council of the 21st of Sept. 1868, the observatory was placed under the control of the Department of Marine and Fisheries. Ashe must henceforth request leave and direct correspondence through the Department. In the ensuing exchange of correspondence with Wm. Smith, the Deputy Minister of the Department, Ashe provided the design which was requested for a time ball mechanism for Saint John, N.B. It was the design he would choose for Quebec, if a change were made, and hence he was interested in having it tested. The Saint John time ball (Fig 7), which was commissioned in June 1870, was contained within a cage of four rods rather than sliding on a mast, but it is not known whether this was actually Ashe's design. He also suggested that by the use of the Jones method recently patented in England, an impulse from a central observatory (Quebec) could synchronize a pendulum in each of the principal cities across the country. It would be much less expensive than a multiplicity of observatories.

Ashe defended his position over the watchmaking trade in the matter of rating chronometers. No one, he claimed, should have the authority to observe stellar transits and determine time without having first passed a qualifying exam. And no one without access to fundamental time with a transit instrument should rate chronometers. The contrary opinion in some quarters was that a watchmaker was perfectly well qualified and that facilities at the observatory represented a waste of public funds.

Because of the possibility of Canadian astronomy assuming a place of international importance, Ashe requested that a proper dwelling, with rooms for computing and for processing photographic plates, be built, together with sheltered access to an observatory alongside. He felt confident that great and important discoveries in astronomy of the solar system were at the door of Canadian scientists. To support his contention, he added that "the Magnetic Observatory at Toronto (is) nearer to the magnetic pole than any other, and the climate of Quebec (is) better suited than any other for celestial photography."

However in reply to his request for improved facilities, the following was written:

"Dominion of Canada
23rd January 1872.

E.D. Ashe, Esq.,
Observatory Quebec.

Sir:

I have to acknowledge receipt of your letter of the 15th instant in reference to the increase to the vote for the observatory under your direction and enclosing extracts from letters received from eminent astronomers giving testimony to the value of the "Solar Negatives" taken at Quebec; and in reply I am to inform you that the Minister does not consider it necessary, at present, to recommend to Council that the amount to be inserted in the estimates for the next financial year for the Quebec Observatory should be doubled, as recommended by your letter.

I am,

Sir,

Your most obedient servant

Wm. Smith

Deputy Minister of Marine, etc."

During 1872 Quebec Observatory was selected as one of the Chief Meteorological stations in the network organized by Professor Kingston of Toronto. To make his work efficient, Ashe secured approval to have the telegraph line extended to his home.

May 1874 saw the fulfillment of an objective. The new observatory and house which had been requested for some years were built. Now all the observations with the transit as well as with the 8-inch (9-ft. focal length) telescope could be taken with the comfort of a closed passage-way from his office to his observing locations. The time ball on the Citadel, 2 miles away, was dropped by electricity. Mr. Pope of the Montreal Telegraph Office assisted in correcting the many errors of the new wiring system. But Ashe himself had to attend to the problem which arose when his daughter pressed the key, causing the ball to drop one minute early, as she showed her doll how to send a message.

During 1874 Ashe was requested by the Crown Lands Department to determine the position of four places along the Ottawa Valley to help delineate timber preserves. Permission was granted by his department, but under the provision that the expenses should be met by the Commissioner of Crown Lands.

Accordingly, during the winter months of 1875, Ashe proceeded to the Ottawa Valley to measure the positions of Point Fortune, Buckingham, Pembroke, Des Joachim, and Portage du Fort. "Mr. Deville, formerly of the French Navy, came as my assistant." Ashe failed to recognize in this assistant the man who was destined to have a distinguished career, finally to become Chief Surveyor for Canada. "When we arrived at our destination, we went in search of a place near the telegraph office where we could place the transit instrument, and then, after fixing a solid support for the instrument, we had a few boards put around it to keep the wind off." "When we had the instrument in position, and the time accurately known (by observation), we took the chronometer to the telegraph office and exchanged signals with Quebec, when the difference of the longitude between the Observatory and the place was known to a small fraction of a second. We then took observations for the latitude, and the result was that the position of that place was fixed with a certainty and accuracy leaving nothing more to be desired."(3)

Ashe was now in his mid-fifties. The equatorial had undergone some repairs, but there were insufficient funds in his annual appropriation from Ottawa to pursue his interest in celestial photography.

During 1877 the position of Trois Pistoles, Quebec, was determined, and the time service showed some expansion beyond the operation of the time ball and the noonday gun, time being given to the Montreal Telegraph Office and to those sections of the Intercolonial and North Shore Railways that chose to use Quebec time.

(3) Sessional Papers (No.5) A1876, 527, Dept of Marine & Fisheries.

The navigation season, and hence the operation of the time ball in 1879, commenced on May 13th and terminated November 29th, with an 8 percent failure of the time ball. The observations in connection with time giving consisted of 426 complete transits. It was the custom in those days to consider 6 stars as a complete set. Ashe does not describe a typical operation at the Transit Instrument, but he doubtless followed the general practice of the day. So 426 transits would constitute 71 observing nights.

The position of Cross Point in the County of Bonaventure was determined that year at the request of the Quebec Government. This was the first time in which reference was made to lending instruments for use at the temporary location.

On January 1st 1880, an inventory of the Quebec Observatory was given as follows:

A Refracting Equatorial Telescope by Alvin Clark of 8 inches clear aperture and 14 feet focal length. [Previously described as 9 feet focal length.]

A Transit Instrument by Troughton and Simms, of 36 inches focal length and 2½ inches aperture.

A Portable Transit Instrument of the same dimensions.

A 42-inch Telescope with 3-inch aperture and tripod mounting.

A Spectroscope.

A standard Mean Time Clock by Moleneux, and a standard Sidereal Clock by Dent.

A Ship's and a Pocket Chronometer.

A complete set of Meteorological Instruments.

December 6th 1882, the transit of Venus was observed from many points across Canada, including Quebec City. The observers at Quebec were Lieut. Gordon, R.N. as observer, and W.A. Ashe, D.L.S. (son of E.D. Ashe) assistant. They used the 8-inch refractor by Alvin Clark, reduced by a circular mask to 6 inches for these observations. At the end of that year, E.D. Ashe submitted his final report to the Minister of Marine and Fisheries, thus completing 32 years of service. His report reads as follows:

"Sir,- I have to submit the following Report of the work performed by this Observatory, for the year ended 31st December, 1882.

As in former years, the giving of the correct time to the shipping of the port, and exchange of time with other points has been our chief work. I have much pleasure in informing you that there has not been a single failure in dropping the Ball throughout the year.

Preparations were completed for the Transit of Venus on 6th of December, but unfortunately the weather on that date was so cloudy as to prevent observations being taken.

I am, etc.,

E.D. Ashe,

Director"(4)

E.D. Ashe resigned early in 1883, and retired on a pension of $980. per annum.

There had been complaints about the inaccuracy and irregularity of the time ball operation at both Saint John, N.B., and Quebec. In 1879 Ashe found it necessary to refute a statement in the Montreal Herald of October 20 that the time ball at Quebec is not regularly dropped, and not

(4) Sessional Papers (no.7) A.1883, 189, Dept of Marine & Fisheries.

dropped at the proper time. "I think it quite unnecessary", he wrote, "that I should mention that I am quite capable of determining the proper time."

The situation at Quebec had deteriorated. Solar astronomy had not been active for several years, yet the annual appropriation to the Quebec Observatory was about double the outlay for a comparable service of weather reporting and timekeeping at the Saint John, N.B., Observatory. Upon receipt of Ashe's resignation, Wm. Smith, the Deputy Minister arranged that the Quebec Observatory come under the direct supervision of Toronto.

On April 2, 1883, Carpmael wrote to Smith, "I beg to draw the attention of the Department to the importance of placing the work of giving the time directly under the supervision of this office, for as at present carried on we have no means of knowing whether accurate time is given at the various observatories. Arrangements are now being made for the absorption of the Quebec Observatory by this service, and if the vote for the Saint John Observatory was passed through the account for this service and the observer instructed that we had the authority to inspect his work, by exchange of time signals or otherwise, it would soon be found that there would be no difficulty in securing accurate time at the various places."

Lieut. Andrew R. Gordon, R.N., Assistant Superintendent of the Toronto Observatory, was sent to Quebec to supervise the reorganization. Both W.A. Ashe, a surveyor, and son of E.D. Ashe, and Thomas Heatley the assistant at the observatory, made application for the position of Director. But in order to make a complete break with the past, it was arranged for the military authorities to operate the time-ball service and report by telegraph to Toronto 3 times a day the meteorological readings. Gordon tranferred the instruments from the Ashe home and adjacent observatory to the Citadel and saw to the necessary repairs. Lieut. Col. Cotton, the Commandant, agreed to use all means to have it efficiently carried on. One of his officers C.W. Drury, Captain "A" Battery, was placed in charge. The annual appropriation dropped from $2750 to $1100 due to the savings made on the salary and observatory expenses that had been paid to the former director.

The mobility of service personnel was not conducive to continuity of staff at the Observatory. Captain Drury remained in charge for two years, 1883 and 1884, and during 1885 the supervision of the work changed hands several times. Therefore on January 10, 1886, W. A. Ashe was appointed to the position of Director. Ten years earlier, Ashe had qualified as a Dominion Topographical Surveyor, having spent several years in survey work in western Canada. In 1884 he joined Gordon in the Hudson's Bay Expedition and surveyed sections of the coast at Port Burwell and Ashe Inlet. As Director he moved the observing equipment back to the house and observatory on Grande Allée. It may be noted that the city now had four daily time signals, the gun at noon and at 9:30 p.m., the time ball at 1:00 p.m., and the ringing of the fire alarm bells at 1:00 p.m. Also the telegraph time exchanges which Gordon under Carpmael's instructions had instituted in 1883 between Toronto and Quebec, and between Toronto and Saint John, gave assurance that the agreement was within a second.

During the eight years of his service at Quebec, W.A. Ashe urged year after year that the storm signal warning lights be changed from oil lamps to electric lights. He also in 1891 advocated a second time ball to be established on the roof of the Custom House, because of the development of the harbour in the direction of the St. Charles River, from where the present ball was not visible. Meanwhile the unused observatory buildings within the Citadel were falling into disrepair, and it was strongly recommended that they be transferred to the military authorities. Such a change would in no way interfere with the "Time Service."

In December 1893 W.A. Ashe died, and Arthur Smith, his assistant, was subsequently appointed to succeed him as director of the Quebec Time and Meteorological Observatory. Beside normal maintenance of the equipment, and routine conduct of duties of his post, one is aware that Smith had increasing rapport with the watchmakers of the city. Calls for correct time increased. The observatory also assumed a more prominent role as a source of weather information for a wide cross section of the community, the law courts, the shipping people, the farmers and the citizens generally.

During World War I the firing of the time gun was discontinued, to be resumed at both noon and 9:30 p.m. on March 29, 1919. The location of the time ball continued to be discussed. B.C. Webber, after his inspection in 1916 reported in June to the Director of the Meteorological Service, Sir Frederic Stupart as follows: "The so called dome at the Custom House at Quebec is an oval construction with ornamental glass let in which makes the ceiling of the large handsome office which it covers. Consequently a time ball on such an erection is quite impossible, as Capt. McGreevy of the 171st CEF now says. The northeast corner of the flat roof is suitable for the ball, but it must be remembered that should it be placed there vessels at Wolfe's Cove, the proposed new harbour, will not be able to see it. The place from which the ball could be seen from all points, including Levis, is on the Cavalier Building near the King's Bastion at the Citadel. The former Commandant of the Citadel objected to that site; now the building is not in use; it was formerly a powder magazine. If Colonel Fiset, Deputy Minister of Militia were approached and informed that the time ball at Halifax is on the Citadel, I fancy there will not be much objection offered to the Cavalier Building."

Stupart relayed Webber's report to the Deputy Minister, but he deleted the last part which read, "I was told in Quebec that in this age of telephones, mariners compared their chronometers by telephone with the observatories and that time balls were obsolete. On this subject I am ignorant."

During the 1917-18 year of operation, Smith reports that "the correct time was given by means of the telephone, and during the season of navigation by means of the old time ball until 6th of August when it was replaced by the new time ball which was erected on the Cavalier building at the Citadel. The ball was continued during part of the month of January as several sea-going steamers were still in the port of Quebec."

Following World War I, Smith renewed his agitation for a new residence. The present one was considered beyond repair in 1913, and during the intervening six years conditions had not improved.

In his report of March 31, 1923, Smith reports that daylight saving time was adopted by Quebec City during the summer of 1922. The time ball was dropped according to standard time, but the noon gun was advanced an hour. "The Bell Telephone Company, having discontinued this year their practice of giving the time to the public, the number of enquiries in this respect has increased to such an extent that it is now practically impossible to answer all the calls made on this office. The population of this city [Quebec] being now nearly 120,000, I suggest that some system be adopted whereby time be given to all the wards of the city by a master clock by means of the fire alarm system."

The annual reports indicate an increasing impact of the observatory on the community. In addition to providing time by the time ball, noon gun, and telephone, chronometers were rated, barometers adjusted, and weather information relayed from Toronto to the public press.

In the 1924 and 1925 seasons, Smith was authorized to arrange for the various meteorological instruments to be installed on board CGS "Alert" and to store the instruments at the end of the season. The regular program of reading meteorological instruments, observing with the transit instrument, and providing time and weather to the community continued.

In 1926 Quebec City observed daylight saving time from May 1 to September 25.

Smith's report of March 31, 1928, includes the following. "I have also given general information concerning the weather conditions, and the exact time, to aviators connected with the Mail Service, and also to Commander De Pinedo and Commander Byrd who personally called at my office." There is a further plea that he be supplied with safer quarters.

The following year he gave "to the wireless operators for the stations in Hudson's Straits the necessary instructions in taking the meteorological observations."

Arthur Smith did not live long enough to see the old observatory abandoned. On October 15, 1929 he went on sick leave and was replaced by Mr. Maurice Royer. By now the requirements for a time ball at the Citadel had ceased and there is no further report on its operation after the close of the 1929 navigation season. Nor was there any need to check the clocks from transit observations of stars because of the daily time signal by telegraph from McGill.

An appropriation for a new meteorological observatory appeared in the estimates for 1934, and a new site at the corner of Laurier and Tachés avenues was selected. The equatorial telescope (the 8-inch Alvin Clark refractor) which had been obtained through the efforts of Lieut. E.D. Ashe in 1864, but which had been out of use for many years, was purchased for a nominal sum by the College des Jesuites, and was given to them when the old observatory buildings were demolished.

Work on the new Meteorological office was commenced in July 1935, and it was occupied on March 28, 1936. While it was primarily designed to report meteorological conditions to the central service, and in turn distribute the forecasts received from the central service, its prestige as a source of correct time continued for several years, first of all McGill and then the Dominion Observatory serving as the source of correct time.

TORONTO

THE BEGINNING OF THE LONG DASH

MASTER COPY

Amendment: Index under "Q", add Quebec ... 44

Beginning of the Long Dash sent to:

Alberta - 12845 - 102 Ave, Edmonton T5N 0M6

B.C. Pub Archives - Parliament Bldgs Victoria V8V 1X4

Manitoba - 200 Vaughan St. Winnipeg R3C 0P8

N.B. Historical Resources Admin - Box 6000,
Fredericton, N.B. E3B 5H1

Prov'l Archives, Colonial Bld St Johns Nfld A1C 2C9

Pub Arch of N.S. 6016 University Ave, Halifax B3H 1W4

Archives of Ont Ministry of Culture & Rec
77 Grenville St, Toronto Ont M7A 2R9

Pub Arch of PEI Box 1000 Charlottetown C1A 7M4

Legislative Library, Govt Bldgs, Que City G1A 1A5

Sask Arch Board, University of Regina, Sask S4S 0A2

Yukon Archives and Records Services, Dept of Info Resources
2071 Second Ave Whitehorse Y1A 2C6

Prince of Wales Northern Heritage Centre, Govt of N.W.T.
Yellowknife X1A 2L9

TORONTO

"A chain of observatories connects the western shores of Ireland and of Spain with the eastern coast of New South Wales, and thus comprises one half of the globe, while the other half is in this respect destitute of any such indispensible means of furthering the purposes of astronomy."

This was the opening paragraph of a letter dated 7 July 1835 from C. Wood, Secretary to the Admiralty, to W. Hay, Esq., Permanent Under Secretary of State for the Colonies.

Mr. Wood continues, "Nor do the more immediate practical objects of geography feel less the want of an observatory in that wide interval, as no standard meridian, nor any point to which comparative observations may be referred, exists throughout the whole continent of America. The establishment of a small observatory in Upper Canada would supply this desideratum, which has been so strangely overlooked by the United States, and would thus reflect more honor in this Country.

"My Lords have been given to understand that the Observatory at St. Helena is about to be dismantled, and that the instruments which have been in use there would be available for the proposed observatory, thus reducing materially the expense to be incurred.

"Should Lord Glenelg see no objection to this arrangement, my Lords would suggest that an inventory of these instruments should be furnished to this Department in order that it might be ascertained what further instruments it would be necessary to procure for this purpose."(1)

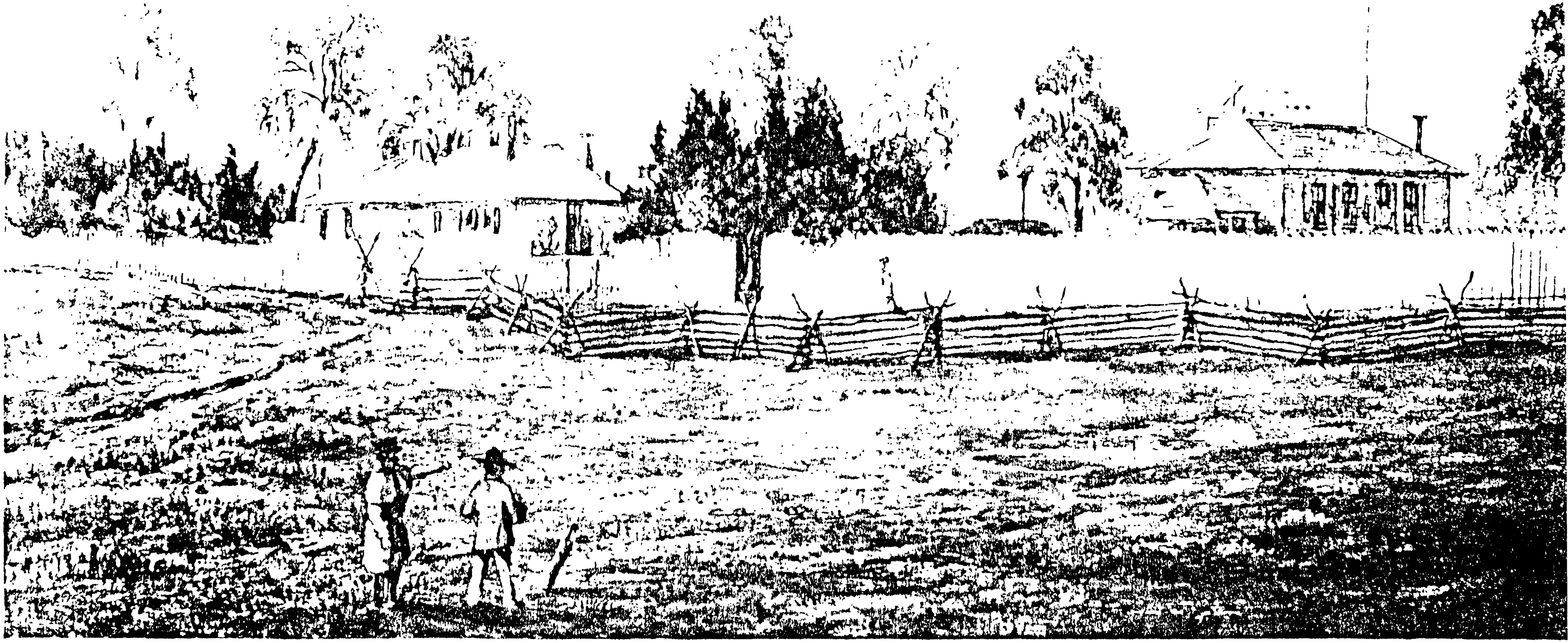
In July 1835 Lord Glenelg, Secretary for War and the Colonies wrote to Sir John Colborne, Lieut-Governor for Upper Canada expressing

(1) Manuscript Group 15, Treasure 28, Treasury Board Out-Letters, Vol 14, Various.

sympathy with the idea of establishing a small observatory in Upper Canada, and using the instruments which had been used at St. Helena, but which were now ready to be shipped. Colborne failed to bring the matter to the Upper Canada Legislature. The following February Glenelg wrote to Sir Francis Bond Head requesting him to find out if the Legislature of Upper Canada would assume the cost of erecting the observatory, or defray the cost of its future maintenance. No answer was given to Glenelg, and the instruments remained packed away at Greenwich Observatory. Meanwhile in late 1835 Professor Albert Hopkins of Williams College brought back from Europe a sidereal clock, a transit and other instruments, and his example was followed by others so that soon there were several small observatories established in the eastern United States. In the words of Dr. A. Vibert Douglas, "Had it not been for the negligence of Sir John Colborne and the apathy of Sir Francis Bond Head in failing to bring before the legislature of Upper Canada an offer from the Lords Commissioners of the Amiralty, Toronto might have had the first astronomical observatory in the New World." (Queen's Quarterly Winter Issue Vol. 78, 4, (1971))

Instead Toronto in 1839 became the site of a Magnetic Observatory, one of several which were erected within the British Empire to assist in a global study of magnetic fluctuations. It was established on property belonging to King's College, later to become University of Toronto. It was administered until 1853 by the Imperial Government Board or Ordinance, then until 1871 by the University of Toronto, after which it became a part of the federal Department of Marine and Fisheries. This last change was the direct result of an increase in federal support from

Fig. 7 & Fig. 8



53%

Fig. 7 The Magnetic Observatory, Toronto, built under the supervision of
Pg. 64 Lieut C.J.B. Riddell in 1840. Painting by W. Armstrong in 1852.
Courtesy Atmospheric

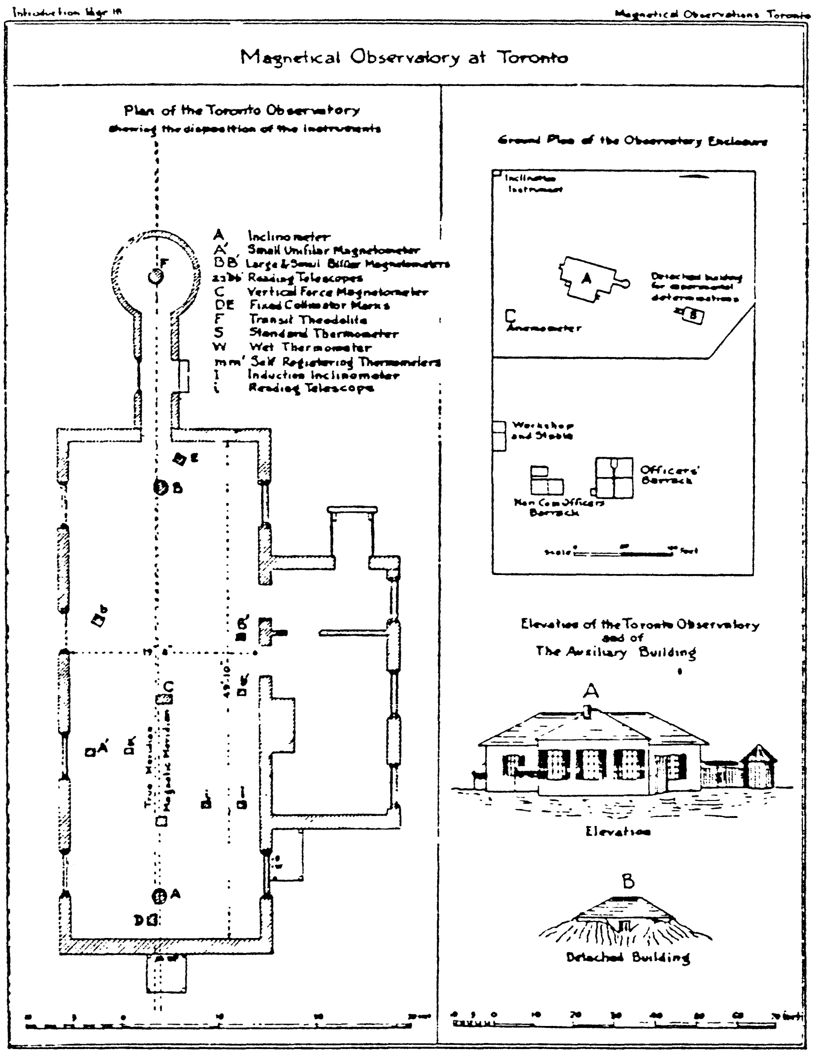


Fig. 8
Fg. 64
Plan of the Magnetic Observatory, Toronto, built in 1840. Courtesy Atmospheric Environment Service, Department of the Environment.

$500 to $5000, soon to be increased to $10,000 for the development of a Canadian Meteorological Service.

Lieutenant C.J.B. Riddell, who established the Toronto Observatory, brought instruments which included "a complete set for magnetic work, transit instruments and the necessary chronometers for obtaining and maintaining correct time, as well as a very full set of meteorological instruments." (J. Patterson, A Century of Canadian Meteorology, Quarterly Journal Royal Meteorological Journal 66, 16, (1940).) When Riddell, due to ill health, retired to England in 1841, he was replaced by Capt. J.H. Lefroy, who, except for two years of northern magnetic survey when Lieut. C.W. Younghusband was temporary director, remained with the observatory to the end of the military regime in 1853. He was an enthusiastic meteorological observer, and encouraged weather observations to be recorded at guard houses of military establishments in Canada. At the time of his recall to England he was at the point of organizing a system of weather reporting by the Canadian grammar schools.

In 1853 Prof. J.B. Cherriman, Professor of Mathematics & Natural Philosophy, became temporary Director, to be followed in 1855 by Prof. G.T. Kingston who was appointed by the University to be Professor of Meteorology and Director of the Magnetic Observatory. Through his energetic efforts the assistance of the schools in making weather observations was organized, and eventually in 1871 financial support of a substantial nature was secured from the federal purse. Prof. Kingston was thereupon appointed Director of the Meteorological Service of Canada in addition to his duties as Director of the Magnetic Observatory. Certain locations such as Montreal, Quebec, Saint John, Fredericton, Halifax, Woodstock, Ont., and Winnipeg became chief reporting stations, manned by competent observers, mainly volunteers, who reported their readings each day by telegraph. An additional body of volunteers, including lighthouse keepers, station agents, and others were supplied with instruments and with forms for submitting data on a regular basis. A daily weather report together with a forecast of probabilities was started, together with an exchange of data with the United States, and soon the budget was up to $10,000 annually. The service was particularly valuable to shipping.

Time, of course, was an essential element in an observational program which involved coordination of effort and the production of a synoptic map. At the Toronto Observatory time was maintained from Fig.9 fundamental observations of the stars and the sun, and according to the report of the Director was the standard by which clocks and watches in Ontario had been regulated since 1853. Commencing about 1872 time was given to Toronto by striking all the fire alarm bells at 11:55 a.m.

On his retirement in 1880 due to ill health, Kingston was succeeded by Charles Carpmael, an eminent mathematician who had joined the Service eight years previously.

It was just two years before the transit of Venus, an event that aroused considerable popular interest and scientific anticipation. Carpmael was asked to report to the Department on the advisability of Canada participating, and in reply stated, "The practical use of the transit observations is ultimately the more correct determination of longitude, and is therefore of the greatest interest to all nations, more especially to those largely interested in shipping. As another transit

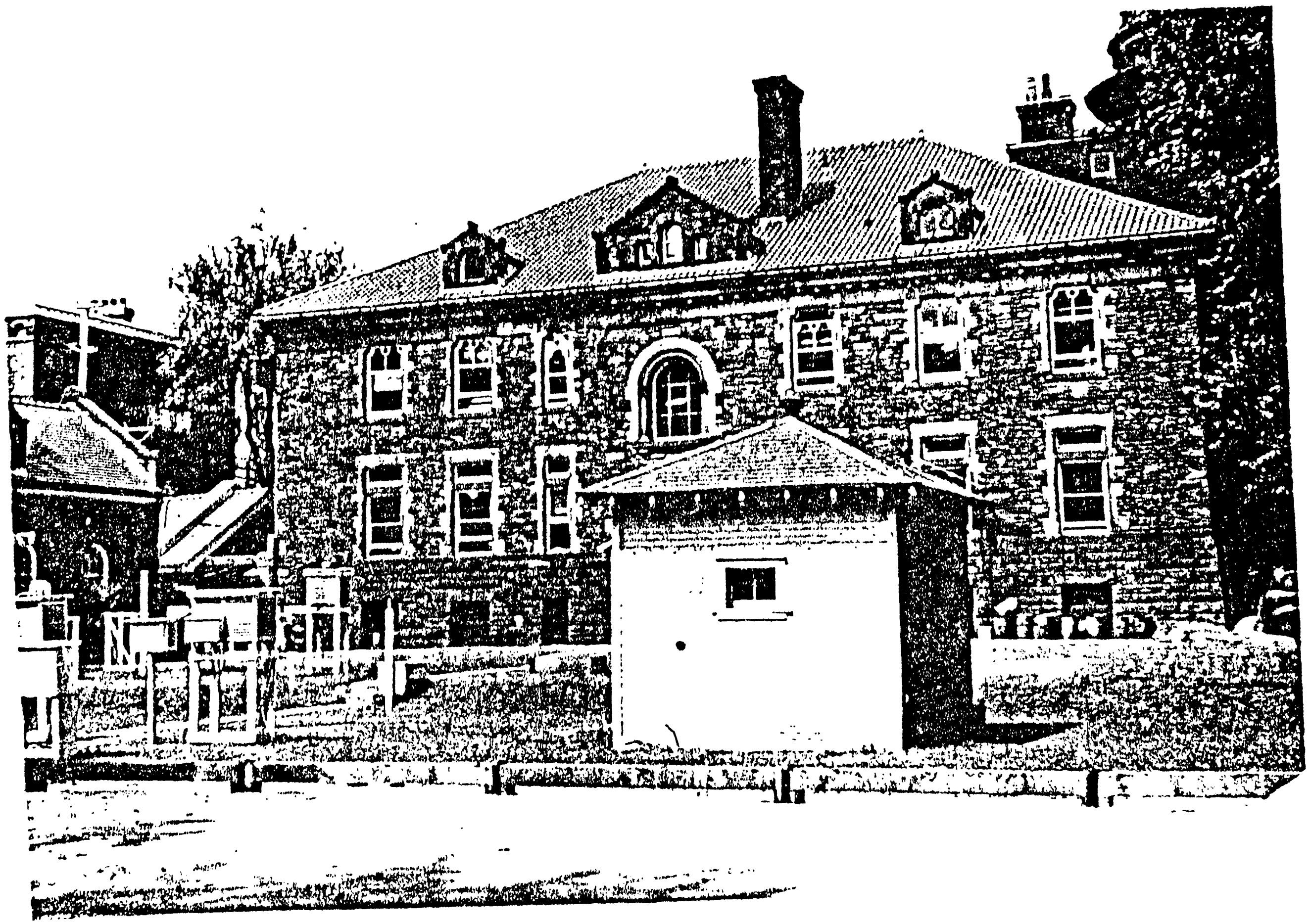


Fig. 9
Pg.66

Meteorological office, 315 Bloor Street West, Toronto. The transit hut with its roof shutter may be seen partially obscured at left centre. Courtesy Atmospheric Environment Service, Department of the Environment.

will not take place till the year 2004, I should deem it exceedingly unfortunate if the opportunity were allowed to pass without being utilized to the utmost."

The transit occurred December 6, 1882. Parliament provided an appropriation of $5000 and as a consequence arrangements were made for observations at the following places:

Winnipeg - Prof. C.H. McLeod, Observer; Mr. H.V. Payne, Assistant. Had a 4-inch acromatic telescope, transit instrument, two chronometers, etc. A temporary instrument shelter was erected by the Bishop of Rupert's Land for these gentlemen on the ground near St. John's College.

Woodstock - Prof. Wolverton had an 8-inch refracting telescope by Fitz, of New York. The aperture was reduced to 6 inches for these observations.

Toronto Observatory - Prof. C. Carpmael had a 6-inch telescope by T. Cooke and Sons.

Whitby - Prof. Hare, Ladies College, 6-inch telescope by H Fitz of New York.

Cobourg - Prof. Bain, Victoria University, 4¼-inch telescope by Smith, Beck & Beck, of London, England.

Kingston Observatory - Prof. Williamson, 6½-inch telescope by Alvin Clark and Sons of Cambridgeport, Mass.

Belleville - Mr. Shearman, 4-inch achromatic.

Ottawa - F.L. Blake, D.L.S., Observer, B.C. Webber, Assistant. A 4-inch achromatic telescope from McGill University, and a transit instrument loaned by the Department of the Interior.

Montreal Observatory - Prof. Johnson, a 6¼-inch achromatic telescope.

The object glass of this telescope being found faulty was ground over by Clacey of Boston.

Quebec Observatory - Lieut. Gordon, R.N., Observer, W.A. Ashe, D.L.S., Assistant. 8-inch refracting telescope by Alvin Clark and Sons of Cambridgeport, Mass., aperture reduced to 6 inches for these observations.

Halifax - A. Allison, Esq., 4-inch refracting telescope by Dolland.

Charlottetown - H.J. Cundall, Esq., C.E., 4-inch refracting telescope.

Fredericton Observatory - Dr. Jack, 7-inch refracting telescope, reduced to 6 inches for these observations.

The transit observation involved four phases, the arrival and departure of the planet at the east limb, and the arrival and departure of the planet at the west limb of the sun.

Since the time of each phase as seen at each location was required, a telegraphic exchange of time was made between stations both before and after the transit. C.H. McLeod made a telegraphic exchange with Prof. Hough of Dearborn Observatory, Chicago, to verify his longitude. Free use of the telegraph lines during the exercise was a contribution of great assistance.

On the day of the transit the fortunate stations were:

Winnipeg - where Prof. McLeod got the last two contacts.

Cobourg - Prof. Bain got the third contact; atmosphere very unsteady.

Belleville - Shearman got third contact imperfectly.

Kingston - Prof. Williamson got second, third and fourth contacts.

Ottawa - F.L. Blake, D.L.S. got second, third and fourth contacts.

Considering the time of year and the weather probabilities, the results were quite acceptable, and were considered to be a valuable contribution to the British system of observations.

Canadian astronomy benefited by the surge of popular interest. Carpmael was able to secure a six-inch achromatic telescope by Cooke and Sons, which he mounted in the dome of the Magnetic Observatory, and subsequently used it to study solar flares. A new transit of three-inch objective and 36-inch focal length by Troughton and Simms, a gift of the City of Toronto, improved the timekeeping capabilities.

During the year 1883 the time ball observatories at Quebec City and Saint John, N.B., were transferred for administrative purposes to the Meteorological Service. Capt. E.D. Ashe, R.N., Director of the Quebec observatory since 1850, had at one time been active in longitude work and also in solar astronomy. But more recently his principal contribution had been limited to the daily reporting by telegraph of meteorological readings, and the operation of the time ball during the navigation season. His retirement in May of 1883 provided an opportunity for a reorganization, in effecting which Carpmael had the able assistance of Lieut. Andrew R. Gordon, R.N., Deputy Director of the Meteorological Service. Gordon personally supervised the removal of all the meteorological and timekeeping equipment to the Citadel and arranging with the Commandant Colonel Cotton to maintain the services. The annual expenditure for Quebec dropped from $2650 to $1100, which was comparable to the cost of maintaining Hutchinson's work in Saint John, N.B.

All four observatories, Toronto, Montreal, Quebec and Saint John provided correct time for the benefit of local industries and watchmakers and surrounding communities. Prior to the reorganization, there had been complaints about irregularities in the time service both at Quebec and Saint John. In order to provide some control, Carpmael, with the cooperation of the telegraph company, initiated a system of time exchanges. Clock beats would be requested from each observatory on a notice of only half a day, and these would be recorded at Toronto on a drum chronograph together with the beats of the Toronto clock. The transit observations would also be submitted, and the clock error at each observatory determined. C.H. McLeod of McGill voluntarily cooperated in the exercise. His work was of such a high quality that in 1890 Carpmael combined the Toronto and Montreal time determinations to form the Standard Observer, from which the deviations of each of the four observatories was measured. Initially, the time results from Saint John were somewhat erratic, but improved considerably with improved instrumentation. Carpmael took the occasion of the clock exchanges with Saint John to give A. Allison, meteorological observer in Halifax, time checks. This continued until April 7, 1896, by which time Saint John daily time signal was available by telegraph throughout the Maritime Provinces.

A report of the Toronto time service for the year ending 1891 is as follows: (2)

"The time exchanges with Montreal, Quebec and Saint John have all been registered on the chronograph at Toronto, the comparisons taking place during the afternoon with Montreal and Quebec, and in the evening with Saint John.

"During the year the time at Halifax has also been regularly compared with that at Toronto, the comparisons taking place during the same evening as that with Saint John.

(2) Sessional Papers, Dept of Marine & Fisheries, 1892, 127.

"The errors of the Toronto clock, and of the time-pieces used by the observers elsewhere, are computed from the latest observations.

"The examination of the monthly clock and chronometer comparisons and transit observations, sent in from the observatories at Quebec and Saint John, has been performed.

"During the year observations of 783 stars and 1 solar observation were made from which the time at the Toronto Observatory was obtained. The position of the stars used in the reductions are from "Berlin Jahrbuch." The collimation error of the transit instrument has been determined frequently from micrometrical measurements on the collimating telescope and by reversals on "Polaris" and other stars.

"The following table shows the difference between the time by standard observer and that given at the various exchanges.

"The sign + indicates that the time as sent from the various observatories is faster than that by the standard observer.

	Toronto	Montreal	Quebec	Saint John
1890	Secs.	Secs.	Secs.	Secs.
October 8th	+0.06	-0.06	-2.15	-1.52
do 31st	+0.27	-0.27	-1.23	-1.36
November 21st	+0.10	-0.10	-0.15	-1.53
December 10th	+0.68	-0.68	.....	.....
do 30th	+0.23	-0.23	+3.70	-1.78
1891				
January 21st	+0.18	-0.18	-1.32	-1.63
February 6th	.....	.....	-3.02	-0.74
do 25th	+0.36	-0.36	+0.03	.....

March 17th	+0.11	-0.11	+0.11	+0.31
April 3rd	0.00	0.00	+0.54	+0.08
do 20th	+0.29	-0.29	0.00	-0.20
May 7th	+0.28	-0.28	-2.10	.....
do 21st	+0.15	-0.15	+0.03	-0.06
June 9th	+0.15	-0.15	-0.38	.....
do 25th	+0.15	-0.15	+1.45	-0.36
July 9th	+0.09	-0.09	-0.67	-0.93
do 31st	.....	.....	-0.07	-0.71
August 27th	+0.23	-0.23	+0.77	-1.28
September 11th	+0.11	-0.11	-0.08	-1.67
October 5th	+0.04	-0.04	-0.08	-1.39
do 30th	+0.01	-0.01	-1.39	.....

"The time by standard observer is obtained by taking the arithmetical mean of the times as determined at Toronto and Montreal, after applying the personal equations between the observers and the director of the Magnetic Observatory, whose absolute equation is known to be almost insensible.

"NOTE.- Where no exchange has been made with Montreal the Toronto time corrected for its observer's personal equation is adopted as standard time for the comparisons with Quebec and Saint John."

Carpmael reported in January 1884 that the telegraphic exchange of time could readily be extended at small cost to the country so that every sea port could be provided with correct time for the benefit of mariners. He also was pleased to report "that the Corporation of the

City of London, Ontario have, in order to avail themselves of the distribution of correct time from this office, erected on the top of their City Hall a time ball signal; they have made arrangements with the Telegraph Company for the use of the wires daily, and the ball has been dropped at noon of standard time, 75th meridian, every day except Sundays and statutory holidays." Carpmael noted that a similar service could be had by any municipality at the small expense of the wire rental, providing an approved apparatus was installed. There is no report of other communities making use of the Toronto offer.

In July 1884 Lieut. A.R. Gordon, R.N., was directed by the Minister of Marine and Fisheries to take charge of the Hudson's Bay Expedition. The primary object of the expedition was to determine for what period of the year the Hudson Straits were navigable, and so attention was to be paid to the formation, break-up, and movements of the ice, as well as details of the weather. R.F. Stupart of the Toronto observatory accompanied the expedition, leaving Carpmael short handed. In order to maintain uniformity in the time at each observing station, the several observing parties were each provided with a sundial and a correction table to 75th meridian time to check their timepieces at noon when possible.

Correct time at any location is largely dependent upon correct longitude. C.H. McLeod had a growing suspicion that the longitude of Montreal, as given by E.D. Ashe in 1857, was subject to error. Carpmael supported him in his proposal to make a direct telegraphic exchange with the primary station at Harvard in 1883. He also supported McLeod nine years later when he organized the direct exchange with Greenwich by trans Atlantic cable. On each occasion the longitude of Toronto was also redetermined.

Carpmael was also a strong supporter of Sandford Fleming in his program of time reform which led to the adoption of standard time by the City of Toronto November 18, 1883.

R.F. (Sir Frederic) Stupart became Director following the death of Carpmael in 1894. Under his direction regular sun spot observations were commenced on March 20, 1895, using the 6-inch equatorial purchased at the time of the transit of Venus in 1882. A solar image 4 inches in diameter was obtained by projection, from which drawings were traced. The observations were made as soon after 10 a.m. as the condition of the sky permitted.

In September 1897 a seismograph designed by Prof. John Milne of England was added to the Toronto equipment, followed a year later by the installation of a similar instrument in Victoria. The Seismological Committee of the British Association had requested this cooperation in order to study the phenomena associated with earthquakes.

The expansion of the Toronto street railway, and the attendant wires carrying heavy electric currents were beginning to have a serious effect on the magnetic records obtained at the observatory. So in June of 1898 a new observatory building was commenced on a quiet site at the village of Agincourt, about 10 miles to the northeast. Stupar devised a break circuit for the mean time pendulum so that time pulses could be sent automatically for the weekly time check at Agincourt. The daily signal which rang the Toronto fire alarm bells at 11:55 a.m. as well as the daily signal to the C.N. telegraph, were also controlled automatically.

City of London, Ontario have, in order to avail themselves of the distribution of correct time from this office, erected on the top of their City Hall a time ball signal; they have made arrangements with the Telegraph Company for the use of the wires daily, and the ball has been dropped at noon of standard time, 75th meridian, every day except Sundays and statutory holidays." Carpmael noted that a similar service could be had by any municipality at the small expense of the wire rental, providing an approved apparatus was installed. There is no report of other communities making use of the Toronto offer.

In July 1884 Lieut. A.R. Gordon, R.N., was directed by the Minister of Marine and Fisheries to take charge of the Hudson's Bay Expedition. The primary object of the expedition was to determine for what period of the year the Hudson Straits were navigable, and so attention was to be paid to the formation, break-up, and movements of the ice, as well as details of the weather. R.F. Stupart of the Toronto observatory accompanied the expedition, leaving Carpmael short handed. In order to maintain uniformity in the time at each observing station, the several observing parties were each provided with a sundial and a correction table to 75th meridian time to check their timepieces at noon when possible.

Correct time at any location is largely dependent upon correct longitude. C.H. McLeod had a growing suspicion that the longitude of Montreal, as given by E.D. Ashe in 1857, was subject to error. Carpmael supported him in his proposal to make a direct telegraphic exchange with the primary station at Harvard in 1883. He also supported McLeod nine years later when he organized the direct exchange with Greenwich by

On December 21, 1897, Stupart wrote to Major F. Gourdeau, Deputy Minister of Marine and Fisheries the following. "I beg to acknowledge the receipt of your letter of the 17th instant No. 7/26 enclosing a copy of one forwarded by the Secretary of State for the Colonies issued by Mr. John Milne, Secretary of the Seismological Investigating Committee of the British Association in which he asks for a list of the times used in various parts of Canada. In reply I have the honour to enclose herewith a statement of the times used in the various parts of the Dominion.

"Nova Scotia - The Railways and Telegraph Companies use the 75th meridian or (eastern standard time) but for other purposes the time generally used is the 60th meridian or (Atlantic standard time).

Example: Halifax 5 a.m. = 9 a.m. G.M.T.

"New Brunswick - The Railways and Telegraph Companies use the 75th meridian or (eastern standard time) but most places in this Province use local mean time. Saint John local time is 35m 44s fast on 75th meridian or (eastern standard time).

"Ontario and Quebec - (eastern standard time) 75th meridian is generally used for all purposes throughout these Provinces as far west as Port Arthur [now Thunder Bay].

"Quebec, Montreal, Ottawa, Toronto - 4 a.m. = 9 a.m. G.M.T.

The Railway and Telegraph Companies east of Port Arthur, as far as the Atlantic coast, use 75th meridian time or (eastern standard time).

"Manitoba, North West Territories and British Columbia - West of Port Arthur to the Pacific Coast, the Railways, Telegraph Companies, Cities, and Towns all use the same time, according to the different meridians hereunder mentioned. From Port Arthur to Brandon, Manitoba, the time used is the 90th meridian or (central standard time).

Winnipeg - 3 a.m. = 9 a.m. G.M.T.

From Brandon to Donald, B.C. the 105th or (mountain time) is used.

Calgary 2 a.m. = 9 a.m. G.M.T.

From Donald westward in British Columbia, the 120th or (Pacific time) is used.

Vancouver and Victoria 1 a.m. = 9 a.m. G.M.T.

Also west of Port Arthur to the Coast, the Railways use the 24-hour system, the p.m. hours from noon to midnight being numbered from 12 to 24."

At the turn of the century, Stupart was able to report as follows: "The time service under the control of the Meteorological Service comprises, in addition to striking of fire alarm bells in Toronto at 11:55 a.m. daily, the dropping of time balls at Quebec and Saint John, N.B., and the firing of the gun at Vancouver." In 1904 the maritime service was expanded to include the operation of a time ball in Halifax, and in 1915 Napier Denison inaugurated a time ball in Victoria, B.C.

Correct time was important throughout the Meteorological Service, whether the observations were made at the well equipped principal reporting centres such as Montreal, Quebec and Saint John, N.B., or by any of the large number of secondary posts, manned for the most part by capable volunteers. In the maritime provinces the daily signal from Saint John was available wherever the telegraph went. The rest of Canada was served by the McGill signal which was also distributed over the telegraph network. Stupart and his staff made annual inspection trips so that each year some of the stations would be visited, the equipment repaired or replaced, and the operators encouraged in their work.

History was made on the occasion of the Geophysical Conference, held in Toronto on September 8, 1904, when a direct telegraphic time comparison was made at midnight with Washington. The difference in time was five hundredths of a second. The following May 6 another comparison was made with Washington which showed exact coincidence. Communication between these two cities was a natural consequence of the fact that they were both data centres for meteorological research, and custodians of correct time.

Transit observations for the fundamental determination of time at Toronto continued year by year, the number of nights varying from a low of 57 in 1905 to a high of 139 in 1925. During the earlier years an occasional transit observation of the sun was made to supplement stellar observations during periods of poor weather. After World War I there are no further reports of solar observations for time. There was an active program to maintain a record of sun spot numbers, the six-inch equatorial being used to project an improved image of five inches. In 1923, due to retirements, the transit work was turned over to the Department of Magnetism under W.E.W. Jackson. By now the work at the central office in Toronto included weather forecasting, atmospheric physics, climatology and agricultural meteorology, terrestrial magnetism, astronomy. The last comprised the maintenance of the time service, and solar observations for sunspot numbers.

It is tempting to digress at this point to delve more fully into some of the other four areas of activity mentioned above. Weather forecasting, which has the most immediate impact on the community, had for many years past included Newfoundland, and at the request of the Newfoundland Minister of Marine, telegraph reporting stations had been maintained and regularly inspected. At Cape Race, Newfoundland, a federally owned radio station broadcast a weather bulletin twice a day. In his inspection report in 1923, T.G. Sharp of the Meteorological Service in Toronto wrote, "The work of broadcasting weather information and forecasts from Cape Race has grown enormously; in fact it is now a service of first importance to Canadian and International shipping in touch with Cape Race. Mr. Kerton, the manager of the Cape Race Wireless Station, said he could not express too strongly his appreciation and admiration of the forecasts sent down from our office. He said he would like, just to show us the value of the work, to have us discontinue the service for even two weeks. There would be such an outcry from shipping of all nations that we would be in no doubt as to the esteem in which the forecasts are held. The work of sending out forecasts on request has grown to such a volume that if we were paying for it at the ordinary commercial rate it would cost us one hundred thousand dollars per year. In fact such requests are so numerous that they are interfering with the commercial work of the Marconi Company and the Government will be asked for some relief in this connection." Doubtless the forecast service on the West Coast, the Great Lakes, and across Canada generally would have received a similar accolade.

Time signals by radio opened the door for closer coordination of meteorological observations across the continent. At the time of the transit of Mercury May 7, 1924, Prof. L.B. Stewart of the School of Practical Science University of Toronto assisted the meteorological people by setting up a radio receiver so that the Toronto sidereal clock could be compared directly with the Arlington time signals. As a consequence, the times of the 1st and 2nd contacts at ingress, in terms of the Washington clock were $16^h\ 42^m\ 46\overset{s}{.}38$ and $16^h\ 45^m\ 27\overset{s}{.}71$ respectively.

Stupart favored the principle of receiving wireless time signals. Two years previously he had recommended the acquisition of a radio receiver on the west coast to monitor the signals from San Francisco. Otto Klotz, Dominion Astronomer, was asked for an opinion, and voiced strong opposition to the proposal. He felt that the time service provided by the Dominion Observatory was superior to that which emanated from San Francisco. The acquisition of a radio was an unnecessary expense, particularly when the ultimate product was inferior to that which was available at home. Also, he felt it was humiliating that any part of Canada should admit dependence on a foreign product when telegraphic communication could make the native product available with a reliability superior to that of radio. Undoubtedly there was some degree of rivalry between the two men. Both of them had developed a time service, the separate tentacles of which were commencing to overlap. And both had an active interest in the geophysical disciplines of magnetism and seismology. It was with some dismay that both Toronto and McGill saw a new observatory built in Ottawa at the turn of the century. Both institutions had urged the need for expansion and the continual up-dating of facilities, without which the routine operation of a time service is no longer attractive to fresh young scientific minds.

So it was that radio receivers came into use in the Meteorological Service. From Victoria, F. Napier Denison made his last report of transit observations for the year 1919-20. James Weir, Director of the McGill Observatory, makes no mention of star transits after the report for the year ending March 31, 1919, but instead refers to a wireless receiving set "recently installed". Presumably he commenced receiving Arlington signals in 1920.

Sir Frederic Stupart, who had been Director of the Meteorological Service since December 1894, retired in 1929. He was succeeded by John Patterson, M.A. Sir Frederic had his first contact with the Toronto Observatory in 1872, at the age of 15, which means that he was attached to the Meteorological Service from the beginning. His school had been the school of practical experience, and the high quality of his contribution had been recognized by the knighthood bestowed on him in 1916.

In the annual report for the year ending March 1931, Patterson writes,(3) The time service was maintained with increased efficiency during the past year. Thermostatic control of the temperature in the clock room resulted in greatly improved clock rates and consequent saving in time necessary for transit work. Time exchanges were made about once a month with Quebec, Montreal, and Saint John and the results were quite satisfactory. The mean differences were:

Toronto - Quebec = -0.12 sec

Toronto - Montreal = -0.17 sec

Toronto - Saint John = -0.70 sec.

In February 1931, a long wave receiving set was installed for the purpose of checking time with the Arlington signals and the result of daily checks through the month of March gave:

Toronto - Arlington = -0.07.

Time signals were telegraphed one a week to Agincourt to check and control errors of the clocks and chronometers. A daily signal is sent out over the Toronto fire alarm system for the city of Toronto, and hundreds of

(3) Report of the Deputy Minister, Dept of Marine & Fisheries, 1930-31, 64.

calls over the telephone are received daily for correct time from watch-makers, surveyors, and the general public."

The following year it was reported that "the time service has been controlled by daily reception of the Arlington time signals". In October 1931 a radio receiving set was installed in Agincourt.

The time service continued to be of direct concern to the Meteorological Service, though fundamental observations for time were discontinued at all observatories except Saint John, N.B. McGill provided a signal each day to the telegraph companies which was relayed Dominion-wide, and except for Victoria, Toronto, Ottawa and the Maritimes, the time for Canada was set by McGill.

The Observatory at Ottawa, established in 1905, had developed an expertise in timekeeping, with modern equipment in both transit instruments and precision clocks. Hence in the federal reorganization in December 1936, timekeeping for Canada became the responsibility of the Dominion Observatory. The magnetic and seismic survey activities of the Toronto Observatory were also transferred to Ottawa. The Meteorological Service was thus left free "to devote all its efforts to provide a weather service for the Dominion". (Annual Report of the Assistant Deputy Minister, Department of Marine 1936-37.)

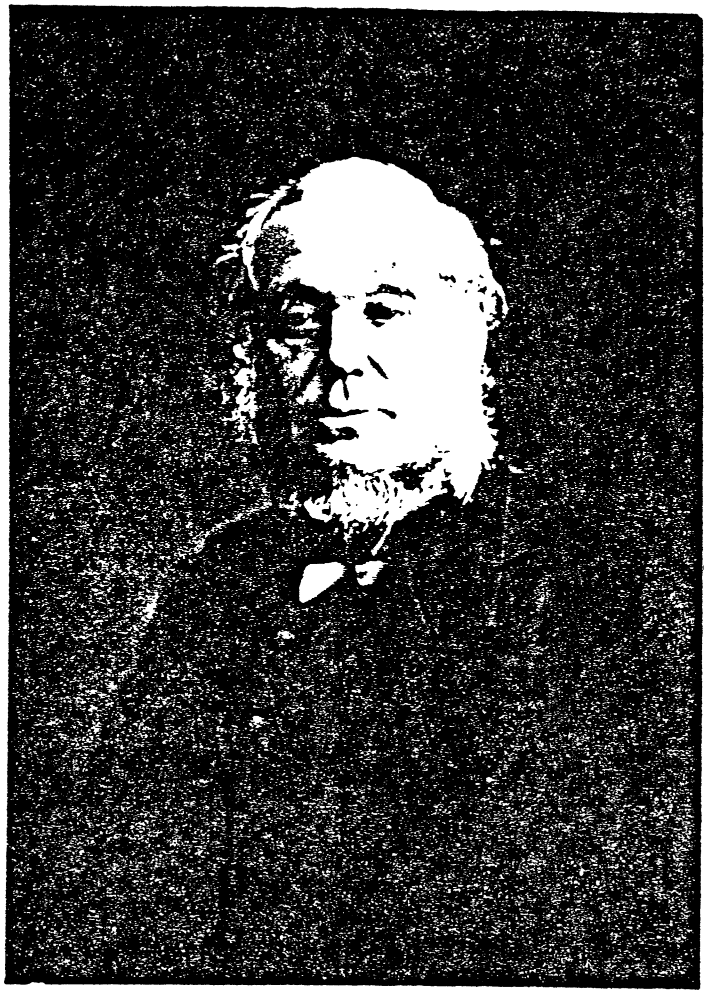
Montreal

MONTREAL

The Natural History Society of Montreal included many prominent citizens who had direct contact with McGill University. One was Dr. (Sir) John William Dawson, a Canadian geologist who was appointed Principal in 1855 on the recommendation of the Governor General, Sir Edmund W. Head. Another was Dr. Charles Smallwood, an English born physician with a great interest in meteorology and astronomy. At his home at St. Martin, Isle Jesus, nine miles west of Montreal, Dr. Smallwood had a collection of instruments, mainly of his own construction for observing weather and maintaining time, and he published a number of scientific papers as well as detailed weather summaries. As a result he was given an honorary degree of LLD by McGill, and in 1856 he was appointed during the pleasure of the Governors, and no longer, to be Professor of Meteorology, but without salary.

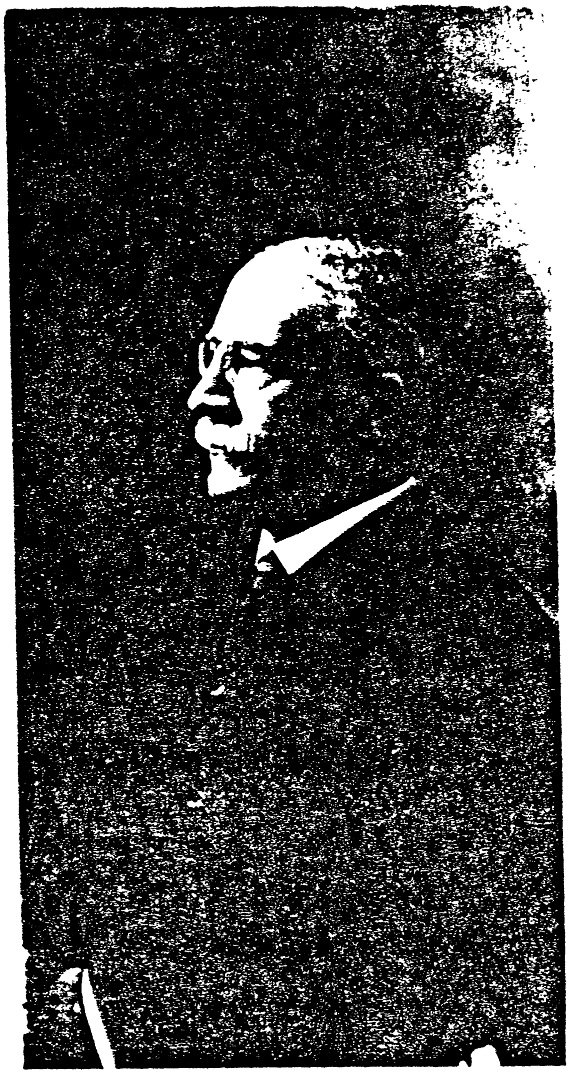
In 1858, Mr. E.T. Blackwell, President of the Grand Trunk Pacific Railway Company, proposed to erect an astronomical observatory, suggesting that McGill provide a site. Railway companies in the United States were making similar proposals, since they were in need of correct Fig. 10
time. A few years later Dr. Smallwood offered to bring his meteorological instruments onto the campus if a suitable site were provided. In 1862 the work got under way and the stone tower, forming the earliest part of the Observatory, was built at a cost of about $2000.

For a decade the elderly Smallwood pursued his several duties with characteristic energy. The time, which was determined astronomically at McGill, became the standard reference for business establishments, the railway, and for the operation of a time ball in the harbour. The



(7) SIZE 85%

Fig. 10 Pg. 82 Dr. Charles Smallwood (1812-1873), who founded the McGill Meteorological Observatory in 1862. Courtesy McGill Observatory.



(8) SIZE 85%

Fig 11 Dr. C.H. ("Bunty") McLeod (1851-1917), Professor of Geodesy and
Pg. 83 Surveying, and Vice-Dean of Applied Science, who was Superintendent of the McGill Observatory for forty years. Courtesy McGill Observatory.

Observatory was also connected with the fire alarm circuit of Montreal by means of which correct time was furnished at 7 a.m., noon, and at 6 p.m. for the use of workshops and factories. The winding, rating, and correcting of ships' chronometers formed an important item in the work connected with the McGill Observatory. Commencing in 1869, a signal from Montreal furnished the correct time for firing the noon day gun at Ottawa, for the purpose of regulating the Government time under the direction of the Postmaster General.

Smallwood was keenly aware of the need to correlate weather observations, and welcomed the opportunity to have McGill become a principal reporting station, cooperating with and reporting to the Magnetic Observatory at Toronto.

A small amount of revenue was realized by the Bursar's office at McGill from the railway companies, the Harbour Commissioners, and from some of the jewellery and other business establishments in Montreal in return for the time service. Also the McGill Observatory was in receipt of a government subsidy of $500 per annum. But in common with other educational institutions, McGill always seemed to be operating at the poverty level of existence.

Smallwood died in December 1873. Earlier that year he had signed the diplomas of the first group of McGill engineers to graduate as a class. One of the five young men was Mr. Clement H. McLeod, who Fig. 11
eventually became Professor C.H. (Bunty) McLeod, Professor of Geodesy and Surveying, and Vice-Dean of Applied Science. As an undergraduate he had assisted in the meteorological work. Principal Dawson therefore invited him to take charge of the meteorological observatory, and permitted him to go to Toronto for a week of special training under

Professor G.T. Kingston. Montreal thereupon became a chief station in the new network, connected by telegraph to Toronto so that observations could be reported without delay every three hours.

It would appear that McLeod did not take over the timekeeping responsibilities of the Montreal community on the death of Smallwood. Instead they were maintained from the private observatory of Mr. Charles Seymour Blackman. He was apparently a man of some means. The Montreal Directory of 1874 gives his residence as Belair Villa, 46 Belmont, and lists his place of business as E. Atwater & Co., of 17, 19, 21 St. Nicholas. They were Oil, Lead and Colour Merchants, importers of German sheet window glass of favorite Star and Diamond Star brands, Manufacturers of varnish and japans. In 1879 he retired, but not before making a handsome gift to the university of all his astronomical equipment, thus launching McLeod on his career as official custodian of time for Montreal and all its connections. In his annual report, McLeod states as follows:

"McGill College,
Montreal, January 10, 1880.

Sir, -- I have the honour to present the Annual Report of the McGill College Observatory for the year ending December 31st, 1879:-

The meteorological work done during the year has consisted in the continuation of the tri-hourly series of observations, referred to in former reports; in the transmission, each day, of three telegraphic signals to the Central Meteorological Office, at Toronto; in the publication, through the local press, of daily, monthly and yearly results; and in attending to the inquiries of persons seeking special information. No change has taken place in our equipment of meteorological instruments, since I had the honour to describe them in a previous report.

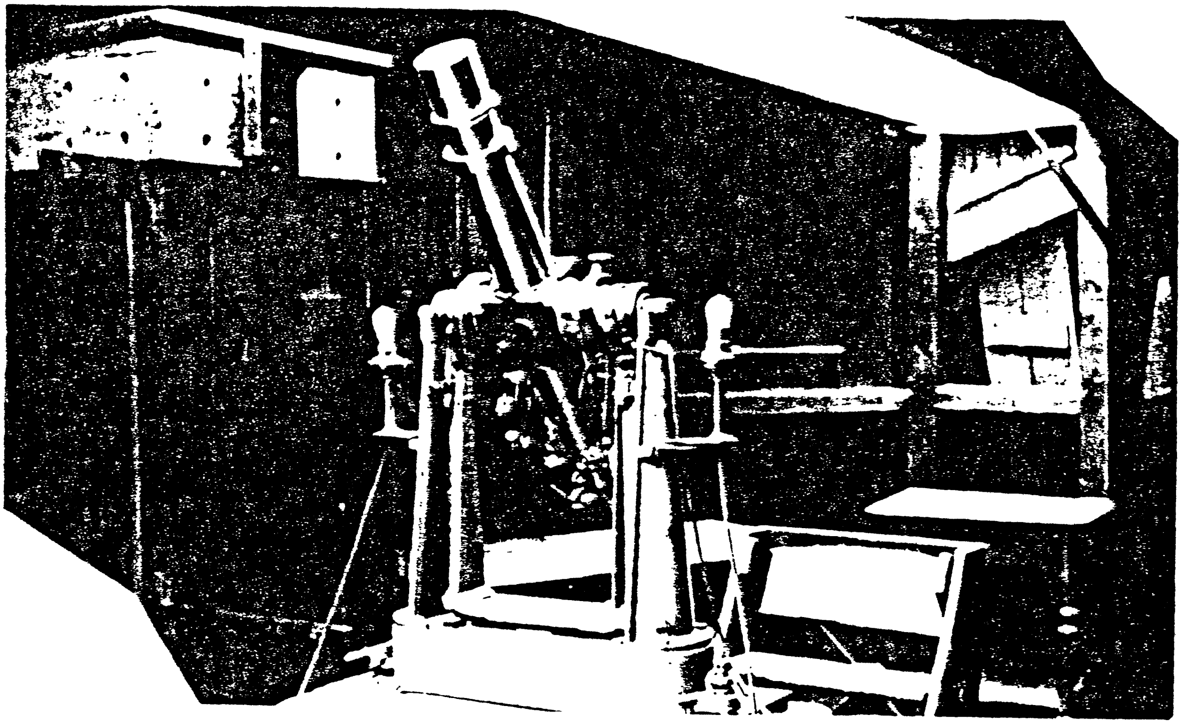


Fig. 12 Interior of McGill transit hut showing the Troughton and Simms transit, mounted on a solid stone pier. Courtesy McGill Observatory.

Pg 85

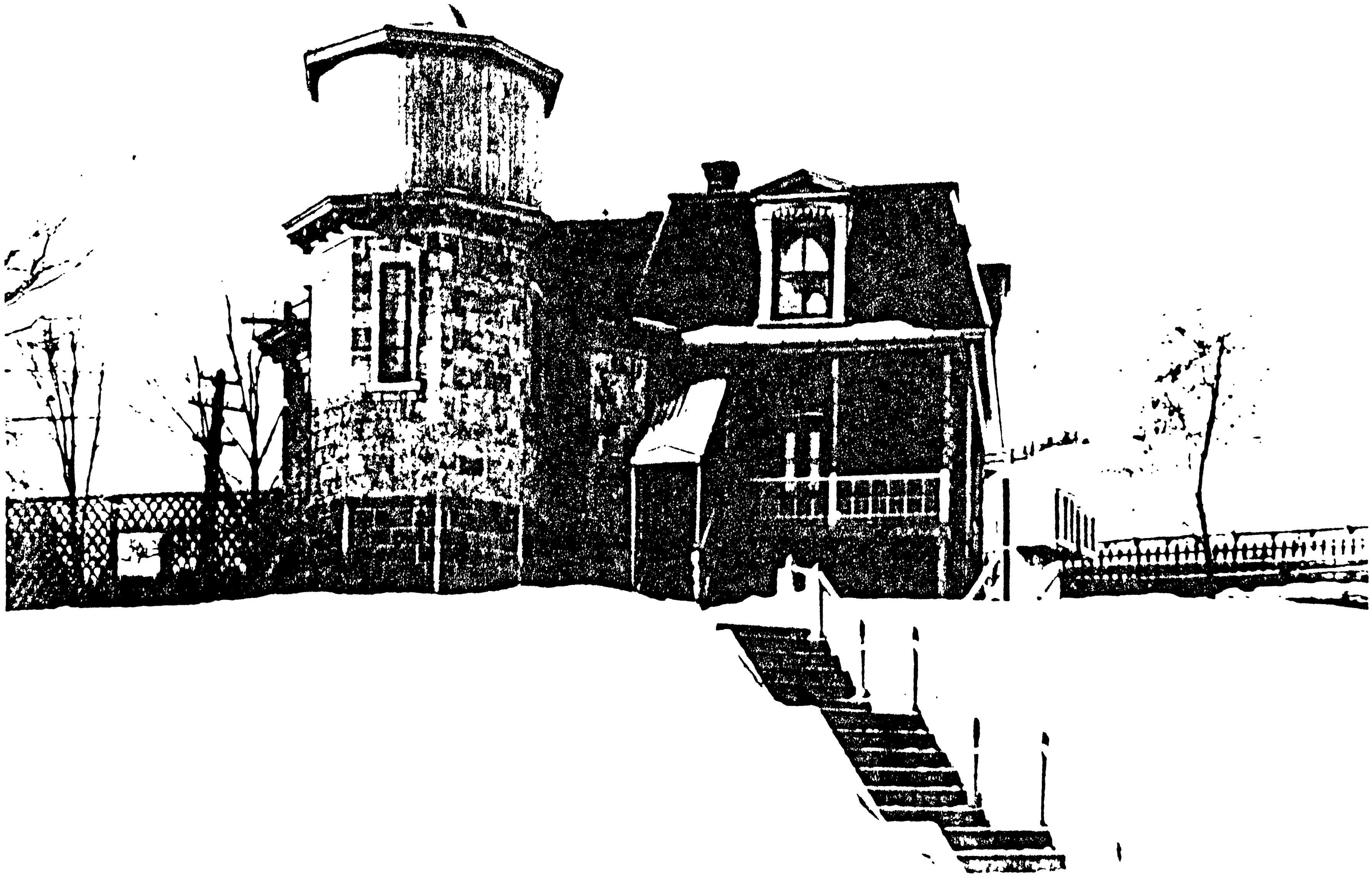


Fig. 13 An early view of McGill Observatory House with the observatory tower at the southeast corner. The original tower has been extended upward to accommodate the Blackman telescope. Courtesy McGill Observatory.
Pg. 85

During the year, the Observatory has been presented with some valuable astronomical instruments by Charles S. Blackman, Esq., B.A., formerly of Montreal, and now a resident of New Haven, Conn. These are as follows: -- An Equatorial Telescope; a Transit Instrument; a Mean Time Astronomical Clock; a two-day Chronometer; a Sidereal Clock; an Electric-Dial; Two Minute Breakers and an adjustable Meridian Mark with Lens. Fig. 12

The Telescope has a focal length of seven feet, and a 6¼ in. aperture; it is provided with seven celestial, one terrestial and one zenith eye-piece. The object glass is by H.G. Fitz, of New York, and the mounting by W.T. Gregg, of the same place. The declination circle is 6 inches in diameter, and is graduated to read to minutes of arc. The right ascension circle is of the same diameter and reads to 6 seconds of time. The motions in declination and R.A. are both fast (friction) and slow (tangent screws with handles). The seeker has an aperture of 2 inches.

To accommodate this instrument the tower of the Observatory was partially rebuilt, and a new pier carried up from seven feet below the surface of the ground to a total height of 31 feet 2 inches. The pier is entirely free from contact with the building, and the telescope is thus protected from the vibrations to which a house is subject. The cylindrical form of dome was adopted for the Equatorial Room; it is rotated on iron balls, rolling between two iron troughs or grooves. The lower portion of the tower is used as a clock and electrical apparatus room. Fig. 13

The Mean Time Clock is by Howard, of Boston, with Denison gravity escapement and zinc and steel pendulum compensation. It is provided with electric attachments for minutes and seconds contact.

The Transit Instrument -- by Jones & Son, of Charing Cross, London, -- is of 3¼ inches aperture, and 42 inches focal length. It is mounted on a solid stone pier, and is sheltered by a small wooden structure. The position of this instrument was of course chosen so as to obtain the best possible view of the Meridian. It is situated about seventy feet to the east of the main Observatory building.

The Sidereal Clock is mounted in the Transit House, where are also an electric dial or seconds jumper and a minute breaker, which are in connection with the mean time clock. A second dial and minute breaker are placed in the equatorial room.

Since the 1st of October, the true mean time has been given to the city and shipping by the dropping of a ball, placed on the dome of the Harbour Commissioners building, and by striking all the fire alarm bells at noon, precisely. This latter is not done directly from the Observatory, but through the Fire Department; the error of the clock in the Fire Alarm Office being determined by signals from this Observatory at specified times, between 11:55 a.m. and noon. This service is a continuation of the work done by Mr. Blackman previous to his departure from Montreal; the city having for many years, and - through his very handsome donation to this Observatory - still continuing to be indebted to him for a knowledge of true time.

The mounting of the instruments having only been completed late last fall, no special astronomical work has, as yet, been undertaken.

I have the honor to be, Sir,

Your most obedient servant,

C.H. McLeod,

Superintendent.

To the Honourable

The Minister of Marine and Fisheries."

The longitude of Montreal had been determined on March 12, 1857, by Lieut. E.D. Ashe, Director of the Quebec Observatory. A temporary observatory had been established in Viger Garden, and an exchange of time effected between it and Quebec by telegraph. Previous to this Quebec had been linked to the primary station, which was Harvard College Observatory. But in both these links, it was possible for error to arise due to the personal equation of the observers. The usual practice was for the observers to exchange positions so that the errors due to the individual could be measured. No such exchange had occurred in Lieut. Ashe's determinations. The suspicion of an error was heightened when in 1882 General Catts of the U.S. coast survey used Mount Royal as a heliotrope station in a geodetic net, and a preliminary result was at variance with Ashe's determination by more than a second of time.

McLeod felt responsible for the accuracy of the Montreal position, because it was essentially the reference for the Canadian survey network. Also the time service of the observatory was receiving careful attention. Observations were being made on every clear night to obtain a close control of the clock rate. The time ball in the harbour was dropped with but few failures, and McGill time was enjoying wide recognition throughout the city and through the telegraph networks of the railway companies. The importance of thorough accuracy in the time service for the use of the large number of ocean ships visiting the port of Montreal was recognized. Furthermore this accuracy was based on the precision with which the geographical position of observatory was known. An uncertainty of a second of time was intolerable.

Arrangements were therefore made with Professor E.C. Pickering, Director of the Harvard College Observatory at Cambridge, Mass., for the redetermination of the longitude of McGill Observatory in 1883. Free use of the telegraph lines of the Great Northwestern Telegraph Company during the longitude campaign was arranged for by Mr. Angus Grant, Manager of the Montreal office. Doubtless this is an example of the good rapport which existed between McLeod and men of the business world. The work was done by Prof. W.A. Rogers of Cambridge, assisted by Mr. J. Raynor Edmonds, while at Montreal Mr. C.H. Chandler, M.A. provided the necessary support for Prof. McLeod. Telegraphic exchanges of clock signals and observations for the determination of clock errors, both before and after each exchange, were made on six nights, and a complete time determination for personal equation was made by both observers (Rogers and McLeod) on two nights at Montreal and two nights at Cambridge. Half the expense of the exercise was born by Harvard.

When the calculations were completed, the longitude of Montreal, based on that of Harvard College Observatory, proved to be $4^{h}\ 54^{m}\ 18^{s}.543 \pm {}^{s}.045$. The corrected value of the longitude as obtained originally from Quebec was $4^{h}\ 54^{m}.\ 17^{s}.74$. So the improvement amounted to $0^{s}.803$. McLeod then collaborated with Charles Carpmael in a similar longitude determination which yielded the position of the Toronto transit as $5^h\ 17^m\ 36^s.649 \pm {}^s.049$.

In 1888, McLeod reports that the facilities of the observatory were made available to Capt. E.G. Deville, Surveyor General, for the purpose of a longitude determination of some point in the west with a view to closing the chain of longitudes then being carried across the continent in connection with the Dominion Lands Survey. Obviously this was recognizing McGill as the best reference point in Canada.

On December 6, 1882 there occurred an astronomical event which attracted wide public as well as professional attention, namely the transit of Venus. McLeod pursued the project with characteristic energy, and in collaboration with Carpmael of Toronto, arranged with the Astronomer Royal for the use of an artificial transit with which prospective observers might gain practice. Most of the professional men who participated in the campaign did in fact have a dry run with the artificial transit device either in Montreal or in Toronto.

Professor McLeod was assigned Winnipeg as his observing site. His first operation was to verify his position by telegraphic connection with Dearborn Observatory, Michigan. The weather favoured the Winnipeg site, and the observational results were sent to Mr. Carpmael, the scientific coordinator of the Canadian effort.

The improved longitude for McGill as a result of the direct exchange with Harvard had little impact on the ordinary citizen. Far more important was the change which occurred on November 18, 1883, when "in consonance with the railroad companies and at my suggestion" (annual report for 1883) the Mayor and the Corporation of Montreal authorized a change of $5^{m}\ 41\overset{s}{.}541$ so that the clocks of the city read 75th meridian time (eastern standard time). McLeod was one of many who supported the move, spearheaded by Sandford Fleming, to have zone time adopted in Canada.

It was this same year (1883) that the observatories of Quebec City and Saint John, N.B. were placed under the general superintendence of Charles Carpmael, Director of the Magnetic and Meteorological Observatory at Toronto. McGill Observatory, being a part of the university, with an annual grant of only $500 from the federal purse, remained under the supervision of the university. Nonetheless, McLeod was happy to cooperate with Carpmael who established a fortnightly intercomparison of time between each of the four observatories, Toronto, Saint John Quebec City and Montreal. There was thus no possibility of an error creeping into the McGill time service. Occasional time exchanges were also made with Harvard, and McLeod was pleased to note the continued close agreement.

In common with other universities, McGill was plagued with financial problems. McLeod tried in vain to obtain an increase in the federal grant, but instead had to exercise strict economy. In spite of this he was able to make a steady improvement in the equipment of the observatory; a sidereal clock of Ballow Manufacturing Company, Hartford, Conn., at a cost of $500 in 1885; a photoheliograph for solar photography in 1886; improvements to the instrumentation for recording weather phenomena and measuring soil temperature. In 1885 a chronograph by Messrs. Cooke & Sons of York, England, was changed from tape to cylinder form under McLeod's direction. The following press report, clipped from a Montreal newspaper of that year reads as follows:

"A Chronograph Clock

Mr. F. Gazeley, instrument maker, of 767 Craig Street, has just completed a chronographic clock to be used in time observations at the McGill Observatory. This clock is said to be the first of its kind manufactured in this city, and consists of a large brass cylinder connected with gearing to a regular clock movement, controlled by an electric current which causes a stylographic pen attached to a carriage to traverse a screw tramway and thus secure the record of observations. The clock is governed by a weight of 120 pounds, and mounted on a handsome mahogany stand, forming with its switch attachment and electrical control a very fine looking instrument. The cost is between $350 and $400, and is expected to prove of considerable service in the observatory under the charge of Professor McLeod."

In his annual report of December 1, 1890, McLeod states that doubt has arisen as to the accuracy of the transatlantic longitude determinations upon which the geographical positions on the North American continent are based. A complete summary of all the work prior to 1883 has been recorded by O.J. Klotz in the Sessional Papers of the Dept. of the Interior 1893.

Prior to the completion of the first successful Atlantic cable in 1866 the longitude of initial points on the American continent rested on determinations from moon culminations, from eclipses and occultations, and from transport of chronometers.

It may be interesting to quote from the Coast Survey Report of 1867 the results up to that time for the longitude of Washington.

"1. From observations of eclipses and occultations.

Walker, corrected value from observations before 1843	$5^h 8^m 11^s.4$
Peirce, from eclipse of 1851, July 28th	11.57
Peirce, from emersions of Pleiades, 1839, Sept. 26	11.45 ± 0.3
Peirce, from emersion of Pleiades, 1856-1861	13.13

but neither of the last three determinations is considered by Professor Peirce as final.

"2. From moon culminations.

Walker, from Cambridge observations 1843-1845	$5^h 8^m 10^s.01$
Loomis, from Hudson observations, 1838-1844	9.3
Gilliss, from Capitol Hill observations, 1838-1842	10.04
Walker, from Washington observations, 1845	9.60
Newcomb, from Washington observations, 1846-1860	11.6 ± 0.4
Newcomb, from Washington observations, 1862-1863	9.8

Walker considered $9^{s}.96$ as the most probable value from moon culminations, and Newcomb assigned $11^{s}.1$ as that indicated by those observed at the Naval Observatory, from 1846 to 1863, inclusive.

From chronometers trans-ported between Boston and Liverpool.

Indiscriminate mean from 373 chronometers previous to 1849	$5^{h}8^{m}12^{s}.46$
Bond's discussion of 175 chronometers, expedition of 1849	11.14
Walker's discussion of 175 chronometers expedition of 1849	12.00
Bond's discussion of 175 chronometers, expedition of 1849	12.20 ± .20
Bond's discussion of 52 chronometers, six trips, expedition of 1855	13.43 ± .19

"All of these values require to be increased by $0^{s}.06$ to conform to the new telegraphic determination by the Astronomer Royal of the longitude between Liverpool and Greenwich.

"The discordance of results, which individually would have appeared entitled to full reliance, is thus seen to exceed four seconds; the most recent determinations, and those which would be most relied upon, being among the most discordant. No amount of labour, effort, or expense had been spared by the Coast Survey for its chronometric expeditions, inasmuch as the most accurate possible determination of the transatlantic longitude was specially required by law; and the thorough accuracy of Professor Newcomb's investigations is well known to astronomers. Yet the result of the latest chronometric expedition differs from that deduced by Newcomb from moon culminations observed at the Washington Observatory since its regeneration, compared with those observed at Greenwich, by more than three and a half seconds of time. The value employed by the Coast Survey, from 1852 to 1859, was $5^h\ 8^m\ 11^s.2$; since 1859 it has been $5^h\ 8^m\ 11^s.8$."

Upon completion of the cable in 1866 the United States Coast Survey took immediate steps for utilizing it for the determination of longitude.

The four stations occupied were Greenwich, Valencia, Ireland, Hearts' Content, Newfoundland, and Calais, Maine, the last named place having already been included within the telegraphic chain of longitude determinations in the United States. In the work of 1866 there was no automatic registration of the clock signals received. The signal received manifested itself by the deflection of a very small mirror -- a mirror galvanometer -- and the recorder would tap a telegraph key in circuit with his clock and chronograph as soon as the deflection took place. This necessarily involved the error of noting and unless the error of noting was the same for the two observers at the termini of the cable, the longitude would be affected by one half the difference between the two. Another weak link in this work was the land line of about 1,100 miles between Heart's Content and Calais, whereon there were several repeaters, or double relay magnets. It is always highly desirable to work on a through circuit without the intervention of repeaters. The trans-atlantic determination of 1866 rests on the observations of five nights.

Of the final results J.E. Hilgard in the Coast Survey Report for 1872 says: -- "Although the longitude value thus obtained was more nearly certain than that of any previous determination, there was still left a larger margin of doubt as to its precision than is desirable in a fundamental determination. This uncertainty, which probably does not exceed a quarter second of time, is due to the fact that there was no determination of the personal equation difference between Mr. Dunkin, the Greenwich "Standard Observer," and Mr. Boutelle, the Coast Survey Observer at Calais; and that while we can measure the total time of transmission of signals through the cable and back again, we are unable to separate the duration in opposite directions, and are obliged to assume it to be equal -- an assumption which may not be exact within a sensible fraction of a second."

The French cable across the Atlantic from Brest to Duxbury, Mass., via St. Pierre was completed July 23rd, 1869, and steps were thereupon taken by the United States Coast and Geodetic Survey of verifying the former results. At that time, however, there was no cable connection between Brest and England, and it was not till 1872 that the necessary observations for the link were obtained, when also a trans-atlantic redetermination was made, this time with an intermediate station at St. Pierre, where the long cable makes a landing.

In the work of 1870 the ends of the two cables were joined at St. Pierre by bringing their several condensers into contact, so that cable signals were exchanged between Brest and Duxbury, Mass.

From the Coast Survey Report of 1874 we find the result of the transatlantic operations of 1866, 1870, and 1872: --

"The longitude of Cambridge (Harvard College Observatory dome) west of Greenwich (meridian):--

1866	$4^h\ 44^m\ 30\overset{s}{.}99 \pm \overset{s}{.}10$
1870	$30\overset{s}{.}98 \pm \overset{s}{.}06$
1872	$30\overset{s}{.}98 \pm \overset{s}{.}04$
Mean	$4^h\ 44^m\ 30\overset{s}{.}98 \pm \overset{s}{.}04$
Washington -- Cambridge	$0^h\ 23^m\ 41\overset{s}{.}11 \pm \overset{s}{.}03$
Washington -- Greenwich	$5^h\ 08^m\ 12\overset{s}{.}09 \pm \overset{s}{.}05$

From the observations of 1857, resting on Quebec and Cambridge, the longitude of McGill College Observatory was found to be $4^h\ 54^m\ 17\overset{s}{.}74$. Connection with the triangulation of the United States Coast and Geodetic Survey in 1882, gave the longitude as $4^h\ 54^m\ 18\overset{s}{.}87$.

In 1883 observations were made at Montreal and Cambridge for determining the difference of longitude between the two observatories. McGill College Observatory was found to be west of the centre of the dome of the Harvard College Observatory $9^m\ 47\overset{s}{.}510 \pm \overset{s}{.}019$.

"The pier of the transit instrument at the McGill College Observatory is therefore in longitude $4^h\ 54^m\ 18\overset{s}{.}543 \pm \overset{s}{.}045$ west of Greenwich." -- (Trans. Royal Society Canada 1885.)

As a result of the doubt that had arisen as to the accuracy of this previous work, it had been suggested that there be an independent determination for Canada by direct transatlantic cable connection with Greenwich. The matter was brought to the attention of the British Government at the request of the Royal Society of Canada, through His Excellency, the Governor General. Sir Charles Tupper also placed the matter before the Astronomer Royal, who gave it his hearty support. Similar proposals for improvement of longitude determinations had been advanced by the Superintendent of the United States Coast and Geodetic Survey, and on behalf of the European longitudes, by Otto Struve, Director of the Pulkovo Observatory, Russia.

The memorial addressed by the Royal Society of Canada to the Honorable the Minister of Marine in May 1890, states:

"1. Now doubt has recently been thrown on the accuracy of the result of observations by which the longitude of Harvard Observatory has been obtained. This doubt, of course, affects the positions of all places determined by reference to it -- that is to say, briefly, it affects the whole geography of the continent. As there are better means available at present for observations and interchange of signals across the Atlantic than at the time of the American determination, it is deemed of great importance that an effort should be made at once to remove the doubt referred to.

2. The Department of Marine, more particularly, is interested in the work, as it affects navigation. The accurate determination of a ship's position at sea, and therefore often the safety of the ship depends on the chronometer. The error of the chronometer has always to be determined in leaving a Canadian port by reference to the local time, and the longitude of the place to Greenwich. This Canadian longitude again is determined by reference to the longitude of the base station, such as Montreal or Harvard Observatory, hence the necessity for extreme accuracy for the base station.

3. The object to be attained is not only of Canadian but of Imperial and not only of Imperial but of International importance."

The Admiralty accordingly set aside the sum of £350 for the instruments and £300 for the operations connected with the work. The sum of $2000 was also appropriated by the Parliament of Canada for the same purpose. The details were arranged by the Royal Greenwich Observatory and McGill College Observatory, and in August 1891, the Astronomer Royal sent the necessary instruments to Montreal for the two Canadian stations, Canso NS, and Montreal, to provide time for familiarization. The other two stations involved in the campaign were Greenwich Observatory and Waterville (County Kerry) Ireland. The four observers were Professor C.H. McLeod of McGill, Otto J. Klotz, D.L.S. of the Department of the Interior, H.H. Turner and H.P. Hollis both of the Greenwich Observatory. The work was conducted in the summer of 1892 in four stages as follows:

	Montreal	Canso	Waterville	Greenwich
1	Klotz	McLeod	Turner	Hollis
2	McLeod	Klotz	Hollis	Turner
3	Turner	Klotz	Hollis	McLeod
4	Klotz	Turner	McLeod	Hollis

Klotz records that his transit instrument was one of a series used in the transit of Venus in 1874 (not to be confused with the 1882 transit), and that the other observers had similar ones. The observer took his individual transit and level with him from station to station and mounted it on the fixed pier. The Klotz instrument had a clear aperture of 2-31/32 inches, a focal length of 36 inches, and setting circles 3 inches in diameter reading to minutes. Klotz further explains that a night's program involved four sets, LE, LW, LW, and LE respectively (LE and LW refer to reversed position of the transit in the stand). Each set included one polar, one sub-polar (if available) and five or six other stars distributed between the zenith and 20° south declination. The stars were selected from the Berliner Jahrbuch, plus 11 additional ones from the Nautical Almanac. Each night, regardless of the weather, timing pulses were exchanged across the network.

In 1896 the Astronomer Royal visited Montreal on his way to Japan, and announced the definitive result of the 1892 campaign. The longitude of Montreal (centre line of the transit instrument) is $4^h\ 54^m\ 18\overset{s}{.}670$. Based on the longitude of Cambridge, the campaign of 1883 combined with the subsequent survey work of C.H. Sinclair of the Coast and Geodetic Survey, the former value for Montreal was $4^h\ 54^m\ 18\overset{s}{.}565$, which makes the new value greater by $0\overset{s}{.}105$. In the 1897 report of the U.S. Coast and Geodetic Survey, the Montreal value was included in the adjustment of the longitude net of the United States by C.A. Schott. The resultant value for Montreal was then adjusted to $5^h\ 54^m\ 18\overset{s}{.}634$, and it formed the base to which Ottawa was attached. Because of his work on Longitude, McLeod was made a Fellow of the Royal Society of Canada.

The various activities of the McGill College Observatory at the close of the 19th Century are indicated in the annual report submitted by Professor McLeod for the year 1894.

"McGILL COLLEGE OBSERVATORY,

Montreal, 31st December, 1894.

To the Honourable
The Minister of Marine and Fisheries.

Sir, -- I have the honour to present the report on this observatory for the year now closed.

Meteorology. The "chief station" observations of the pressure, temperature and hygrometric conditions of the air: the velocity and direction of the wind; the percentage of bright sunshine and of cloudiness; the character and amount of precipitation; and the general weather conditions, have been made at every fourth hour (beginning at 3h) throughout the year. The series of bi-hourly temperatures, commenced in 1884, and being supplementary to the above, has also been carried forward without interruption. While the primary object of these observations is to obtain some knowledge of the laws of the diurnal and annual variations of the meteorological elements for this district, they are also of great commercial importance as a record of climate to which authentic reference may be made, as for instance, in connection with loss or damage to property, or as to the varying seasonal effects of climate as regards agriculture. The complete investigation of the climatology of the station can, however, only be properly carried out by means of continuously self-recording instruments, a full equipment of which should be procured, in order that so important a work may be commenced without delay. The telegraphic observations forming a part of the Canadian series of observations, upon which the general weather predictions are based, have been regularly despatched at the hours 8, 15 and 20 to the Meteorological Office, Toronto. The daily and monthly results have been published in the *Montreal Gazette* and the monthly summaries in the *Canadian Record of Science*.

There has of late years been a very persistent and increasing demand on the part of the public of Montreal and vicinity for special weather forecasts, which under the existing arrangements of the meteorological service I am unable to furnish. The plan of establishing local forecast offices has been adopted with great success in the United States. It is scarcely necessary to point out that in Montreal there are many large and important industries in connection with the prosecution of which a knowledge of the special local weather probabilities is of the highest importance. Facilities for the issuing of local forecasts here, under the direction of the Meteorological Office, would be of very great value to the commercial interests of the city, and would be highly appreciated by the citizens of Montreal.

Time Service. -- Determination of clock errors have been made by the observation of 756 star transits on 134 nights. A determination of the clock errors is made in the following manner: -- A comparison of the sidereal clock, and the mean time clock is obtained on the chronograph. The transits of six stars (one polar star and two equatorial stars, in each of the reverse positions of the instruments) are then observed and recorded on the chronograph. The inclination of the axis is measured before and after the observations of the stars in each position. The observations being completed, the clocks are again compared. The chronograph sheet is then read and the observations recorded, the instrumental errors deduced, and finally the clock errors are obtained. The error of the sidereal clock is allowed to accumulate, whereas the marking of the mean time clock is made to correspond to the local mean time on the 75th meridian known as Eastern standard time. All the signals issuing from the observatory correspond with the marking of this clock.

The noon time-ball, for the use of shipping, has been dropped on every week day during the season of navigation. Special signals have also been transmitted daily to the Montreal fire alarm office for the noon stroke on the alarm bells.

By means of the automatic system of clock signals, which has been in use here for several years, a knowledge of standard time has been widely distributed through the corporations and institutions named below:--

The Canadian Pacific Railway Co., transmitting it daily to all stations along their lines to the Pacific coast.

The Grand Trunk Railway Co., through the Great Northwestern Telegraph Company, for all their lines east of Kingston.

The Great Northwestern Telegraph Co., transmitting it daily to all the telegraph stations in eastern Ontario and the province of Quebec.

The Harbour Commissioners at Montreal.

The time signals of this observatory are also transmitted through the Great Northwestern Telegraph Company to Ottawa, for the firing of the noon gun at the Parliament buildings. I regret again to have to state that the imperfect arrangements at Ottawa in connection with this service are such as to make the noon signal quite unreliable as a time standard for Ottawa. (McLeod considered this as an unfair reflection on the McGill time service.)

I had the honour, under date Jan. 12th, 1889, to report, making recommendations for the improvement of this service. The proposed changes were approved, but certain difficulties arose which prevented the completion of the work at the time. I understand that the difficulties referred to, do not exist, and would respectfully urge that the service be at once remodeled after the plan proposed in the report above mentioned.

Exchanges of clock signals with the Toronto Observatory were made on 19 days. The average of the differences obtained between the mean time clocks of the observatories is 0.25 sec., and the greatest difference on any one day was 0.68 sec. The comparisons for the year show that the probable error of the time as given by one observatory at any time as compared with that given by the other, is 0.20 sec.

(C.H. McLeod)"

Attempts to enlarge the scope of the astronomical activities of the observatory never materialized, largely due to lack of funds, and in part due to the fact that the director was primarily a civil engineer.

C.H. (Bunty) McLeod encouraged good public relations. He took a great interest in student activities, and as an expert on time he was called upon occasionally to provide accurate timing at the annual student sports events. For some years he was chairman of the grounds committee. Enquiries from the public received careful and sympathetic attention.

In a feature article on the McGill clock, which appeared Aug. 13, 1904, the Montreal Witness describes the wide distribution of McGill time. "The McGill Observatory clock supplies the correct time daily to all the stations on the Grand Trunk Railway system and to points on the Canadian Pacific and Intercolonial Railways from St. John, N.B. to Bamfield, B.C. The McGill time is automatically repeated at Canso, N.S. to the Azores Islands; the inhabitants of Bermuda and Jamaica receive it from Halifax, where it is repeated by hand; the British warships correct their chronometers (get it from CPR) by it at Halifax and Victoria, and the German fleet does the same at the Azores (get time by signals from the land); the operators at the islands in the Pacific where the Australian cable lands, set their watches by it, and it automatically regulates a large number of the electric clocks in the city.

"The CPR has an official timekeeper at all its terminal points, who corrects the watches of the trainmen... from the daily messages received from Montreal. This message is sent through at 11:54 a.m., and the seconds are ticked off until 11:56 a.m., when the message closes. During the first minute, a single "click" identifies each second, and during the second minute a double click is heard. Automatic repeaters at Fort William [Thunder Bay], Winnipeg and Swift Current take the signal to the western terminus.

"About 3/100 of a second is occupied in passing through each repeater, and the time occupied on the wire itself is about 2/100 of a second. Thus the actual time consumed between Montreal and Victoria is about 15/100 of a second."

Thus McGill Observatory was performing a service to the railway that was envisioned by Blackwell half a century ago.

Death overtook the 66 year old Professor McLeod as he sat at his desk on Dec. 6, 1917. The McGill report of March 31, 1918 states as follows:

"Prof. C.H. McLeod, who since 1873 had been in charge of the meteorological work at McGill University, died very suddenly and the service was thus deprived of an experienced and valued observer and meteorologist. His successor in office, Mr. James Weir, who for several years had been chief assistant, has furnished an exhaustive report of which the following is a synopsis:--

> The usual activities of the station have been carried on continuously throughout the year. Four eye observations of the various meteorological instruments are made daily and are used to standardize the continuous records obtained from self-recording instruments. Two reports are telegraphed daily to the central office, Toronto, for purposes of the weather map. The forecasts from the central office are received here through the Great North-western Telegraph about 11 a.m., and are thereafter available for

the information of the public. The first report is by telephone and contains only the forecast proper. The bulletin arrives about 3 p.m. Scattered calls for the forecast are made, but the public are as yet not sufficiently aware of this facility.

Time service: -- Determinations of clock errors have been made by observations of 576 standard transits on 110 nights. The set in a night usually consists of 6 stars, one polar and two equatorial stars in each of the reverse positions of the instrument. The observed times of transit are recorded on the chronograph. The Troughton and Simms transit used is provided with a micrometer eye-piece arranged to make contacts. The probable error of the determinations usually is several hundredths of a second. Greater precision is futile in view of the timekeeping possibilities of the astronomical clocks in use, and the fact that the time signals given out, if kept well within the second, are subject to no criticism from the city, shipping and railway services which they supply. The Howard mean time clock is regulated to carry 75th meridian time, or rather, at present, one hour in advance of it, and by means of its automatic system of signals, a knowledge of this time is given to a wide public. The following corporations receive these time signals: The Canadian Pacific Railway Company transmitting it daily to all stations along their lines to the Pacific, the Grand Trunk Railway Company despatching it from their head offices for their Eastern lines, the harbour commissioners of Montreal and the shipping. The noon time-ball for the use of shipping is regularly dropped on week days. At such times in the winter as it was ascertained the ball was not in action, the responsibility was placed with the harbour custodians. No failures to throw the switch at the observatory are to be reported throughout the year. By a special set of noon signals the fire stations and city utilize our time. In addition several jewellers requiring an accurate time standard have had installed loops and ticker service. Rental of the lines is chargeable against this service and the electric work is attended to by the Dominion Gresham Guarantee Company. It has been recently ascertained that the railways are satisfied with the character of service received and the intention is that their subscription, as well as those of the jewellers, shall be made payable to the bursar's office of the university and appear in the observatory items of grants and revenues."

In 1907 the observatory at McGill was supplied (from Government funds) with a Reifler astronomical clock with invar pendulum and air-tight case; this, with a modern Troughton and Simms astronomical transit, (referred to above), fitted with micrometer eye-piece, electrically recording on a drum chronograph, furnishes ample means for the accurate determination of time (O.J. Klotz in J. RASC 13 7 (1919).

During the year 1919-20, a wireless receiving set was acquired for the purpose of receiving Arlington time. A second Howard astronomical clock was also acquired from the Geodetic Laboratory, raising the complement of precise pendulums to four, two sidereal and two mean time. Mr. A. Stirling, a skilled artist with time pieces, cleaned and adjusted them at no expense to the university.

The above statements point to the changing times that were overtaking McGill. The two main activities which had been developed by C.H. McLeod, weather observing and time service, continued under the

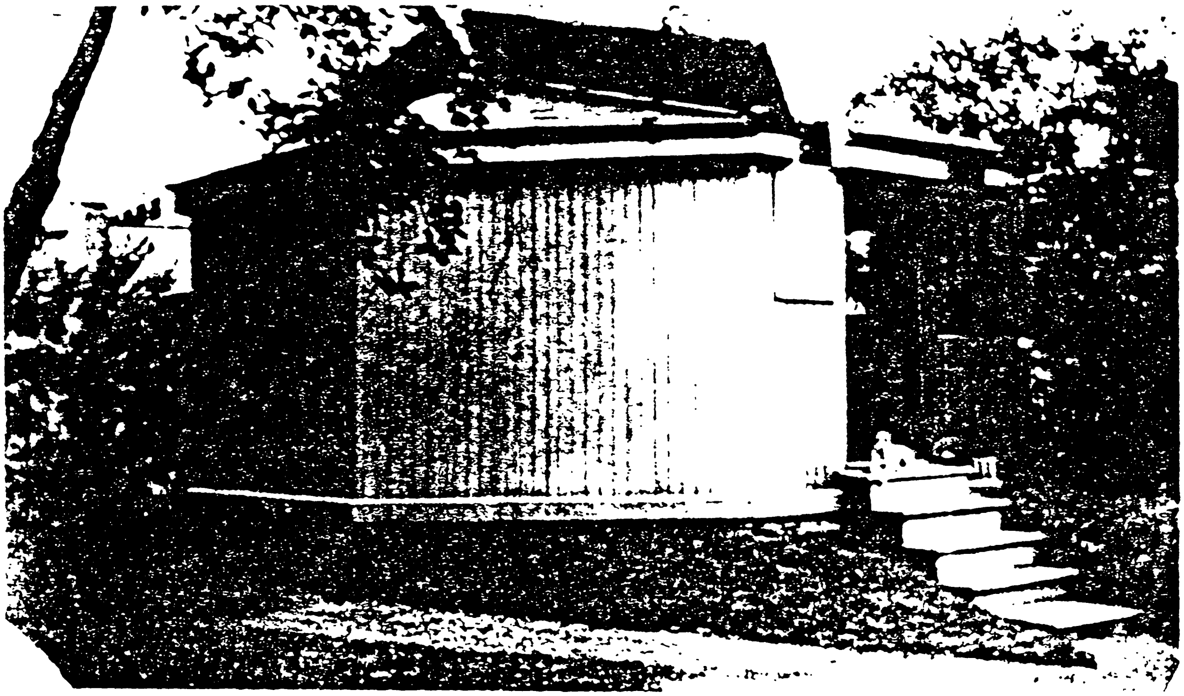


Fig. 14
Pg. 107 Exterior view of the transit hut, McGill. It was removed in 1926 to make way for Redpath Hall. Courtesy McGill Observatory.

impetus he had given them, but with changing emphasis. In 1922 the Bell Telephone Company discontinued its practice of answering requests for time, thus adding another load to the observatory. A.J. Kelly replaced James Weir as Superintendent of the Observatory, and for the year 1924 reported that transit observations for time had been made on 67 nights. Meanwhile F.R. Redpath and A. Stirling had since 1921 been experimenting with the reception of wireless time signals from Arlington at noon and 10 p.m. The time-ball continued to operate until the 1930's, at which time its usefulness had ceased to exist. It had long since ceased to have a commanding view of the harbour, and radio equipped ships were now using radio time signals.

In 1926 the McGill transit hut had to make way for Redpath Fig. 14
Hall, an extension of the Arts building. It was never re-established. So, after nearly seven decades, McGill's contribution to the determination of astronomical time came to a close. The time room, however, remained active for another two decades, and as far as the services provided to the railways, the jewellers, and the business establishments were concerned, there was no change.

The Blackman Telescope (6-inch equatorial), which had been at McGill since 1879, seems to have disappeared. One recollection was that it was forwarded to the Dominion Observatory, Prof. Kimble being under the impression that it was government property. From the diary of J.P. Henderson, it appears that a transit instrument together with Riefler No. 712 arrived at Ottawa from McGill in June, 1945., but no equatorial.

A time signal, prepared by the Dominion Observatory, in the particular code required by each of the two telegraph companies had been introduced into the Ottawa terminals in 1938. In 1947 they replaced the McGill signal.

1963 marked the end of an era. After a century of service, the observatory and attached dwelling were razed to make way for the Stephen Leacock Building, in which a plaque marks the site and commemorates McLeod's work. A new quartz controlled timekeeper, synchronized by regular observations of CHU time transmissions, provides correct time for the McGill Weather Observatory, and for the several establishments in Montreal that depend on McGill for correct time.

Saint John, N.B.

SAINT JOHN, N.B.

Saint John has the distinction of being the first Canadian city to receive a charter of incorporation. This was in 1785. Situated at the mouth of the Saint John River, with a harbour which is open year round, Saint John was a natural port of call. Many of the United Empire Loyalists who were forced to leave their homes in the United States made it their home, joining forces with those who had arrived by a more direct route from the British Isles and Europe. Nova Scotia at one time included what is now New Brunswick, and extended to the Maine boundary. But Halifax was too far away from Saint John and other centres, and the dissatisfaction resulted in the division of Nova Scotia into two, thereby forming the new province (1783). The need to have a capital city brought Saint John into the limelight. But the proposal to make Saint John the capital was rejected in favor of Fredericton which had better natural protection against any hostile move of the American neighbors.

It was natural that the thriving community should attract artisans and scholars among those who chose to make Saint John their home. Wm. Mills, who died August 9, 1886, came from Ireland about fifty years before and taught school. Not only did he teach mathematics and navigation, but he also built a small observatory where he could pursue his hobby. It was this location that was used by Prof. Wm. Brydone Jack of King's College, Fredericton, when in 1855 he verified the longitude of Saint John using the new telegraph technique for a time comparison. Mills also assisted in the operation by contributing some of his own observations all properly calculated.

There were three watchmakers listed in the city directory for 1867. One of these, named George Hutchinson, of 70 Prince William Street, claimed that his business dated back to 1819. His advertisement contained the statement, "Chronometers rated by a transit instrument, and Astronomical clocks."

When therefore the new Federal Parliament decided that time ball observatories should be established in Saint John, N.B., and at Halifax, N.S., in order to assist the mariners in these two busy ports, there was no lack of skilled personnel. The Imperial Government had taken the initiative by establishing a time ball mechanism and observatory at the Citadel in Quebec. Since 1855 Lieut. E.D. Ashe, R.N., had attended to its operation, hoisting it to the top at five minutes to the hour and dropping it at 1 p.m. local mean time. It was in full view of the harbour and served as an effective time signal by which the mariners could check the time and rate of their chronometers. It was in fact a design that could be followed when preparing a similar facility for the other two busy sea ports. Ashe was consulted, and the changes incorporated in the Saint John time ball mechanism may have been on his advice.

$1500 was voted by Parliament for observatories in Nova Scotia and New Brunswick for the financial year ended June 30, 1869, and a suitable site was thereupon selected for Saint John. It was on Fort Howe Hill and was obtained from the War Department at an annual rental of £1 5s. Half the alloted sum, i.e., $750 was spent the first year, the other half being reserved for Halifax. The second year a further $390 was spent, thus completing the observatory building and the time ball mechanism.

The Daily Telegraph, March 1, 1870, carried the following report. "The Observatory on Fort Howe is completed, with the exception of having placed in it the instruments for marking time and taking observations. The building is composed of two wings and is one story in height. The tower is 20 feet high and is surmounted by the iron rods inside of which the ball runs up and down.

"The Ball was made by Mr. John Kennedy; is of zinc and measures five feet in diameter. It has a piece of 2½ inches iron tubing running through the centre across its diameter. The ends of the tube run to the outside surface of the ball and are finished on the outside by a collar which is secured tightly in its place by a screw on the upper side. The four rods which run parallel with each other to a height of 12 feet from the top of the tower, and then are brought together, form a guide for the ball. In the centre of the base of the tower is an iron cylinder 12 feet in length, 16 inches in diameter, which is placed in a vertical position. The cylinder is provided on the inside at the bottom with a rubber cushion, and is opened at the top. A 2½ inch piston runs up from the cylinder and passes into the tube at the under side of the ball until it is stopped by a collar cushioned with rubber at a distance of about six inches from the end. The piston is hoisted by a winch and raises the ball 12 feet. As soon as it is raised it is secured in its place by an ingenious contrivance, and at the proper time it is let go by pulling a cord which lets the piston drop, followed by the ball. The ball drops almost instantaneously for a distance of seven feet, where the escape of air from the cylinder is rendered slower and lets the ball down easily to its place. Besides the tower there are two other rooms, one about 10 × 12 feet and the other 12 × 14 feet....... Fig. 15

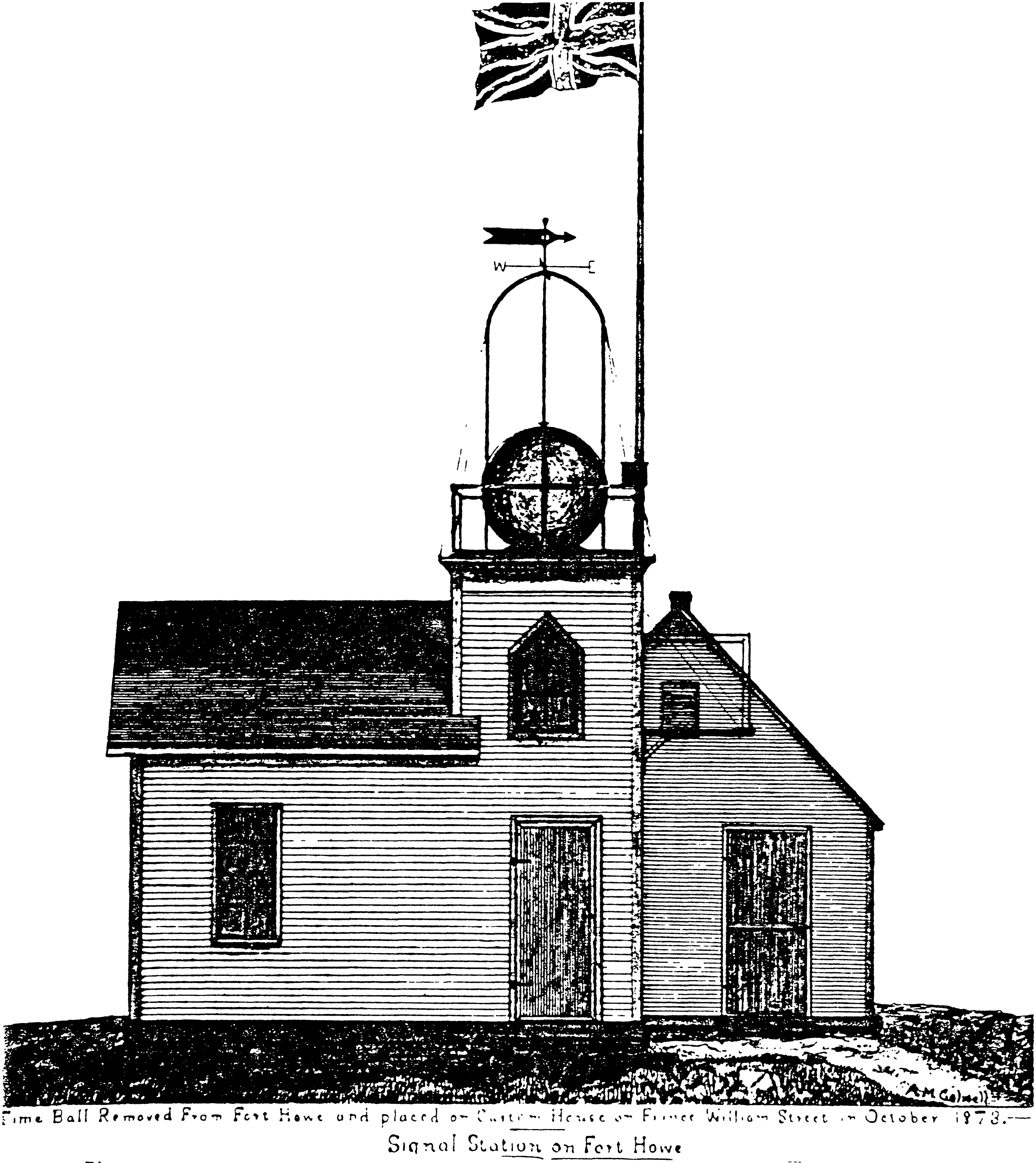


Fig. 15 Pg. 111 Ink and colour drawing by A.M. Colwell of the Fort Howe Signal Station, showing the copper Time Ball which was removed and placed on the Custom House in 1873. Courtesy of the New Brunswick Museum.

Fort Howe, while it commanded an excellent view of the harbour, was too far removed and the time ball was not easily seen. So, in 1873 it was moved to the roof of the Custom House on the water front, where it was much more centrally located and available to the general public as well as to the ships in the harbour. Fig. 16

In his annual report of January 1876, Hutchinson reports, "The ball is dropped at the given time, and is taken from a chronometer, which, on each occasion is previously compared with an astronomical clock. ..... The clock is frequently tested by solar and sidereal observations taken with a transit instrument. From the extreme care which I take in testing time, I am fully satisfied that the time ball at this port affords an excellent opportunity to shipmasters and others of getting true time and enabling them to correct their chronometers and time pieces." (Sessional Papers, Department of Marine and Fisheries, 1877)

The year 1876 saw some repairs to the manual release mechanism performed by Messrs. Allan Bros. who had done the original installation at the Custom House. Also the ball was repainted black with a gold band, thus providing good contrast against the sky background.

On June 20, 1877 the Observatory and Signal Station were destroyed by the great fire that occurred at Saint John. As a consequence a temporary ball was mounted on the roof of the Anchor Line Warehouse.

With the completion of the new Customs Building in 1881, the time ball was mounted on the north tower. It had a more commanding location than previously, being 123 feet above water, with a drop of 12 feet. In his annual report Hutchinson said, "The pier on which the transit instrument is placed has been built in the Observatory on top of

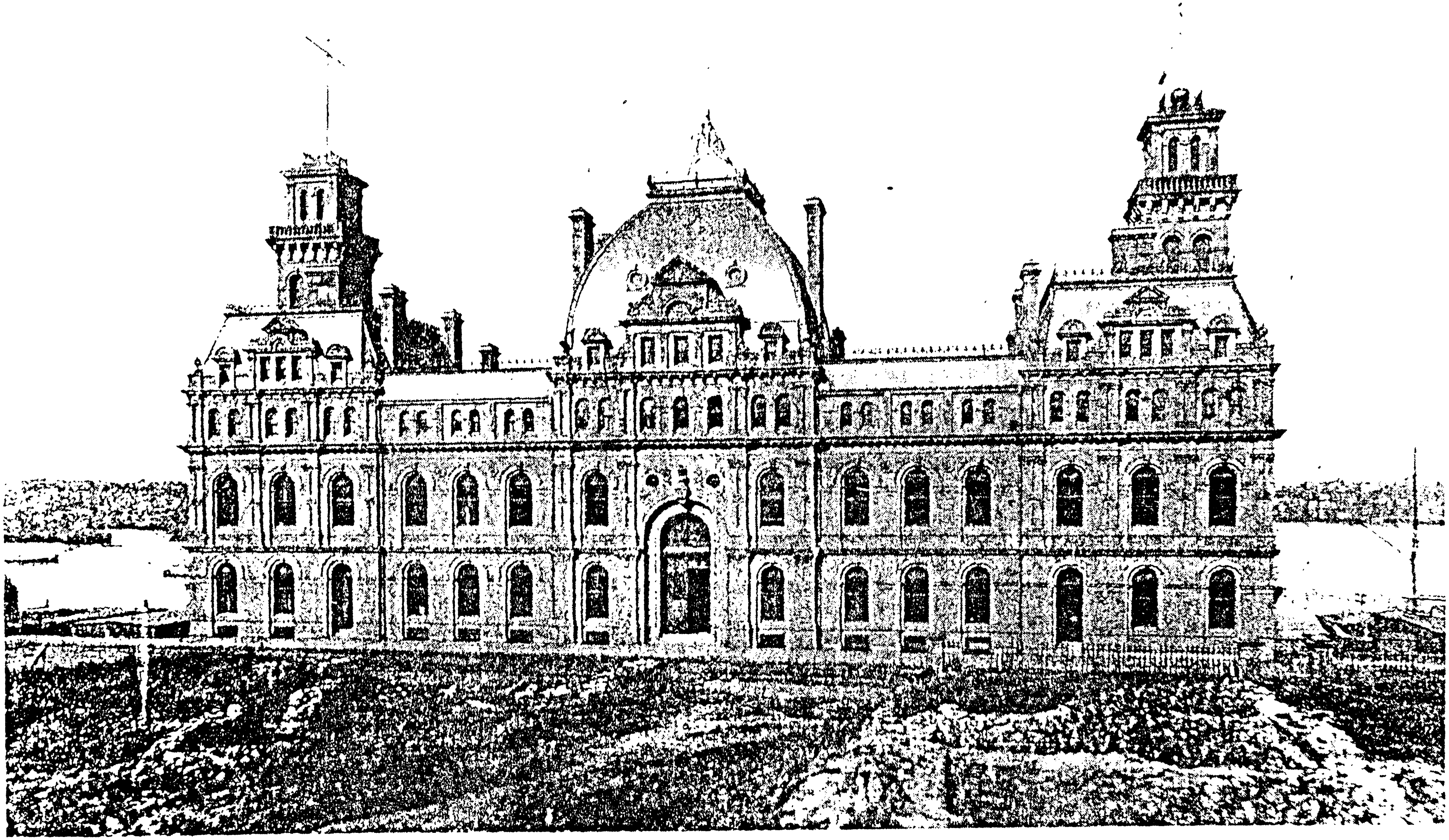


Fig. 16
Pg. 113

The Custom House, Saint John, N.B. with the time ball on the tower to the right, and weather signals on the tower to the left. The picture appeared in The Dominion Illustrated of Aug. 3, 1889. Courtesy Public Archives, Canada.

the Custom House. It has been so solidly constructed (on top of one of the vaults) that there is not the least vibration. Its position is such that there is an uninterrupted view of the meridian both north and south .... I think that this observatory can well be used for other scientific purposes." The change came less than two years later. In his report for 1883 he states: (Sessional Papers, Dept of Marine & Fisheries, 1883)

"On the 1st July last, this observatory was transferred to the Meteorological Department, and was supplied with a set of meteorological instruments, which are read six times in the 24-hours, at regular intervals of four hours, and reports sent to the office in Toronto." [The readings commenced at 3:44 a.m.] "The observatory has also been furnished with telegraph instruments, connected by a loop line through the Western Union Telegraph Company's office which are used for exchanging time with Toronto, direct from the observatory, and may also be used in transmitting correct time to any part of the Provinces having telegraphic communication with this city." (Sessional Papers, Dept of Marine & Fisheries, 1885)

Charles Carpmael, Director of the Canadian Meteòrological Service, Toronto, noted that the Saint John time was frequently in error by more than a second. Inadequate equipment and not the skill or technique of the observer was blamed. A new transit instrument made by Negretti & Zambra of London was acquired during 1884 to replace the old one which had been used for years. Also a sidereal clock was set up to supplement the mean time clock. A suitable room was provided by Public Works, and the stairway leading to the transit room was improved.

Hutchinson, in December 1885, describes his observing technique as follows: "The method used at this observatory for the determination of the time consists in the observation of from six to ten clock stars, half of the set being observed in a reversed position of the rotation axis of the transit instrument. The error of azimuth is computed from the observation of two pairs of stars, having considerable range and different signs of declination, one pair being observed in a reversed position of the axis. The collimation error is determined by reversing the instrument on slow moving stars, and the error of level by the measurement of the inclination of the axis with the striding level." (Sessional Papers 188·

This was the standard observing technique of the day. It was impossible to mount a sidereal clock in the transit room, so the portable mean time chronometer which was used in dropping the time ball was taken into the transit room for each observing session. It was compared before and after with the sidereal clock. There was a systematic error, as the time exchanges with Toronto indicated, and this was attributed by Hutchinson to an error of "something more than a second" in the adopted longitude of his observatory. He requested that the transit room be enlarged, and also that a drum chronograph be acquired to record the passage of the star at the instant of crossing each wire of the telescope.

The daily routine of the station now 1885 included a signal to the Intercolonial Railway at noon of 75th meridian time, which corresponded to $12^h\ 35^m\ 45^s$ local time at Saint John. The railway observed 75th meridian time (or eastern standard time, as it is called today) right through to Halifax. Western Union Telegraph used 60th or Atlantic standard time, while the time ball continued to be dropped at one o'clock local mean time, or 1:24:15 p.m. Atlantic standard time. So three different times were observed within the city. City council, however, formally rejected the adoption of railway time, i.e., the 75th meridian time.

On July 7, 1891, Geo. Hutchinson passed away. There had been an attempt by the department to retire him the previous year, but an appeal by him to Sir Leonard Tilly stayed the action. His successor was his son, D.L. Hutchinson, who had for some time served as an assistant.

The following year, on March 20, fire again struck the Customs Building, and the transit room was destroyed. All the instruments except the transit telescope were saved. and for a while an old Troughton and Simms loaned by A.B. Smalley, was pressed into service. The Pugsley building became temporary quarters.

Two years later the new Troughton and Simms transit arrived from London, and shortly thereafter electric lights were installed. In spite of technical improvements the time exchanges indicated that the Saint John and Quebec clocks differed from the reference clock by more than a second on several occasions. The reference clock was the mean of the Toronto and McGill time determinations.

The Saint John Observatory, and its Director, D.L. Hutchinson, were making an important impact on the whole maritime community. Not only was the time distributed daily by telegraph, but commencing Feb. 1895, the Saint John Observatory became the distribution centre for the daily weather forecasts from Toronto. They covered the coastal community from Chatham to Boston. "Because of the correctness of the forecasts wired from Toronto", reported Hutchinson, "I have many calls for the probabilities, especially during the stormy season."

By 1901, with the addition of a clock by Victor Kullberg of London in 1899, the observatory was equipped to transmit by telegraph an automatic time signal daily from 8:58 a.m. to 9:00 a.m. 75th meridian time, which was the same as 9:58 to 10:00 a.m. Atlantic time. It became known as the 10 o'clock signal, and was soon recognized as the official time throughout the maritimes.

When standard time was adopted by the railway system in 1883, Toronto, Montreal and Quebec adopted the time of the 75th meridian. The city council of Saint John had reviewed the question in 1890 and recommended no change from the present custom of local mean solar time. Five years later, on October 15, 1895 the Saint John Board of Trade reversed its previous decision and prepared the following resolution.

"Resolved that this Board memorialize the Dominion Government to adopt Standard Time in all Government offices in this city and county."

On October 24, W. Frank Hathaway, President, and Ira Cornwall, Secretary of the Saint John Board of Trade submitted a request to the Privy Council for the use of eastern standard time in the Custom House, Saving Bank, and other Government offices in Saint John, as it is in use by railways, steamships, etc.

November 6, 1895, John J. McGee, Clerk of the Privy Council, reported approval of the above in P.C. 3072.

In due course R.F. Stupart was asked to prepare a suitable notice for the marine services at Saint John, and in a communication of May 6, 1902, addressed to Colonel Anderson, Chief Engineer, Marine and Fisheries, Ottawa, one reads, "In compliance with the request contained in your letter of the 2nd instant, I will arrange with Mr. Hutchinson to

NEWFOUNDLAND

Signal Station Latitude and Longitude.	Place.	Signal adopted.	Situation of Time Signal.	Time of Signal being made. Greenwich Mean Time.	Time of Signal being made. Local Mean Time.	Additional Details.
47° 31' 10" N. 52° 40' 27" W.	St. John's	Gun* (32 pounder.)	Near Block House on Signal Hill. 517 feet above high water.	h. m. s. 3 30 43	h. m. s. 0 00 00	Gun fired every day at noon, St. John's (Chain Rock Battery) mean time. [*Note.*—No preliminary signal is given. This signal has been reported to be occasionally in error.]
CANADA.						
45° 15' 42" N. 66° 3' 45" W.	St. John, N.B.	Black ball with gold band.	Northern tower of new Custom House. 123 feet above water. 112 feet above ground. (Drop 12 feet.)	h. m. s. 5 24 15	h. m. s. 1 00 00	Ball hoisted half way up as preparatory at 15 minutes before signal. Ball hoisted close up at one minute before signal. Ball dropped at $1^h\ 00^m\ 00^s$ p.m. St. John mean time.
46° 48' 23" N. 71° 12' 35" W.	Quebec	Ball	At Citadel, 1,370 yards from Observatory. 355 feet above water. 46 feet above ground. (Drop 8 feet.)	6 00 00	1 00 00	Ball hoisted half way up as preparatory, at $12^h\ 45^m\ 00^s$. Ball hoisted close up at $12^h\ 55^m\ 00^s$. Ball dropped (by electricity from the Observatory) at $1^h\ 00^m\ 00^s$ mean time for 75° W. long. or $6^h\ 00^m\ 00^s$ from the meridian of Greenwich. If signal fails in accuracy, ball is hoisted half way up, and kept so for half an hour. [*Note.*—Signal not made on Sundays.]
45° 31' 0" N. 73° 33' 15" W.	Montreal	Black ball (diameter, 4 ft. 6 in.)	Tower of Harbour Commissioners' building. 145 feet above water. 119 feet above ground. (Drop 8 feet.)	5 00 00	0 00 00	Ball hoisted close up as preparatory at about 5 minutes before signal. Ball dropped (by electricity from the Montreal Observatory) at noon, mean time of the 75th meridian. Signal may always be depended upon within half a second. [*Note.*—Signal made during the season of navigation. Signal not made on Sundays.]
44° 38' 48" N. 63 34 49" W.	Halifax	Gun*	From the Citadal.	4 00 00	0 00 00	Gun fired at noon, mean time of the 60th meridian. [*Note.*—This Gun is fired for local purposes only, and is not to be depended upon for rating Chronometers.
BERMUDA.						
32° 19' 22" N. 64° 49' 35" W.	Ireland Island	Ball (diameter 21 inches).	Flagstaff on western jetty, in front of the main building of the Dockyard. 90 feet above high water. 84 feet above ground. (Drop 30 feet.)	h. m. s. 4 19 18.3	h. m. s. 0 00 00	The ensign usually on the flagstaff is hauled down, and the ball hoisted, as preparatory at $11^h\ 55^m\ 00^s$ a.m. Ball dropped at noon, Bermuda mean time. [*Note.*—Signal made on Saturdays only.]

* See note, page 2.

Fig. 17

DOMINION OF CANADA.

NOTICE TO MARINERS.

No. 33 of 1902.

(ATLANTIC NOTICE No. 19.)

All bearings, unless otherwise noted, are magnetic and are given from seaward, miles are nautical miles, heights are above high water, and all depths are at mean low water.

NEW BRUNSWICK.

(121) Saint John—Time ball—Change in time of dropping.

From and after 15th June, 1902, the time ball maintained on a staff on the Custom house in the harbour of St. John, by the Meteorological Service of the Dominion of Canada, will be dropped at 1 p.m. by Atlantic or 60th Meridian time, or exactly 5 hours Greenwich mean time, instead of 1 p.m. local time as heretofore.

60th Meridian time will be kept by all branches of the Marine Department in the Maritime provinces after 15th June next, when it will be adopted on the *Canadian Pacific* and *Intercolonial* railway system throughout the three Maritime Provinces.

Source of information: Report from Director Meteorological Service of Canada.
Admiralty charts affected: Nos. 1551, 352, 353, 1651 and 2670
Publication affected: Sailing directions for the S. E. coast of Nova Scotia, 1894, pages 306 and 307.
Department of Marine and Fisheries of Canada, File No. 7426.

F. GOURDEAU,
Deputy Minister.

DEPARTMENT OF MARINE AND FISHERIES.
OTTAWA, CANADA 10th May, 1902.

Pilots, masters or others interested are earnestly requested to send information of dangers, changes in aids to navigation, notice of new shoals or channels, errors in publications, or any other facts affecting the navigation of Canadian waters to the Chief Engineer, Department of Marine and Fisheries, Ottawa, Canada. Such communications can be mailed free of Canadian postage.

Fig. 18 Pg. 118 Notice to Mariners No. 33 of 1902, notifying of official change from local time to 60th meridian time at Saint John, N.B. Courtesy Public Archives of Canada.

adopt Atlantic Standard Time for the time ball on the 15th of June, and Fig. 17
I enclose herewith a draft notice to mariners similar to the original Fig. 18
which you send, which I think will do very well." So standard time was adopted by the city and harbour of Saint John on June 15, 1902.

September 22, 1902, a drum chronograph was delivered to the Saint John observatory from Warner and Swasey Company. The drum, 7 inches in diameter, could be driven at either I rpm or 2 rpm, and at the slower speed would record for 2½ hours. Now the passage of the star behind successive lines of the reticle could be recorded by the pressing of a key, and compared to the clock beats which would also be recorded. Previous to the installation of the chronograph, observations of stars for the determination of clock errors and rates were made by the eye and ear method.

May 30 the following year a new and larger transit by Messrs. Troughton and Simms of London, England, was received. It was fully modern, and capable of higher precision than the older type. "The instrument has a reversing carriage, and with the delicate level attached to one of the 6-inch finding circles and micrometer which is available in declination as well as right ascension, may be used as a zenith telescope as well as a transit. Small electric lamps are used for the illumination (annual report 1903)." (Sessional Papers 1905). The observing pier had to have its top section rebuilt to take the larger instrument. Electric lights were also introduced at this time into the storm warning signals and proved to be far more efficient and reliable than the oil lanterns which they replaced.

The time service was expanded locally with the installation of a clock in the lobby of the Saint John Post Office. An automatic hourly synchronizing signal from the mean time clock in the observatory assured its accuracy.

It also expanded with the installation of a time ball in Halifax. R.F. Stupart, Director of Met Service reported for the year ending June 30, 1905: "A time signal has been placed in operation on the Citadel at Halifax, the ball being dropped by an electric circuit from the observatory at Saint John. Mr. Hutchinson deserves much credit for the able manner in which he has arranged for apparatus for this time service which is, I believe, greatly appreciated by the people."

In his report Hutchinson states, "the Halifax time ball was started in operation on October 1, 1904. The ball is on a staff with base and small house for protection of the hoisting gear and electric release. It is situated on the citadel a little north of the main signal station. .... A clock especially designed for this (release mechanism) service was placed in the Western Union Office at Halifax. This clock has a good movement and a mercury pendulum, is wound electrically and is daily corrected or synchronized by the final dot at 10 a.m. of the signal sent by our transmitting clock. ... The ball is automatically and electrically dropped at the instant of 1 p.m., the times of hoisting half elevation, full elevation and drop being synchronous with the ball at Saint John. The master clock in Halifax sends a signal to the citadel every hour and corrects a subsidiary clock placed there by the Meteorological Services for the guidance of the hoisting man. The Royal Engineers have charge of the hoisting mechanism and Mr. C.W. McKee, manager of the Western Union has charge of the electric clock. To keep check on the time of the Halifax clock it is fitted with a break circuit attachment which registers a signal on the chronograph in Saint John together with one of our standard clocks. It shows only a small rate during the day. No failure to synchronize it has occurred. On two days when wire trouble existed the Halifax ball was dropped from Saint John, the same signal which synchronized their clock dropping the ball." (Sessional Papers, 1906) It was Hutchinson's decision to place the time ball on the citadel because by inspection it had a commanding view of the Harbour.

That same year the Saint John Observatory acquired sidereal clock No. 94 by Dr. S. Riefler of Munich. This was the finest design of clock then available, being enclosed in a glass cylinder which could be made airtight and maintained at a constant pressure. A mercury barometer was enclosed in the case. The Riefler free escapement combined with the nickel steel pendulum made in a superb timekeeper. The clock along with the new transit and the drum chronograph made the time room fully modern.

A detailed report by Hutchinson for the year ending March 31, 1924 indicates the extent to which the Saint John time service had permeated the Maritimes.

"The transmitting clock is run on Atlantic Standard time and has a very small daily rate. After comparison with the Sidereal clocks any outstanding error is adjusted by a switch outside of the protecting case that electrically controls two small weights which by this means may be placed on or off a small shelf attached to the pendulum, it may be accelerated or retarded and usually in a few minutes exactly corrected. The well known code of signals from this clock are entirely automatic.

"Three loop lines connect the observatory with the outside time signal service, two of these loops run to the Telegraph Office and one to the Telephone Office.

"One loop line from the observatory to the Western Union Office is also extended to the time ball tower on the Customs Building here and is used at 1 p.m. for automatically releasing the time ball at that hour. The clock signals are widely disseminated throughout the Maritime Provinces and are also received at all telegraph offices on the Intercolonial division of the Canadian National Railways and their branch lines, as well as at the Dominion Atlantic Railway in Nova Scotia.

"At many points such as Halifax, Truro, the Sydneys, Moncton, Charlottetown, etc., the Telegraph Company has installed clocks which are electrically wound and daily corrected by the 10 a.m. signal, this is done by one of their operators throwing a switch during the ten seconds pause before the dot made at the hour exactly and throwing it open during the ten seconds pause of safety after the hour. These clocks have second hands and are set to the second. As our time is available to the Telegraph Company every hour they may correct any of these clocks at hours other than 10 a.m. These corrected clocks being installed in the Telegraph Company's public offices, the public are afforded the opportunity of obtaining the correct time.

"Another contact maker on the transmitting clock which closes the circuit on the 59th second and opens it at the hour exactly is purely for local purposes and is used for the correction of tower, hotel, street, bank, factory and watch and chronometer rater clocks. [Rater clocks were usually associated with a watchmakers shop (author).] In these cases the clocks are purchased outright and the signal of correction automatically is sent from our transmitting clock every hour day and night on a loop connecting the observatory clock relay with a special switchboard in the operating room of the Telephone Company, who charge an annual rental for the wire service to the owners of the clocks. Within a prescribed radius the fee paid to the Telephone Company by the users is ten dollars yearly. Some watchmakers have bells or sounders which give them a signal stroke every hour. Another loop in the Telegraph Office is used for synchronizing clocks in their Saint John Offices and operating room."

The Director of the Saint John meteorological observatory had for three decades become increasingly recognized as the man with the weather information. The local readings of the instruments were reduced to three per day in June 1900. But the reports from all the maritime stations were sent in to Saint John where they were available for quick recall in matters of litigation. Also regular summaries were forwarded to Toronto to be included in the annual review. Storm warning signals were hoisted on the Customs building as soon as they were received, and the Toronto forecast together with local readings were eagerly awaited each day by the local press.

The time service continued to expand, for in the report a year later one reads, "Time signals have since December 1924 been broadcasted from C.N.R. radio station at Moncton (CNRA) on Tuesdays and Fridays at 10 p.m."

A telegram from J. McMillan, General Manager of C.P. Telegraphs, to C.P. Edwards, Deputy Minister of Marine and Fisheries, dated 13 June 1925, states, "Time signals from Saint John, N.B. to Camperdown started yesterday." A fee of $10 per month for a C.P. line between these points was agreed to by the department. (Camperdown, on a height of land seaward from Halifax harbour continued as a radio communication point till a new station replaced it in the late 1960's.) The time signals were sent by land line to the transmitter, (VCS, 417 kcs) then relayed by hand.

One of the last developments witnessed by D.L. Hutchinson was a clock with a six-foot dial installed on the Dominion Public Works Building in Saint John in 1926. The mechanism was of the waiting train type governed by a master clock which had a wire connection direct from the standard mean time clock of the Observatory for hour control.

The following year he died. His passing marked the end of six decades of duty by the Hutchinson family, father and son, to the meteorological and the time service of the maritime provinces. His replacement, Francis M. Barnes, continued in the tradition of the Hutchinsons. Saint John was the centre to which each of the weather observers of the martimes reported, and it was the centre from which all weather reports and forecasts for the area were circulated, though they Fig. 19
originated in Toronto. In addition the Saint John Observatory set the clocks of the Maritimes, as indicated in the annual report of March, 1936.

"Transit observations with the three-inch meridian telescope for the determination of time have been made as frequently as possible and comparisons made with the Riefler and Kullberg sidereal clocks. The Riefler sidereal clock situated in the basement of the observatory continues to give excellent service.

"Time signals are automatically sent from our mean time transmitting clock every week day over the Canadian National wires to all their offices in the Maritime Provinces as well as to the Dominion Atlantic and

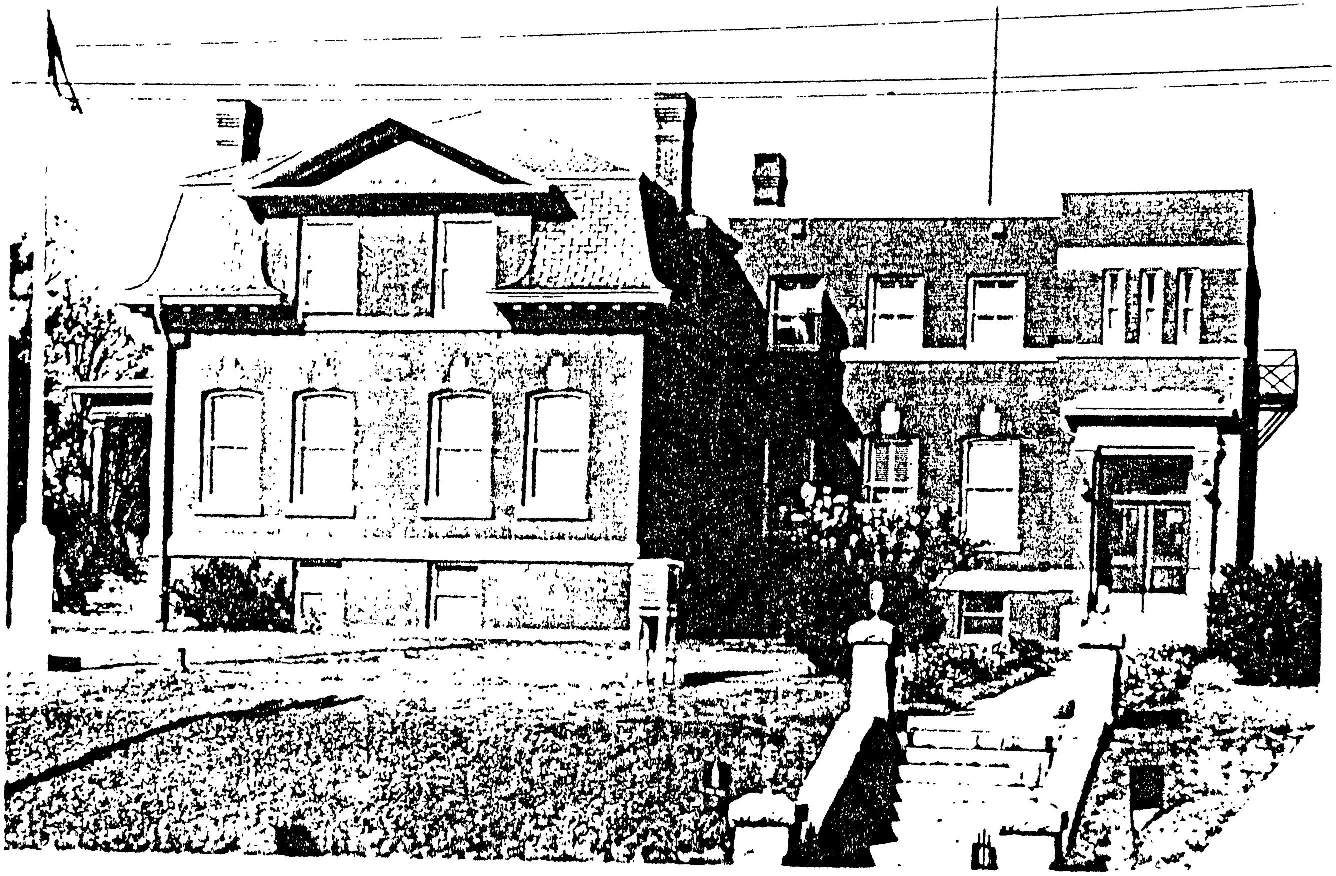


Fig. 19 Pg. 123 The Douglas Street Meteorological Observatory, Saint John, N.B., which was officially closed in 1951 and turned over to the RCMP. Courtesy Royal Canadian Mounted Police, Ottawa.

Canadian Pacific Railway Companies. Automatic signals for broadcasting are sent over the Canadian Pacific land lines to Camperdown.

"The daily time signals in Saint John have been given to shipping and others by the dropping of the time ball on the Customs House. In Saint John the system of hourly synchronizing of office, street and tower clocks continues to give most satisfactory and useful service. The comparison of time between the telechron clocks throughout the city and the mean time transmitting clock continues to give satisfaction. The number of telephone calls for correct time has increased.

"The equipment has been maintained in good condition throughout the year. Minor repairs were made to the impulse clock and the tower clock.

"Many visitors, including Junior service clubs were welcomed to the observatory during the year and conducted through the building."

But times were changing. In a rearrangement of Federal responsibilities in 1936 timekeeping was turned over to the Dominion Observatory at Ottawa. The fundamental determination of time had ceased to be performed at any of the other meteorological centres across Canada. Instead reliance was placed on the time which originated at either Ottawa or Washington. All except Saint John. Here the transit instrument continued in use on clear nights and the network of time circuits controlled by the observatory remained active until Barnes reached retirement age in 1949. Radio time signals had long since made the time ball redundant. But when it was out of commission for two months in 1934, owing to a breakdown in the hoisting and dropping mechanism, public concern caused it to be restored to service, and it remained in service for another decade or more.

In spite of the fact that the responsibility for correct time had been officially transferred to the Dominion Observatory in Ottawa, the observatory in Saint John remained operative until 1951. This was due to public pressure. Andrew Thomson, Controller of the Meteorological Services of the Department of Transport, had addressed a letter to the New Brunswick Telephone Company which said in part, "As our Mr. F.M. Barnes has reached the retiring age, he has advised us that he wishes to give up his active duties at the Observatory during 1949. At the time of Mr. Barnes retirement we wish to advise you that the Meteorological Division will be compelled to discontinue the provision of time service to your company."

Fundamental timekeeping based on astronomical observations had ceased as of May 1947, giving way to radio time signals from Ottawa, London and Washington. The time ball on the Customs Building became inoperative in 1946 and was never restored to service.

C.S. Beals, the Dominion Astronomer, gave a sympathetic hearing to various public and private groups who felt that the closing of the Douglas Street Observatory deprived them of service that was rightfully theirs. Action was delayed, but in 1951, two observatory employees, Wm. Foisey and Clarence O'Neil, a watchmaker and a carpenter, proceeded from Ottawa to Saint John. One of the clocks was installed in the office of the telephone company and wired directly into their services. The radio also was left with the telephone company to provide radio time checks. One clock was shipped to the Dominion Astrophysical Observatory in Victoria, B.C. The two remaining, one of which was Riefler #94, together with other paraphernalia, were brought to Ottawa.

Radio Time Signals - Met Service

Saint John, Oct. 22, 1926 - D.L. Hutchinson to Alex Sutherland, Halifax
Wireless Officer, HMC Dockyard, Halifax, N.S.

The attached clipping will give you the transmission time and spacing of our time signal sent each week day morning over the CPR and Western Union lines. We are also broadcasting from Moncton at 3 p.m. AST on week days as well as 10 p.m. Tuesday and Friday nights.

"Time signals will be sent each week day morning as follows: Beginning at 9:58 a.m. Atlantic time, dots are made each second up to and including 9^h 58^m 57^s, then a pause of two seconds, followed by a dot at 9^h 59^m 00^s, then a pause of two seconds follows. The clock then makes dots each second up to and including 9^h 59^m 50^s, a pause is then made, followed by a dot at 10 a.m. Atlantic, or Standard time of the 60th meridian west longitude, equivalent to 2^h p.m. G.M.T."

1926 C.P. Edwards to R.M. Stewart

Station	Call	Wavelength	Character of Transmission
Chebucto Head, N.S.	VAV	600 metres	synchronous spark, 480
Estevan, B.C.	VAE	600 metres	synchronous spark, 480
Gonzales Hill, B.C.	VAK	600 metres	Valve I.C.W.

Halifax

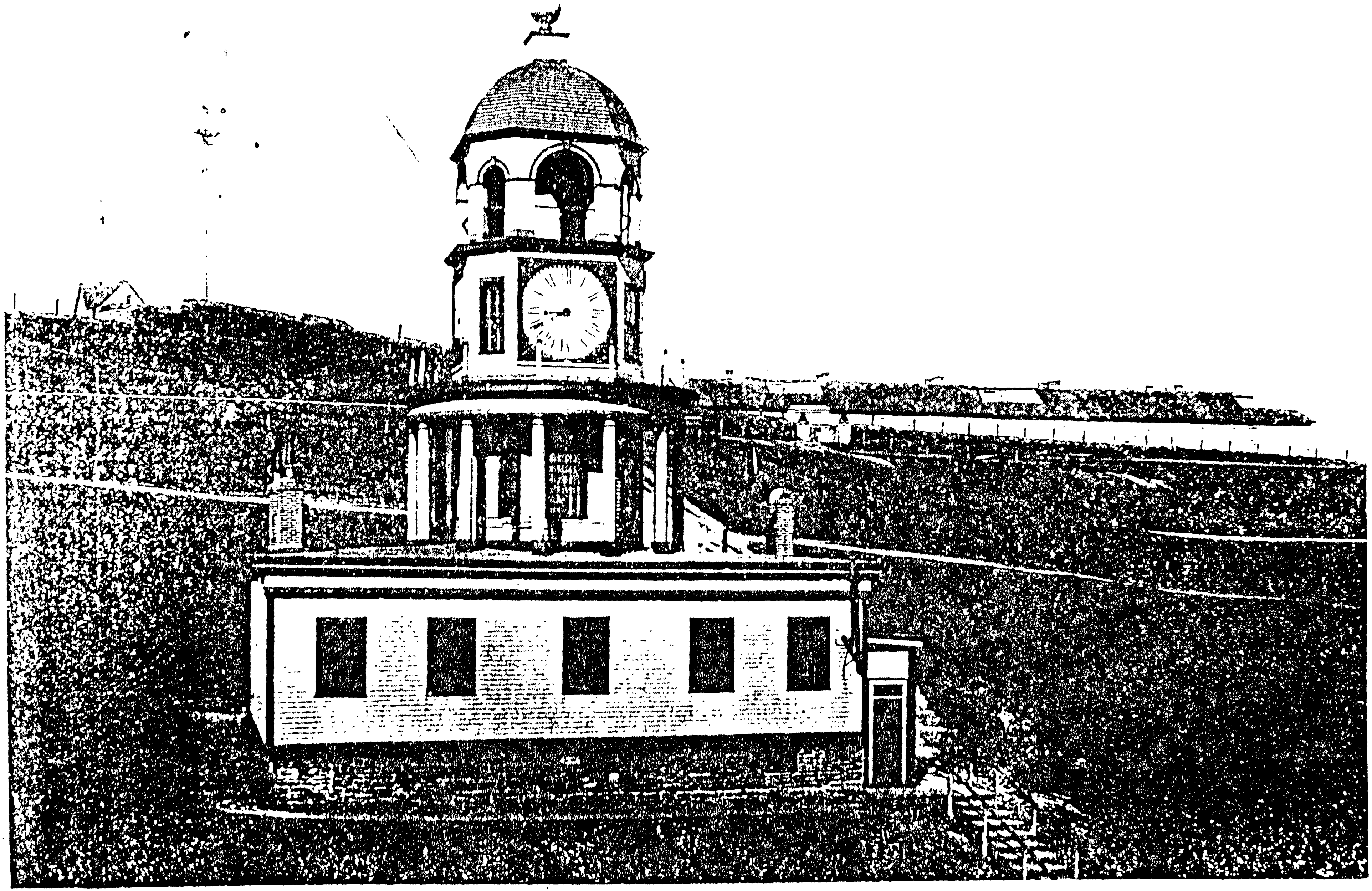


Fig. 20 The Old Town Clock, Halifax, built in 1803 by Edward, Duke of
Pg. 127 Kent. Courtesy Public Archives, Ottawa.

HALIFAX

The city of Halifax can claim many Canadian firsts. It was the first English town in Canada (1749), it had the first public school (1749), the first printing press (1751), the first dockyard (1758), and so on.

Since the founding of Halifax in 1749, a gun has been fired every day at noon. According to the Halifax Order Book it was announced on May 1, 1803, that a second gun was to be fired at 9 o'clock to bring people back into the stockade. The oldest known public clock in Canada is to be seen atop the Dockyard Fire Hall. It was constructed by Aynesth Thwaites in Clerkenwell, London, and installed over the sail loft in the Dockyard in 1772. Here it operated continuously until becoming a casualty in the explosion of 1917. It was repaired in 1941 and moved above the new fire hall.

Below the Citadel is the Old Town Clock, built on the instructions of Edward Duke of Kent, father of Queen Victoria, and installed in 1803. So time was announced to the populace by both clock and gun. According to an account in the Acadian Recorder of January 17, 1873, people wondered whether the gun or the clock was correct. It was stated that the gun was fired by sun time and that it was correct only twice a year, April 13 and October 13, while a man named Herbin was reported to have kept the market clock according to time taken from observing the moon. (Halifax Directory 1875-76 lists John Herbin as Watchmaker & Jeweller at 200 Lower Water.) Fig. 20

Halifax seemed to resist steady growth. By 1757 the Imperial Government had poured £560,000 into the settlement, and there were influxes of people such as the influx of United Empire Loyalist in the 1780's. However the people did not stay, but tended to move on to the older colonies. Fishing, the main industry, was neglected, and the colony subsisted mainly on money expended by the army and navy. In a brief historical sketch in McAlpine's Maritime Directory for 1870, one reads "Halifax was of incalculable importance, however, to Great Britain in a military point of view, and to its position as a military and naval station may be ascribed, in a great measure, the downfall of the French power in America." It had the title of Warden of the North, but not till 1840 did it become incorporated as a city.

At the time of Confederation, July 1, 1867, Quebec City had for a dozen years been provided with an observatory and time ball by means of which correct time was provided for the shipping in the harbour. No such facility was available at either Saint John, N.B., or Halifax, yet these two important ports were open twelve months of the year. They were not readily accessible to the rest of Canada until the completion of the Intercolonial Railway in 1876. Nevertheless the new Dominion felt responsible for those whose livelihood was on the sea, and the first parliament voted $1500 for the construction of two time ball observatories, one at Saint John, the other at Halifax.

It is rather noreworthy that the geographical position of Halifax was measured with respect to that of Harvard College Observatory in 1852 by the new electric telegraph method of exchanging time. It thus became the key position to which the Canadian coastal surveys of Captain P.F. Shortland, Captain W.F. Owen, Captain H.W. Bayfield and others were tied to the American surveys. Its position with respect to Greenwich also being now firmly established, it would have been a proper place for a local time service. But Halifax was really more of a military base than a port of commerce, being part of the Marine quadrilateral of England, Malta-Gibraltar-Bermuda-Halifax.

Halifax was not without skilled artisans. William Crawford, a clockmaker, who learned his trade in Glasgow, established himself in Halifax in 1830. Shortly thereafter he applied to the House of Assembly for aid to enable him to erect an observatory and to rate and regulate chronometers. He had in his possession a clock and transit instrument belonging to the Marine Insurance Association. He required in addition a reflecting telescope of sufficient power "to espy the satellites of Jupiter and their various occultations and eclipses; and also a repeating circle." These would cost £100. With them he would be able to "regulate ship chronometers so perfectly as to indicate true longitude, with little chance of error, and thus more perfectly guard the property and protect the lives of those who are engaged in foreign commerce." (Journal of the House of Assembly of Nova Scotia, 1832.)

The investigating committee recommended that the sum be made available to the Marine Insurance Association rather than to Crawford directly, and the instruments would then be assigned to a competent person.

In 1865 Robert H. Cogswell bought out his predecessor, Wm. Crawford, and enlarged and improved the premises at 155 Barrington Street. Besides dealing in a complete selection of nautical instruments and books and charts, he is credited with being a "standard authority on true time, keeping Halifax, Boston, and Greenwich time by astronomical clocks, and having a transit instrument conveniently mounted on his premises for the rating of chronometers. He, like his predecessor, has had the rating of the chronometers of the Cunard Mail Steamers of the Bermuda and Newfoundland lines since their commencement, and for the general shipping of the port. He has charge also of railway time. He has for years gratuituously signalled the true time by which the noon-day gun is fired at the Citadel and for several years made up the weather report for the daily evening papers." (Halifax and its Business G.A. White Print Company, Halifax N.S. 1876.)

A letter dated October 3, 1868 was dispatched to the Mayor of Halifax, advising him that the Federal Government would be erecting and maintaining a time ball on Citadel Hill, to give true time to masters of sea going vessels. A sum of $750, half the total appropriated for the two maritime ports, was earmarked for Halifax.

In his annual report for the year 1869, Wm. Smith, Deputy Minister of the Department of Marine and Fisheries reported, "No portion of the money voted for an observatory in Nova Scotia has been expended. A site has been offered gratuitously of an eligible position on the Dartmouth side of Halifax Harbour by Colonel Hornby. This offer has been accepted and arrangements will probably soon be made for erecting an observatory and time ball on the site alluded to." (Sessional Papers 1871).

The fragmentary records of the day do not reveal the personalities and politics that entered into the delay, but a year later no progress had yet been made. Instead it was decided to defer any action until it had been ascertained whether the time ball observatory at Saint John, N.B., was of sufficient value to the maritime interests of the port to warrant the expenditure for its maintenance.

In his annual report for 1878 Wm. Smith reveals part of the story when he states, "An allowance at the rate of $100 per annum is made to Mr. Robert H. Cogswell, who for nearly two years past has given the true time at noon to the public at Halifax by means of a ball dropped at his establishment." A similar report appears in the Sessional Papers of the Department in subsequent years up to 1882. Cogswell's name also appeared in connection with professional assistance given to the Hudson Bay Expeditions of 1884-86, conducted by The Department of Marine and Fisheries.

Some years later Wm. Smith wrote to the Agency of Marine at Halifax, and received the following reply from A.W. Johnson, dated 7 January 1890. "In reply to your letter of the 31st ult., I beg to state that I am not aware of any arrangements having been made here for the giving of time by the dropping of a ball at noon. Since the year 1876 Mr. Cogswell has been paid $100 per annum for furnishing to Citadel Hill here the correct time at 12 o'clock noon daily for the gun fired at that hour by the military authorities. The time is ascertained by Mr. Cogswell by transit observations and is transmitted from his place in town by means of the telegraph (private line) to the Citadel Hill and the gun is fired accordingly.

"The time given by the gun is nearly correct, but not sufficiently so for the purpose of rating chronometers. Almost all vessels here send their instruments to Mr. Cogswell's business place to be rated.

"The twelve o'clock gun has been fired for a great many years but I do not think any notice has been issued regarding it. A sum of

$1500 was voted by Parliament for an observatory at Halifax many years ago, and if expended, did not include a time ball."

During the year 1871 when the Department of Marine and Fisheries was developing a system of weather reporting stations, with the establishment of a chief reporting station in each of the major centres, the Halifax appointment was given to Fredrick A. Allison, a man with a deep interest in meteorology. He was succeeded in 1879 by his second cousin Augustus Allison, who died February 4, 1904. It was a telegraphic reporting station, and the direct connection with Toronto made it convenient for the Halifax weather office to receive a time check each time that Saint John, N.B., had an exchange of clock signals. This service was discontinued April 7, 1896. Special time checks were also provided from Toronto for the benefit of the British survey gunboat Rambler at Halifax in 1898. But this service too was superseded by the time service from Saint John, which provided a signal automatically each day at 10 a.m. to the telegraph network. Special signals were also sent by request during the year 1900 from Saint John to the Royal Navy at Halifax, to North Sydney and Halifax for the British and French cable ships, to Mr. W. Bell Dawson for the use of the Tidal Survey, and to others. At no time, however, was there mention of Mr. Cogswell's time service being drawn into the federal service under the general supervision of Toronto.

Instead plans were carried out for a time ball in Halifax to be operated by the Saint John observatory. The Halifax press followed with interest its installation. A report in the Nova Scotian of March 11, 1904, stated that a short time ago an official from the head meteorological office in Saint John visited Halifax and located the site for the time

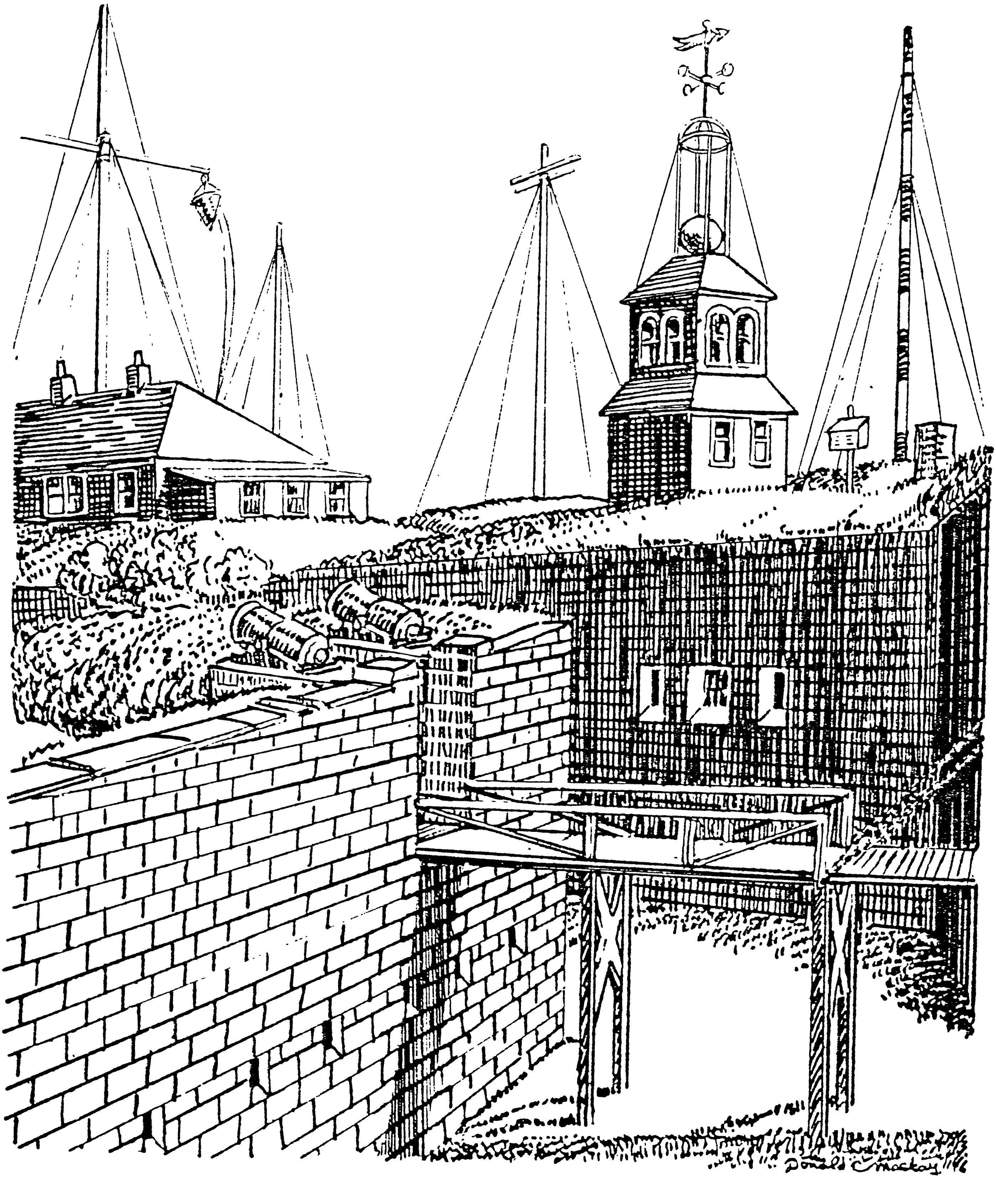


Fig. 21 The time ball on the Citadel, Halifax, Nova Scotia. A pen and
Pg. 133 ink drawing by Donald C. Mackay, Halifax.

ball, pending completion of the Custom building. After viewing the city from the waterfront, the official chose the Citadel at the best location. Fig. 21 The time ball would likely be between the main staff and the storm signal staff.

On August 5, 1904, the Nova Scotian reported that Mr. D.L. Hutchinson, Director of the Meteorological Observatory at Saint John, was in Halifax to superintend the final arrangements for the installation of the time ball, and to make the necessary electrical connections. The ball is to be located on the Citadel, and will be operated from Mr. Hutchinson's office in the Custom House in Saint John.

R.F. (later Sir Frederick) Stupart, in a memo to W.P. Anderson of the Marine and Fisheries Department, 20 November 1913, stated that the Halifax time ball installation cost six hundred and twenty-five dollars ($625).

In his book Halifax, Warden of the North (McClelland and Stewart, 1948), T.H. Raddall implies that the improved time service was appreciated. "The old town clock was usually out of order (alas for the Duke of Kent) but every citizen set his watch and every housewife her clock by the noon gun from the Citadel, and skippers checking their chronometers in the harbour watched the Citadel ramparts for the drop of the gilded time ball."

October 1, 1904, marked the inauguration of the time ball service in Halifax. Hutchinson was warmly praised for his accomplishment of the task. A clock especially designed to be synchronized from Saint John, and to serve as a relay for the control of the time ball and several subsidiary clocks, was placed in the Western Union Office at Halifax.

Following the Halifax explosion during World War 1, D.L. Hutchinson made the following report. "The Halifax time service was temporarily deranged at the time of the explosion (December 6, 1917, about 9:05 a.m.), but though the plate glass windows within a few feet of the pier carrying the master clock were completely shattered this clock was undamaged, did not stop, and upon receipt of the first time signal from the observatory twelve days after the explosion, it was found to be eleven seconds slow. No damage occurred to the time ball apparatus on the Citadel."

Daylight saving came to Halifax by authority of the federal parliament in 1918. Accordingly the clocks were advanced one hour from Atlantic standard time, and the time ball was dropped at the earlier hour. Owing to the objections of the Admiralty, the time ball reverted to Atlantic standard on August 1, 1918.

Year by year the time service continued to receive the 10 a.m. signal from Saint John via the Western Union Telegraph office. The master clock in Halifax, which was daily synchronized by this signal, continued to give satisfactory service for the automatic control of the time ball release, firing the noon gun, and synchronizing the clocks which were connected to its hourly pulse.

The year 1926 marked the change which ultimately sounded the death knell to the time ball. A radio station had been established at Fig. 22
Camperdown, at the entrance to Halifax harbour in 1905, and in 1926 it was reported that the 10 a.m. signals were relayed automatically over the
over the adjacent station at Chebucto Head.
Canadian Pacific Railway lines for broadcast. Prior to this, time signals from Camperdown had been sent out by hand key.

DOMINION OF CANADA

NOTICE TO MARINERS

No. 4 of 1927

(Atlantic No. 2)

All bearings, unless otherwise noted, are true and are given from seaward in degrees from 0° (North) to 360°, measured clockwise, followed by the magnetic bearing in degrees in brackets, miles are nautical miles, heights are above high water of ordinary spring tides, and all depths are at low water of ordinary spring tides

NOVA SCOTIA

(10) South Coast—Halifax Harbour approach—Chebucto Head Radio Direction Finding Station—Time signals transmitted

Position.—Latitude 44° 30′ 01″, Longitude 63° 31′ 20″.

Call Sign.—VAV.

Wave.—600 metres (spark).

Time signal.—9.00 a.m. E.S.T. (2 p.m. G.M.T.)

The time signals are sent in the following manner:— (E.S.T.)

A dot at each second beginning 8h. 58m. 00s. up to and including 8h. 58m. 57s.

A dot at 8h. 59m. 00s.

A dot at each second beginning 8h. 59m. 03s. up to and including 8h. 59m. 50s.

A dot at 9h. 00m. 00s.

For the purpose of these signals the Observatory at St. John, N.B., is connected by land telegraph line to the Chebucto Head D/F Station.

The signals are transmitted daily except Sunday.

N. to M. No. 4 (10) 11-2-27

Authority: Director, Radio Service, Dept. of Marine and Fisheries.
Canadian Hydrographic Survey chart: No. 411.
Admiralty Charts: Nos. 2320, 2410, 729 and 1651.
Publication: Nova Scotia and Bay of Fundy Pilot, 1921, page 128.
Departmental File: Nos. 55163 and 291-1-23.

A. JOHNSTON,
Deputy Minister.

DEPARTMENT OF MARINE AND FISHERIES,
OTTAWA, CANADA,

Pilots, masters or others interested are earnestly requested to send information of dangers, changes in aids to navigation, notice of new shoals or channels, errors in publications, or any other facts affecting the navigation of Canadian waters to the Chief Engineer, Department of Marine and Fisheries, Ottawa, Canada. Such communications can be mailed free of Canadian postage.

Fig. 22 Notice to Mariners No. 4 of 1927 describing time signals from
Pg. 134 Chebucto Head, N.S. Courtesy Public Archives of Canada.

The new service, for which the CPR charged ten dollars a month for rental of the line, continued until the master clock at Saint John ceased to operate May 1, 1951. The operator at the Halifax C.P. Telegraph office then commenced a manual transmission of seconds beats, taking his time from the pendulum which was synchronized with the daily telegraph signal at 11:54 to 11:56 a.m. E.S.T. from the Dominion Observatory at Ottawa. A Notice to Mariners announced the discontinuance of this service on March 31, 1955, and the last broadcast occurred on May 7. Hand controlled second pulses no longer served a useful purpose in the world of modern technology.

Today the Citadel is an historic site maintained by the National and Historic Parks Branch of the Department of Indian Affairs and Northern Development. The modern city of Halifax has gone skyward with high rise buildings that engulf the hill which once had a strategic and commanding view of the harbour. Time for the city has its origin in the national time service, but a link with the past is to be seen and heard in the 6 pounder cannon, a relic of the Boer War, which is fired each day at noon.

Kingston

KINGSTON

The city of Kingston dates its origin to 1673 when the site was chosen by La Salle for a meeting between Governor Frontenac and the Iroquois. The fort which Frontenac built shared in the troublous days of Indian uprising and the struggle between the French and the English. Twice it was destroyed. In 1783 the site was occupied by United Empire Loyalists, and was named Kingston. Shortly thereafter it was selected as the naval base for Lake Ontario, and a dockyard was built on Point Frederick, the present location of the Royal Military College.

In his historical essay entitled "H.M. Dockyard, Kingston", T.L. Brock described the daily routine of the establishment under the administration of Commissioner Rober Barrie. "Inside the gate was a flagstaff, and at the nearby Guard House was located the Dockyard bell. The use of the bell is detailed in the following manner by Barrie:

Herewith you will receive regulations respecting the working hours of this yard. The bell will commence ringing:

at 10 minutes to 6 o'clock a.m.

to cease 5 minutes after 6 o'clock

to be rung precisely at 8 o'clock

to commence ringing at 10 minutes before 9 o'clock

to cease 5 minutes after 9

to be rung precisely at 12 o'clock

to commence ringing at 10 minutes before 1 o'clock

to cease 5 minutes after 1

to be rung precisely at 6 o'clock

Immediately the bell ceases ringing the Gates are to be closed and no artificer or laborer belonging to the regular establishment of the Yard is to be admitted after the gates are closed.

P.S. The bell is to be rung on Saturday afternoons at 5 o'clock... Contractors' vessels... are to haul off from the Yard at 6 o'clock in the evenings, and to haul again in the morning when the bell rings.

The Dockyard went through successive reductions, until finally in 1834 an order was sent to Barrie, which he received at the beginning of March, to close the place entirely by July 1st."

The Bell which marked the time of day so uniformly at the Dockyard is now in the belfry of St. Mark's Church, Barriefield.

There is no doubt that the bell of the Dockyard would be heard across the bay in the village of Kingston, and that by it the villagers regulated their comings and goings.

Kingston became an incorporated town in 1838, and a city in 1846. Governor Simcoe held the first session of the Executive Council for Upper Canada there in 1829, and in 1841-44, it served as the seat of government for the Province of Canada. In anticipation of its remaining Fig. 23
the capital, a spacious city hall was built, which was surmounted by a dome-like tower containing a clock. The clock, made by the same man who made Big Ben, was presented by the Lord Mayor of London to the Mayor (John Counter), Council and Citizens of Kingston. There was fire damage in 1865 and 1908, and in the rebuilding in 1909 a new mechanism, made by Seth Thomas Clock Company, was installed. The four 8-ft dials, about the size of those on the Peace Tower in Ottawa, display the time in the four directions. There was a Caretaker of the City Clock who was

Fig 23 City Hall, Kingston, Ontario, was built on a spacious plan in
Pg. 137 the 1840's in the expectation that Kingston might remain a
capital city. Photo by Photo Image, Kingston.

SIZE 85 %

Fig. 24
Pg. 138

Professor James Williamson LL.D. (1806-1895), Professor of Mathematics and Natural Philosophy. Courtesy Queen's University Archives.

appointed initially at a salary of £10 per annum. Some years later this was recorded as a payment of $40 per annum. Obviously it was but a part time job.

During the war of 1812 a fort had been built on Point Henry to protect the Dockyard. Between 1832 and 1836 it was replaced by another, which recently has been restored and serves today as a tourist attraction. Soon after the fort was established, and through the instigation of Patrick Corbett, a senior officer, the firing of a noon gun at Fort Henry was initiated. For 58 years the gun of the garrison announced the time of noon. On October 3, 1870, with the departure of the Imperial Garrison, the operation ceased. The following year a School of Artillery was opened on the site, and according to Regulations for the Permanent Corps Active Militia, December 1889, it was specified that a gun will be fired daily at noon and again for a curfew at 9:30 p.m.

The impact of Fort Henry upon the growing community of Kingston extended beyond the noon gun. It is not within the scope of this essay to discuss the contribution of the garrison to the social life and economic growth of Kingston other than to say that it was considerable.

The thread of this story now leads on to the founding of Queen's University in 1841, and the hiring, the following year of a 36 year old Scotsman, Rev. James Williamson (1806-1895), as Professor of Mathematics Fig. 24
and Natural Philosophy. For the next 54 years this man identified himself with Queen's, giving of his talents wherever required. In 1876 he was appointed Vice-Principal, and in 1882 he resigned the chair of mathematics, and accepted the honorary position of Professor of Astronomy and Director of the Observatory.

"It would appear", wrote Otto Klotz in the Journal of the RASC, Vol. 12, No. 5, "That the impulse to erect an observatory in the public park at Kingston, was due to the interest aroused in astronomy by the annular eclipse of the sun on May 26, 1854, which was observed at Kingston by Lieut. Col. Baron de Rottenberg with a Dollard 2½-inch objective, 3¼-ft focal length, and by Fred J. Rowan with a Troughton & Simms small telescope attached to a transit theodolite." (J. RASC, 13, 322, (1919).)

(Assistant Deputy Quarter Master General?)

Baron de Rottenberg was ADQMG from 1847 to 1854, and Commander of the garrison in 1855. He was one of the scientific gentlemen referred to in Report Book V, City of Kingston, wherein the Minute, dated May 15, 1855, reads in part: "Your committee has much satisfaction in stating that with the valuable assistance of several scientific gentlemen, they will have it in their power to erect during the present summer an observatory near the centre of the ground which will extremely be an ornament to the place; but what is of greater moment, it will have a beneficial effect upon the minds of the rising generation of the city and of the citizens at large, and will add much to our reputation abroad. Many have subscribed specially for the observatory who would not have paid a penny otherwise to the park. Your committee, assisted by the gentlemen aforesaid, inspected the block house on Union Street, found that it is most substantially built, yet without great additional expense, a sufficient degree of solidity could not be obtained. Therefore, your committee abandoned the idea of applying the block house to the use of an observatory."

Klotz continues his historical note by stating that, "especially through the effort and contributions of Baron de Rottenberg, Professor

Williamson, Judge Burrowes and Dr. Yates, an equatorial of 6¼-inches was bought for $800 from Mr. Clark of Cambridge, Mass. The equatorial was received in the autumn of 1855, and was set up and adjusted on its pedestal under the dome of a small tower erected in the park in the spring of 1856.

"In the following year, February 1857, Lieut. E.D. Ashe observed at Kingston, near the new Court House, for the difference of Longitude by the electric telegraph between Kingston and Quebec. The difference was found to be $0^h\ 21^m\ 05\overset{s}{.}50$, the longitude of Quebec, which had been connected with Harvard, $4^h\ 44^m\ 49\overset{s}{.}02$, thus giving the longitude of Kingston as $5^h\ 05^m\ 54\overset{s}{.}52$."

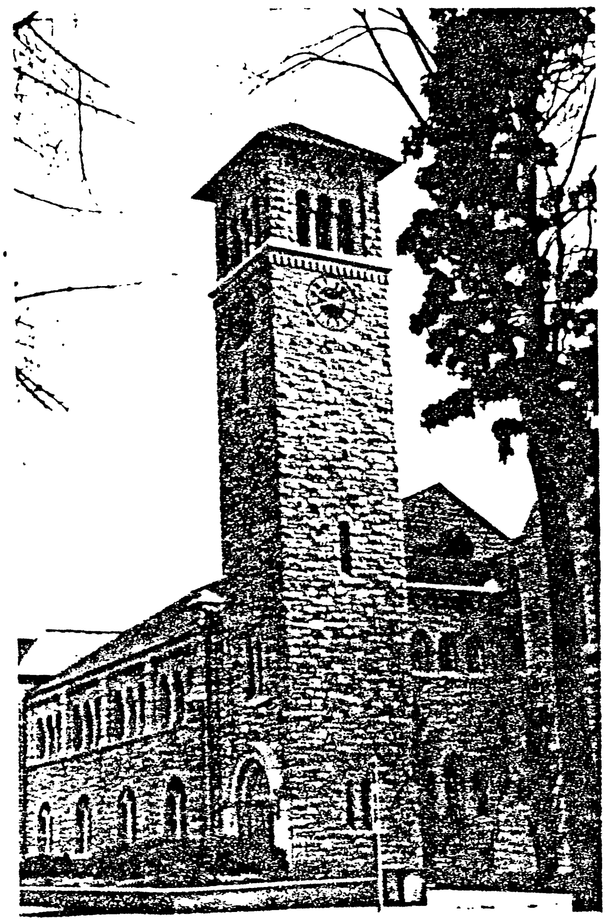
Using the observations of two eclipses, 1845 and 1854, and one transit of Mercury, 1854, Williamson, a competent mathematician and enthusiastic astronomer, had deduced the longitude of Kingston as $5^h\ 06^m\ 08\overset{s}{.}48$, the time being taken from a carefully regulated clock, the pendulum having a wooden rod. Observations of many moon culminations in the following decade yielded a value of $5^h\ 05^m\ 54\overset{s}{.}03$, which compares favourably with the 1905 Geodetic Survey value of $5^h\ 05^m\ 52\overset{s}{.}86$.

Rev. Williamson had returned to Scotland in 1845 to claim the hand of Margaret Gilchrist. Unfortunately the marriage was short lived, for Mrs. Williamson died two years later, leaving one son. Five years later he married Margaret Macdonald, a sister of the then rapidly rising statesman John A. Macdonald.

Building of the observatory in the park to replace the small domed tower was beyond the resources of the local group. An application to Parliament for a grant in aid of the objectives of the observatory was successful, and commencing in 1860 Queen's received an annual grant of $500. The observatory was built at a cost of $1,400. A small transit instrument by Simms was purchased for $180, and the loan of a larger and more useful transit, called the Beaufoy was secured in 1864 on application to the Royal Astronomical Society, London, England.

"The Beaufoy transit, having been properly fixed between its piers, has been carefully adjusted in the meridian and its corrections for level, collimation and azimuth, fully ascertained. The correction for inequality of pivots, which is very small, has also been determined. Having been found, as was to be expected, more stable in its adjustment than the portable transit by Simms formerly placed in the meridian, it is now alone employed for meridional observations, while the latter has been placed in the prime vertical for the purpose of determining the latitudes by a new and very accurate method by means of stars culminating within a few minutes from the zenith. This method is due to my assistant, Mr. Dupuis, ... and many observations for latitude give a mean of 44° 13' 21.7" N."(Report to the Board of Visitors by the Director of the Kingston Observatory for the year ending 31st December, 1865.)

Nathan Fellowes Dupuis (1836-1917), while still an undergraduate, was appointed Observer in 1863. He proved to be a capable technician, a reliable observer and subsequently became a staff member. He was made Professor of mathematics in 1881, and Dean of the Faculty of Practical Sciences in 1894. The cost of an astronomical clock was beyond the budget of the new observatory, so Dupuis made one. And when the mean time clock which had been loaned by the Principal, Rev. Dr. Leitch, was reclaimed by his estate on his death in 1864, Dupuis replaced it with one



Clock Tower Grant Hall Queen's U Aug 18 1973

Fig 25 Clock Tower, Grant Hall, Queen's University.
Pg. 142

of the same design as his sidereal clock. In a historical note entitled Astronomy at Queen's, Dr. A. Vibert Douglas states, "Dupuis, in 1887 gave the university a clock with batteries to ring class-room bells. He designed and directed his students in the construction of the clock still operating (at least three of its four faces show the progress of the hours) in Grant Hall Tower." (Jr. RASC, 52, 80, (1958).) Fig. 25

As soon as the observatory was placed in operation, Williamson continued to observe lunar occultations, lunar culminations, the satellites of Jupiter and other phenomena that came within the competence of his equipment. Without the benefit of micrometer or hand key, he was dependent upon the eye and ear method of determining transit times, and hence of maintaining correct time. This he made available to local jewellers and to the Caretaker of the City Clock, and to all who desired correct time. When the city clock was inoperative due to a fire in the city building in 1865, the Observer, Dupuis, made a second face for the mean time clock which he mounted on the back of the case, then backed the clock against the window of the observatory for all to see.

In his report to the Deputy Minister of Marine and Fisheries dated Dec. 31, 1875, Williamson states, "The observatory building, being in the public park and unenclosed, it has been found difficult for the observer to protect it from damage by the mischievously disposed, especially the young. Repairs to the windows and shutters have in consequence been rendered necessary to the amount of $11.79 for carpenter work, and $15 for repainting. The correct time, so important for this, the principal lake port, has been regularly given to the city. Arrangements have been made for the delivery of two annual free lectures on subjects of general interest in astronomical research [in terms of the deed by the Corporation in favor of the Observatory], and other efforts will be made to render the institution as useful as possible. It will, I may mention, be always accessible to the Professors and Cadets of the Military College, who will thus have the advantage of the use of the various instruments, and a building adapted for the purpose of observation, so necessary in several departments of their course, and which could not otherwise be obtained except at very considerable expense to the government." (Sessional Papers, Dept. of Marine & Fisheries, 1876.)

Meteorological records were also kept at Queen's. In 1870 Williamson received a note from G.T. Kingston of Toronto acknowledging receipt of the annual summaries for Kingston for the years 1859-60-61. In 1871 there was a communication from Charles Smallwood of Montreal suggesting that Williamson assist in observations of weather readings at 8 a.m. and 5 p.m. and midnight daily and report them immediately to the Montreal Telegraph office, and they would be forwarded to Smallwood and he in turn would report them to the War Department, U.S. This would assist in the determination of storm signals connected with the War Department of the U.S.

In 1881 the instruments, including the Beaufoy and the small Simms transits, the Alvin Clark equatorial, and the mean time and sidereal clocks were all moved to a small but neat observatory on higher ground in the rear of the college. Observing conditions were improved, and the problems of interference from encroaching trees and young boys were eliminated. An azimuth mark was established to the north, and a more distant one to the south on Wolfe Island.

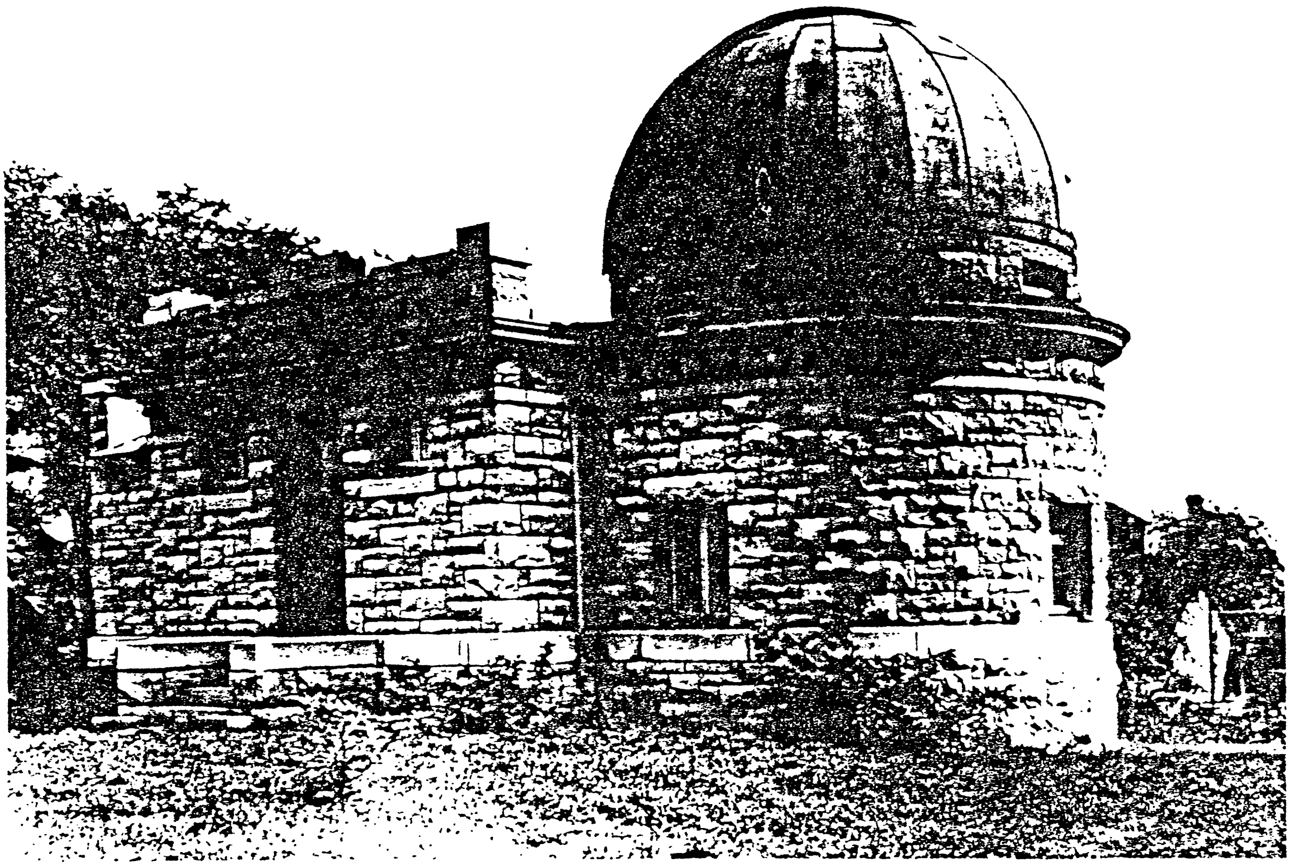


Fig. 26 Queens University Observatory 1909-1946. Courtesy Queen's
Pg. 144 University Archives.

The following year Williamson collaborated, under the leadership of Carpmael of Toronto, in the world wide program to observe the transit of Venus. He had very favourable circumstances and the times of ingress and egress were carefully determined. His observations were duly reported to Carpmael and to the Royal Astronomical Society, London.

Finally, in 1887 Williamson is able to report that the sidereal clock was replaced by a new and modern one made by Fauth and Company of Washington, D.C., with gravity escapement and mercurial compensation pendulum. It was a great satisfaction to have a clock which compared favourably with the best clocks in other observatories. Professor Dupuis made a mean time clock with similar escapement and compensation and presented it to the observatory. Daily observations were maintained, weather permitting.

Another relocation, under the direction of Dean Dupuis in 1909, Fig. 26
resulted in the construction of a "small but impressive limestone observatory built on a site purchased by the Chairman of the Board of Trustees, Mr. Justice Maclennan, and presented by him to Queen's University in 1906 for this purpose" (A. Vibert Douglas J. RASC, 52, 80, 1958.). This was demolished in 1946 to make way for McLaughlin Hall, the new Mechanical Engineering building.

The present observatory, on the roof of Ellis Hall, the Civil Engineering building, was officially inaugurated in 1960. Its principal instrument is a 15-inch Cassegrain reflector, with a 6-inch Catadioptric guide telescope, and a 3-inch astrograph from J.W. Fecker Inc., Pittsburg. It was Dr. A. Vibert Douglas who proposed the roof top observatory when Ellis Hall was in the planning stage in 1955.

Williamson's last annual report to the Deputy Minister of Marine and Fisheries was made in January, 1895. In it he stated that during the past year, time was regularly given to the city and shipping. In September of that year he passed away, one month short of his 89th birthday. By now the McGill time signal which was distributed daily over the telegraph system was becoming recognized, and the observatory, which had been the centre for correct time at Kingston, gradually yielded this authority and became more closely identified as an instrument of instruction within the Mathematics Department of the University.

Victoria and Grey Trust Company added a unique chapter to the story of timekeeping in Kingston in the form of a vertical sundial. As befits the "Limestone City", a pillar, designed by Jennifer McKendry, was built of limestone blocks which had been a part of older buildings, Fi[illegible]7
since demolished. Erected in Churchill Park at Brock and Napier, the pillar measures about 22 feet high, and is 4 feet to a side . It is oriented with one diagonal due north-south, and on the two southerly faces are the two sundials designed for the purpose by M.M. Thomson of Ottawa. The wording on the plaque, which was unveiled at the ceremony on June 20, 1973, reads, "Presented to the City of Kingston to mark its tercentennial year and the 500th anniversary of the birth of Copernicus by Victoria and Grey Trust Company June 1973." Walter E. Harris, President of the Company, made the formal presentation.

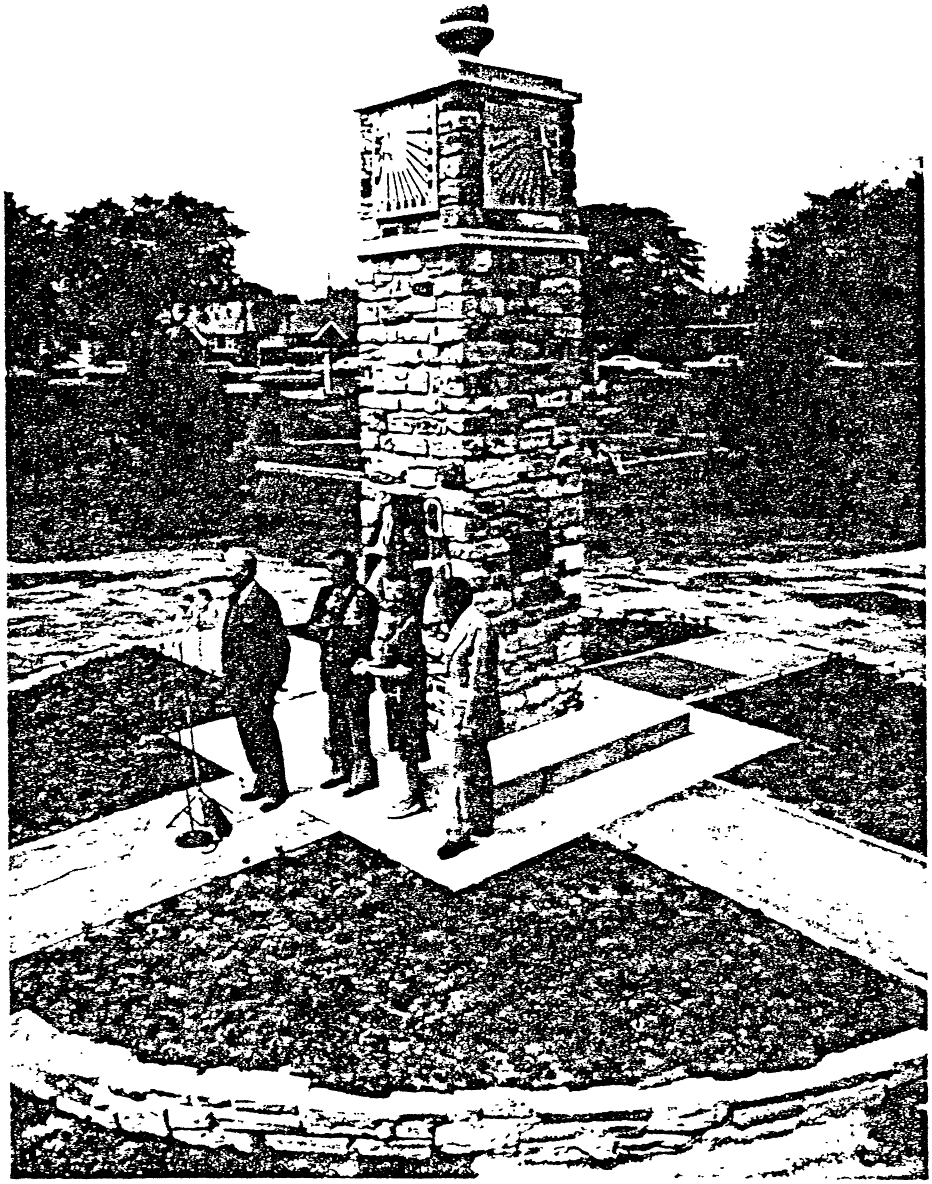


Fig. 27 Pg. 145 Presentation of the sundial to the City of Kingston, June 20, 1973. The four people in the picture from left to right are: The Honourable Walter E. Harris, President, Victoria and Grey Trust Company, His Worship Mayor George Sneal, Mayor of Kingston, Dr. A. Vibert Douglas, Emeritus Professor of Astronomy, Queen's University, and Mr. J.G. Donovan, Manager, Kingston Branch, Victoria Grey Trust Company. Photo by Wallace R. Berry Kingston, Ontario.

Victoria and Vancouver

VICTORIA AND VANCOUVER

Fort Victoria was constructed by Chief Factor James Douglas of the Hudson's Bay Company in 1843. The Oregon Boundary division in 1846 fixed the international boundary along the 49th parallel and the Straits of Juan de Fuca, following which Fort Victoria became the administrative center of the Company west of the Rockies. Upon the establishment in 1849 of the Colony of Vancouver, the Fort became the headquarters for both the Company and the Colony. Immigration, for which the Company was responsible as a result of the Royal Grant in 1849, received a sudden impetus with the discovery of gold in the interior of B.C. in 1858. Victoria, the natural supply centre, prospered. In 1860 it became a free port, and in 1862 the Fort and surrounding community was incorporated as a city.

The gold rush had an even greater impact on the mainland colony of New Caledonia, later known as British Columbia. The colony was inaugurated at Fort Langley on November 19, 1858, and if Douglas, who was now Governor as well as Chief Factor, had prevailed, Fort Langley would have been the capital. Instead Col. Moody favoured a site on the north bank of the Fraser River where New Westminister was established in May 1859, and named by Queen Victoria as the Capital. On July 17, 1860, it became the first community west of the Great Lakes to become incorporated. By 1864 the gold boom had subsided. Declining revenues in the two colonies caused Vancouver Island to seek legislative union with British Columbia. Union was effected on November 19, 1866, the seat of government was established at New Westminster, and at the same time Victoria lost its free port status, which further aggravated the depression. The capital was transferred to Victoria effective May 15, 1868.

The economy of Victoria and the lower mainland was dependent upon coal mining (Nanaimo), lumbering, agriculture, and shipping. Victoria also benefited by the development of the naval base Esquimalt, in the natural harbour right next to the bay on which Victoria was located. The first naval huts at Esquimalt were built in 1855 to house the sick and wounded from the Pacific theatre of the war with Russia.

By 1865 Esquimalt had increased in importance to the extent that it was made the Pacific Station of the Royal Navy. During the 19th century, when the Latin American countries were throwing off the yoke of Spain, and there was much unrest, a fleet of British ships patrolled the ports of the Pacific to protect British trade. Initially the Pacific Station was Valparaiso, Chile. Ships of Her Britannic Majesty paid regular visits to Victoria. For the service men these visits provided a pleasant interlude in which to socialize in a predominantly English community after life in the dried-up and brown communities of the south.

The rapid growth of the young community was accompanied by the usual awareness of time. Dr. J.S. Helmcken, writing of his early experiences at Fort Victoria in his Reminiscences, mentions the use of a bell in 1850, but in such a way that it seemed to indicate meal times rather than correct time of day.

The earliest mention of a time signal, according to W.E. Ireland of the Provincial Archives in Victoria, B.C., appears in the Victoria Gazette of February 5, 1859: "The true time - We understand that Capt. Trevett of the H.B.C.'s (Hudson's Bay Company) steamer Labouchere, now lying in this harbour, has kindly consented to fire a gun every Thursday at 12 o'clock M, in order that our citizens may have an opportunity to regulate their time pieces and obtain the true time." By now there must have been a number of watches and clocks in the town. The Victoria Directory of 1860 claims that there were three watchmakers, and advertisements for two of them were included.

A notice in the Victoria Colonist, April 29, 1876, read, "Change - The time gun of the Rocket will be fired at 9 p.m. instead of 8 p.m. on Mondays, commencing on Monday next, May 1st." And the issue of September 27, 1879 contained the following, "Eight o'clock gun - The time of firing the evening gun has changed from 9 o'clock to 8 o'clock p.m."

The time gun became a regular institution of the community, though just how is uncertain. It was initially for the benefit of the military, and from its location at Work Point Barracks it was fired at noon and 9 p.m. Mrs. F.V. Cornwall, in a story to the Victoria Colonist of September 29, 1961, recalled that her father, the late R.G. Tatlow, came to Victoria as a Captain in "B" Battery of the Royal Canadian Artillery. One of Capt. Tatlow's jobs during the year 1879 was to row out to Brother's Island, near the entrance to Esquimalt Harbour, to load a gun each day, which was fired from the shore at 9 p.m. The same man later became provincial Minister of Finance and Agriculture. Work Point was selected as a site for a permanent barracks December 1, 1887.

The use of a time ball to indicate time of day was also familiar to Victorians a century ago. The following explanation appeared in the Colonist May 16, 1877:

"Editor, Colonist: - It may be of interest to the Captains of ships and others who may wish to rate their chronometers, or to correct their watches, to know that when one of H.B.M. ships is present in any port in the Pacific, such ship (or the senior, if more than one) marks the time daily by a time ball at noon.

"The ball is hoisted 'at the dip' at about 11:55, is hoisted right up at about 11:58, and is dropped at the instant of noon mean time.

"When the British Flag Ship is present, some persons are in the habit of correcting their watches by the evening gun, but it should be understood that the gun only marks the time approximately, whilst in the case of the time ball, the limit of error should not exceed half a second.

"I am, Sir, your obedient servant A.F.R. de Horsey, Rear Admiral and Commander-in-Chief of H.B.M. Ships in the Pacific."
This was dated March 10, 1877, at Valparaiso, Chile.

Confederation in 1867, which brought the eastern provinces of Ontario, Quebec, New Brunswick and Nova Scotia into union, provided for the admission of the remainder of the country when and if conditions were right. The people of British Columbia were divided by three factions, those who advocated the status quo (i.e., a separate British Colony), those who urged joining the U.S.A., and those who urged joining confederation. It is sufficient to state here that once the terms were met, there were no obstacles in the way of the third alternative, and on July 20, 1871, British Columbia joined Confederation. One of the terms was a railway link with the east. The last spike of this Canadian Pacific Railway was driven home at Craigellachie, B.C., on November 7, 1885, thus completing the communication link from ocean to ocean.

Charles Carpmael followed with interest the westward extension of the railway, because accompanying it was the other communication link, the telegraph. In his annual report dated 1886 he stated, "Now that the Canadian Pacific Railway is completed it is desirable that additional [weather observing] stations be established in British Columbia, so that we might have still earlier knowledge of weather changes approaching from the west." That same year a CPR ticket office was opened in Victoria, B.C.

On April 6, 1886, the Township of Granville was incorporated as the City of Vancouver. The first through train from Montreal arrived at Port Moody, a few miles to the east, on July 4. The following year, amid cheers from an enthusiastic crowd, the first train arrived on schedule at the newly completed Vancouver terminal.

The McGill time signal was relayed from the Montreal telegraph office to the western network. It served to coordinate railway schedules, and also provided communities along the way with a source of correct time.

Again in his report of January 1888, Charles Carpmael urged the need for telegraph reporting stations in B.C. There was no doubt about the benefit to the whole community that would result from some indication of the weather patterns that moved in from the west across the country. Public funds were therefore made available, and on July 1, 1890, the Dominion Meteorological Service was established at Esquimalt. E. Baynes Reed, who had joined the Service seven years previously in London, Ontario, was placed in charge. He was 52.

Although he was equipped with a chronometer (John Bruce and Son, London and Liverpool No. 2129) which he checked daily against the McGill time signal, there is no indication that Reed made any contribution to timekeeping in Victoria, or to the firing of the gun at noon and 9 p.m.

It is known that some watchmakers of the city used the telegraph signal from McGill. Reed's job was to take the several readings per day and report daily by telegraph to Toronto. His was the chief station for the province, and to him were sent the readings taken by all the observers throughout British Columbia, from which he made weekly and monthly climatological reports. These were then forwarded to Toronto.

In Vancouver the story was slightly different. As the terminus of the trans-Canada railway line, and hence as the Pacific port, its growth after 1886 was rapid. In 1894 the "nine o'clock gun" was started. Its story as recorded in the Vancouver Sun, July 7, 1951, is as follows: "It was removed from a defence position in Esquimalt to its present Stanley Park site at Hallelujah Point, early Salvation Army meeting place, in 1894. On arrival on the mainland the gun immediately became the pioneer's time signal, taking over from the bell atop the old Water Street fire hall." From this it would appear that the new city had originally adopted the practice of its eastern counterparts and had given the time of day by sounding the fire alarm bell.

A report in the Victoria Colonist, September 25, 1898, tells the following story: "On Friday of next week, and every day thereafter, an explosion of gun cotton on Deadman's Island will announce to the citizens of Vancouver that the noon hour has arrived. A perfect chronometer has been placed in the CPR office in connection with the Toronto Observatory."

R.F. Stupart adds to the story in his annual report of June 30, 1899. "In accordance with instructions from the Department, arrangements were made early in 1898 for the installation of a time signal at Deadman's

Island, Vancouver. It was decided to fire a dynamite cartridge hoisted at the end of a jib and connected by wire with the CPR telegraph office in Vancouver each day at noon, but it was subsequently found that the noise of the city drowned the sound and therefore it has since been fired at 9 p.m. The cartridge is prepared and placed in position for firing by Wm. D. Jones, keeper of the bell tower [also listed as keeper of the lighthouse] at Brocton Point, and at the proper instant an electric contact is made at the telegraph office by the chief operator who rates a chronometer, provided by this service, by the time signal given each morning over direct wire from McGill University, Montreal, by Professor C.H. McLeod. The accuracy of the signal is therefore dependent on three things: firstly the accuracy of the time as given from Montreal; secondly the uniform rate of a chronometer during twelve hours from 9 a.m. to 9 p.m.; and thirdly, the trustworthiness of the operator at Vancouver. It is proposed very shortly to install a gun in place of the dynamite cartridge, as the fire of the gun will probably be heard more generally." The following year the gun was restored.

In 1897 a Milne seismograph was installed in Victoria, one of several which were placed in key positions around the world through the efforts of the seismological committee of the British Association. The following year 32 year old F. Napier Denison was posted to Victoria from Fig. 28
Toronto, arriving in August 1898. In November a forecast service was begun for parts of southern British Columbia. The office was moved from Esquimalt to the Customs House in Victoria, and the following year to the Post Office Building. In his annual report dated 1905, Stupart stated "Mr. E. Baynes Reed, assisted by Mr. F.N. Denison, continues in charge

Fig. 28 F. Napier Denison, (1866-1945). Courtesy Victoria Press Ltd.,
Pg. 152 Victoria, B. C.

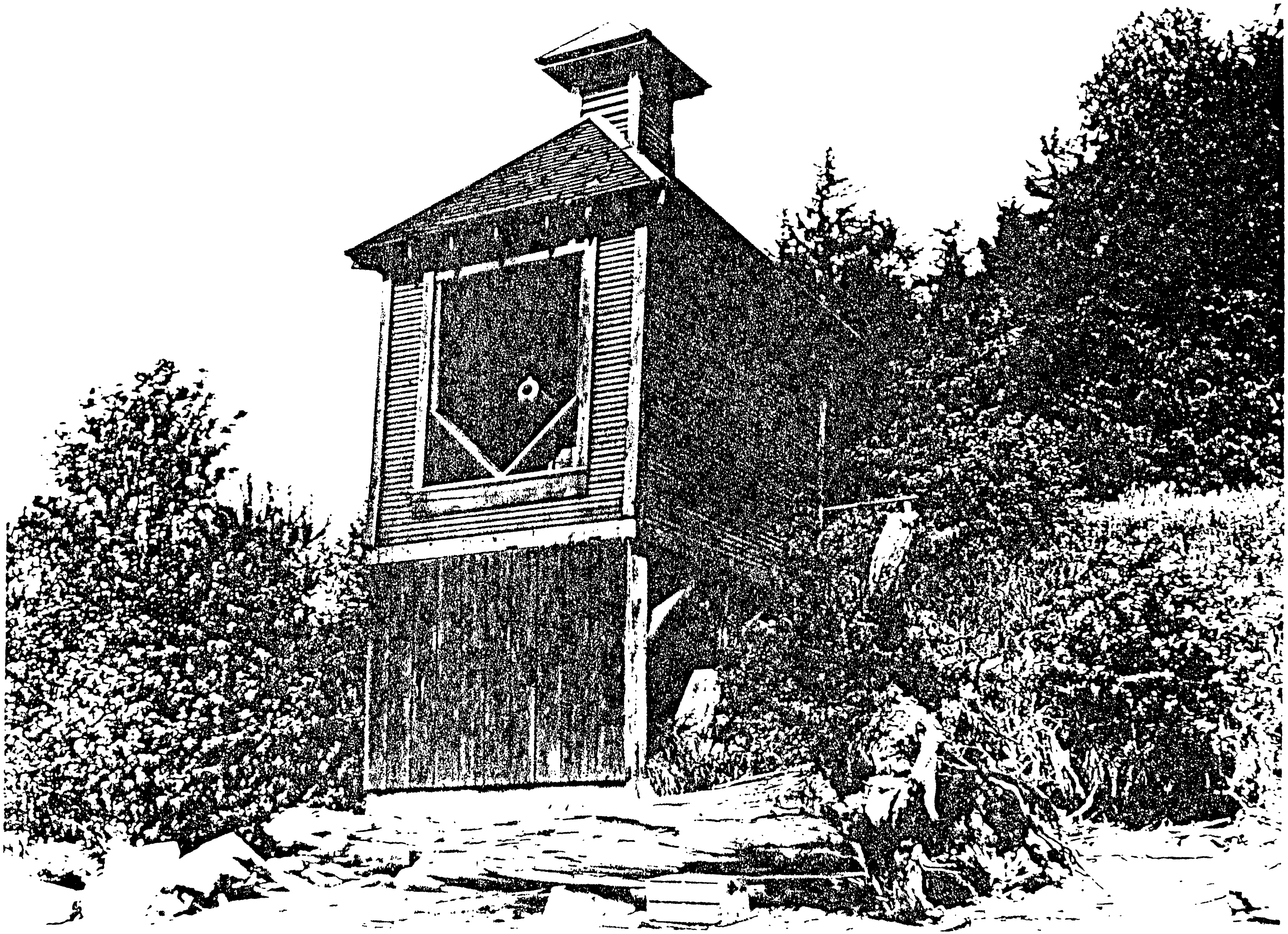


Fig. 29 Pg. 153 9 o'clock gun, Stanley Park, Vancouver, B.C. The housing was demolished April 6, 1936 and subsequently rebuilt. Courtesy Vancouver Public Library.

Fig. 30 T. S. H. Shearman (1862-1944). Courtesy Mrs. Winnifred Dickinson,
Pg. 153 Vancouver, B.C.

of the Provincial Chief Station in British Columbia, and regular daily forecasts have been issued from Victoria with a gratifying degree of success, notwithstanding the difficulties to be met with on the eastern shores of an ocean, all storms and weather changes coming from a blank." Years later this blank would be filled in by having weather reports radioed in from ships.

Other problems of a more immediate nature required attention. Fig. 29
The time gun in Vancouver was not performing properly. Reed went over in 1902 and found another source of error, namely, the wire from the telegraph office to the gun. Also the gun itself was in danger of tumbling down the embankment into the water because the shelter was falling apart and the foundations of its mount had crumbled. Mr. Brown, the local observer in Vancouver whose services were carried out with great care, was not involved with the gun but rather it was the combined responsibility of the gun keeper and the telegraph operator. It is possible that this separation of duties may have been at the root of future difficulties.

In June 1906 T.S.H. Shearman was appointed to replace Brown Fig. 30
who had retired. Reed was delighted with the choice because Shearman was an amateur astronomer with his own telescope. He understood the work involved and he appeared to be the one to lend stature to the office. Two years later Reed recommended that Vancouver replace New Westminster as the telegraph reporting station now that there was a man like Shearman. Then in 1911 Shearman wrote to Stupart to announce that "plans have been discussed here to establish an astronomical observatory in this vicinity for the purpose of distributing time by the wireless method to the rapidly

increasing shipping of this coast and for the rating of chronometers, the study of solar physics, terrestrial magnetism, and in an auxiliary observatory, to use the clean air of the mountains to the north of the city, and in that way to do our share in the establishment of the chain of international observatories strung like pearls along the summits of the Rockies and the Andes Mountains." It was also pointed out that it would be of great advantage to have the proposed observatory connected with the British Columbia University soon to be erected at Point Grey. A resolution to this effect was sent by the Board of Trade to the Hon. Dr. H.E. Young, Provincial Secretary in Victoria.

Shearman continued his letter by referring to a remark in the Victoria paper to the effect that the proposed observatory for Vancouver was merely an attempt to take something from the city. Not so. Shearman had for the past 20 years advocated an observatory for B.C., and now his plans call for a 10-ft. reflector for Grouse Mountain. People like F.N. Denison are simply repeating Shearman's work and claiming it as their own. "Denison is welcome to any improvements to his new seismological observatory, but he is not, as the Victoria papers state, the only man in Canada capable of conducting a B.C. seismological observatory."

Denison, for his part, was inclined to act first and ask later. In 1909 he purchased with his own money a small transit telescope. Five years later the department agreed to reimburse him the $200. In 1912 he also acquired a telescope that had been made by a local amateur astronomer, O.C. Hastings.

VICTORIA, B.C.

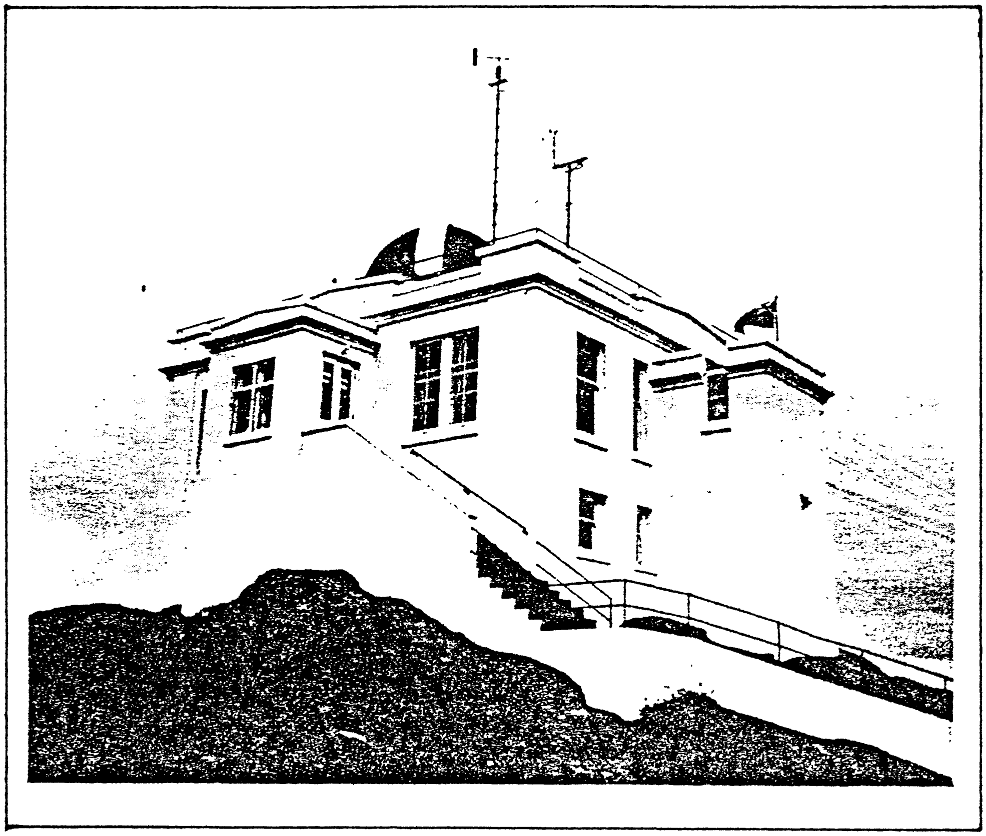


Fig. 31 Gonzales Heights Observatory, Victoria, B.C. Courtesy Regional
Pg. 155 Climate Data Centre, Gonzales Observatory.

The space provided in the Victoria Post Office for the Meteorological Service was becoming inadequate, and it was necessary to plan for new quarters. The views of the two men, Reed and Denison were sufficiently divergent that Denison found it necessary to submit his plan directly to Toronto. It was a well devised plan that would provide facilities for his astronomical work as well as an excellent site for a seismograph. It would be an observatory on Gonzales Heights adjacent to the government radio station. Reed saw only difficulty and expense, one great difficulty being the climb which he, now in his mid seventies and in failing health, found insurmountable.

Nonetheless Gonzales Observatory was built, and visitors to it were impressed by the commanding view of both the city and the Strait of Juan de Fuca. Fig. 31

On April 24, 1914, Denison wrote to Stupart, "I have much pleasure in informing you that on Monday and Tuesday of this week I completed the moving of everything from our old quarters in the Post Office Building to this building, and on Wednesday April 22nd the 5 a.m. observation was taken here."

The previous December he had outlined the requirements for his time service, which included a good sidereal pendulum, a good mean time pendulum, a chronometer, and an electric contact either hand operated or attached by micrometer drive to the telescope. He also submitted plans with estimates of cost for a time ball similar to the one at Halifax.

Stupart had some misgivings about Denison operating a time service, because in March 1915 he wrote, "Before proceeding further with this matter I want your definite assurance that you are sufficiently conversant with the adjustments and use of a transit instrument to carry on the time work in a way that will be a credit to the [Meteorological] Service. I ask this because I have no knowledge of your ever having done such work, and it is altogether important that when once begun, the service shall be continued in a creditable manner."

In his reply, Denison said in part, "I beg definitely to assure you that I am now quite conversant with the adjustment and use of the transit instrument, and to insure most accurate results, Mr. W.S. Drewry, a prominent Provincial and Dominion Surveyor ..... is kindly assisting .... in those parts of the observational and reduction work I had not perfected when learning under Mr. F.L. Blake at Toronto some years ago."

Because of his failing health, E. Baynes Reed was obliged to be absent from the office, and Denison shouldered the responsibility for all the work. It made quite a demand on his time, so as a measure of economy, he and his wife took up residence in the observatory in September 1914. For the next twenty years this modest one room apartment served as their home. G.H. Barnard, M.P., wrote to Stupart on behalf of Reed, but there was no provision in the Civil Service regulations for superannuation benefits to those on the outside service. However his sick leave was extended so that he had leave of absence at full pay. Reed died November 18, 1916, at the age of 78.

Shearman had pointed out the need for an adequate time service for the busy and expanding port of Vancouver. Ships spent more time there than in Victoria, so that ships' captains had a better opportunity to check their chronometers. Stupart supported him, and in 1913 wrote the following letter to the Deputy Minister of Marine and Fisheries:

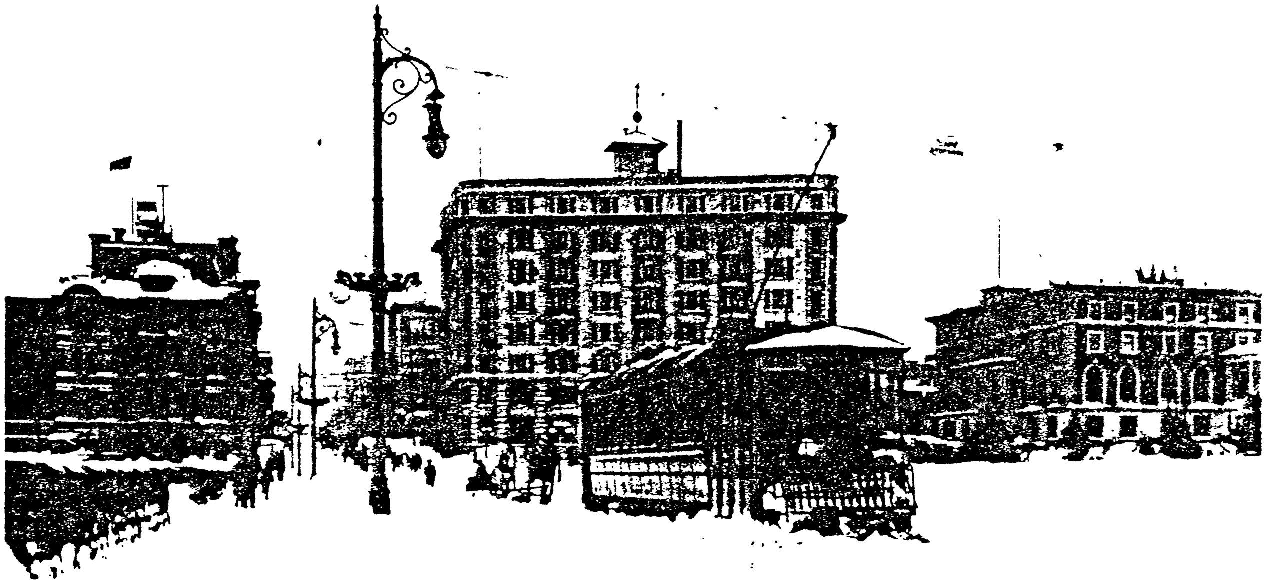


Fig. 32 Pg. 157 Belmont Building, Victoria, B.C., with the time ball mounted above the elevator roof. The picture was taken to show an unusual snow fall, probable date 1916. The street car at that time travelled on the left side of the road. Courtesy Provincial Archives, Victoria, B.C.

"At Vancouver I arranged for a "Time Service" under the supervision of Mr. T.S.H. Shearman, exactly in accord with the recommendation made with my estimates furnished the Department under date of May 29, 1912. Mr. Shearman will have a transit, and his observing station will be connected by wire with a room in the New Public Building to which the Masters of ships may bring their chronometers for comparison and rating and where the public may apply for information regarding climatic conditions of the Province. The room allotted by Mr. Henderson, the Chief Provincial Agent of the Public Works Department, is large and thoroughly suitable for the requirements of the service. It was accepted by me, subject to the approval of the Department. I called on Mr. H.H. Stevens, M.P., and he is quite satisfied with the arrangements I have made, and personally inspected the new Meteorological room." There is no evidence that a transit instrument was ever put into service by Shearman.

Meanwhile in Victoria Denison was pushing forward his own plans. The time ball was successfully mounted on the Belmont Building with the assistance of Hurrell as contractor. On May 24, 1915, it was dropped for the first time. In his report dated May 25, 1916, Denison stated: "The time for this service is obtained from star observations taken nearly every clear evening by means of the transit telescope, which is well mounted in a special room upon a massive concrete pier which rises from the solid rock. The adjustments for collimation and azimuth have been carefully made, and a fine fixed mark for checking these has been established on a government building at a distance of two miles. ..... It is possible to keep the time accurate to within one or two tenths of a second. Fig. 32

"The time ball which is a distance from the observatory, about two miles, is controlled by a telegraph key here in the following manner: At 12:30 p.m. each day (Sunday included) the C.P.R. Telegraph Co. connects our line with the time ball circuit; at 12:45 p.m. a signal of two taps given from here notifies the man in charge of the time ball to hoist it to half mast; at 12:55 p.m., three taps notifies the man to hoist the ball to the top and to set the electric trigger. At one half second to the exact 1 p.m., I press the key here and the ball drops on true time. The operation is checked daily by watching the ball through a telescope here." The cost of installing the time ball was $423, while the daily operation, which involved rental of the line and the services of H. Geake to hoist the ball, cost $5 and $10 respectively per month. Fig

Shearman attempted to secure a similar time ball and storm signal mast for Vancouver, with full support from Stupart. The plan failed when, in February 1917, Henderson of the Public Works Department was obliged to refuse him the use of the Post Office roof. Shearman's office became recognized as the source of correct time where ships chronometers could be brought for rating, and from which the signal was given for the firing of the 9 p.m. gun. It was a telegraph operator, though, and not Shearman who came in to operate the key which fired the gun.

Denison, on the contrary, had everything under his own control. Also he was careful to maintain good public relations. In 1917 in cooperation with E.J. Haughton, Superintendent of Radio for the west coast, he commenced a daily 10 a.m. wireless time signal by hand key from the Observatory through the Gonzales Heights wireless station. The

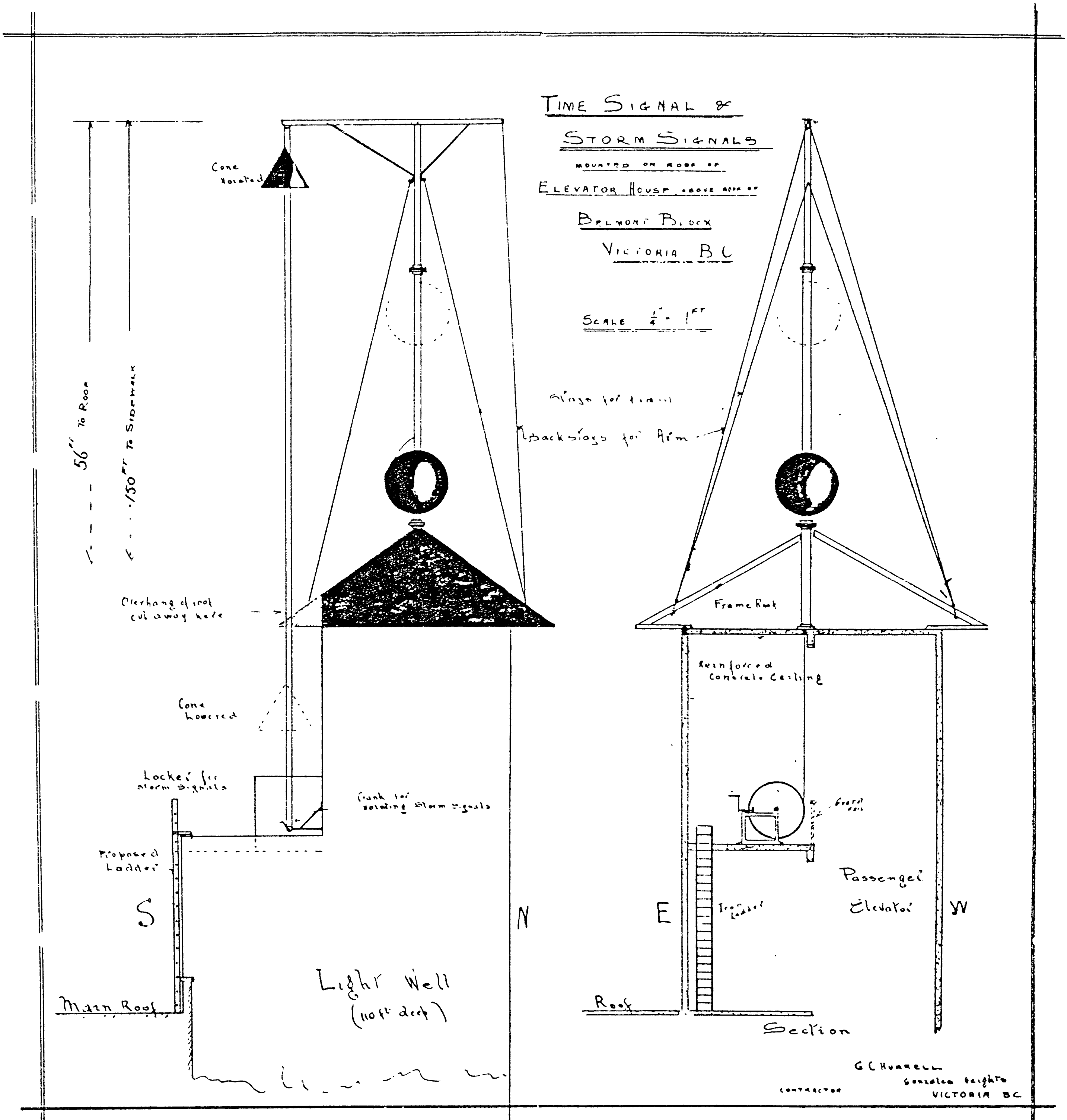


Fig. 33 Pg. 158 Schematic of the time ball at Victoria, B.C. Courtesy Provincial Archives, Victoria, B.C.

signal was reported to have a coverage of two to three hundred miles and to be of benefit to shipping and to other radio stations.

It was a continual uphill struggle to get new equipment. Back in 1913 Denison had requested a good sidereal as well as a mean time pendulum, both of which were overshadowed by subsequent war priorities. So when the opportunity presented itself he purchased two pendulum clocks locally and placed one in service to supply seconds pulses on the seismic recorder. He then asked permission to submit bills for $45 and $100 for the two. An automatic sender was designed to operate from one of the pendulum clocks, which provided uniformity within a few hundredths of a second for the two minutes of radio transmission. Commencing in 1923 the wireless time signal from Gonzales Heights was relayed by hand from the powerful station at Estevan Point, thereby increasing the radius of coverage to some 3000 miles. Also a 10 p.m. radio time signal was started.

In 1921 Denison extended his influence to the time gun. He reports: "As the city of Victoria has for some time been desirous of obtaining a reliable gun-fire time signal at 9 p.m., I am pleased to state that General Ross, Commanding Officer here, has installed a regular gun for this purpose at the barracks, and to ensure accurate time for firing this, I have arranged .... that the officer on duty call this office at two minutes to firing time. ... We also fire the noon gun in the same manner, but this is not heard so generally as the night one."

Both Shearman and Denison recognized the shortcomings of the telegraph time signal from Montreal. Shearman requested that he be supplied with a radio capable of picking up the USA time signal daily from Mare Island, California. In support of this request, Stupart wrote to the Deputy Minister, E. Hawken, in 1921 as follows: "I acknowledge your letter of the 23 [November] instant, 33 008, with communications from C.P. Edwards, Director of Radio Service, and from E.J. Haughton, Superintendent of the British Columbia Branch. I place no credence in Mr. T.S.H. Shearman's statement that the Gonzales Time signal is unreliable, except to the extent that as Mr. Denison's equipment is inferior to that at Mare Island, California, his observations are not capable of the same degree of refinement. I am sure however, that the observations are so carefully taken that an error of a second would be rare. I think, however, on the whole it would be well to install a valve receiving equipment which will enable the Vancouver observer to pick up the San Francisco signal. I note by Mr. Edward's letter of September 21st that this equipment will cost $600, and that equipment for battery recharging will be unnecessary."

Stupart also reveals that "the time received by wire in Vancouver is from Montreal, not Victoria, and is not received automatically from the McGill Observatory clock. The Observatory clock records in the main Montreal Telegraph Office, but the signals are transmitted over the Western Telegraph wires by hand, and are found to be not sufficiently accurate for purposes of rating ship chronometers."

Denison proposed that in place of a $600 radio for Vancouver, a $200 crystal set be purchased, and the remaining $400 be used to acquire for Victoria a modern observatory sidereal clock with electric attachment and a good chronograph. He would then be able to guarantee daily wireless signals from Victoria with one tenth of a second in accuracy.

Within two years, Denison, who found the transit work difficult with his equipment, was listening to the Mare Island time signals as relayed over the telephone from E.J. Haughton's receiver. It was an awkward and at times inconvenient arrangement, so Haughton erected an antenna and assembled a valve receiver for Denison at a total cost of $90. With this receiver, both Washington and Mare Island signals were monitored, and Gonzales ceased to be an independent source of time. Haughton then wrote to his superior, C.P. Edwards, and Denison reported the expenditure to Stupart. It was all within the same Department of Marine and Fisheries, and the Deputy Minister Hawken simply made a book entry against Stupart's account.

Shearman was still having his problems with the Vancouver time gun, problems that might never have occurred had he been the one to press the key each evening. But a telegraph operator was paid to do so. A combination of an increasingly faulty wire and an unreliable telegrapher caused Denison to dispense with both. During 1926 J.H. Walsh, the gun operator, was provided with a chronometer which he checked daily by phoning to Shearman's office. He then fired the gun. Because the result was satisfactory, Walsh requested that his salary be increased by the $100 that had been the annual payment to the telegraph operator. Stupart did his best by way of recommendation to the Department, and succeeded in securing an increase of only $25.

In October and November of 1926, C.C. Smith, A.H. Swinburn and J.P. Henderson, of the Dominion Observatory, Ottawa, occupied an observing site at Brocton Point used formerly in connection with the World Longitude Campaign. A permanent observatory had been built close to and southeast of the lighthouse under the direction of O.J. Klotz in 1900. Their equipment included a modern receiver with which they secured time signals from Washington, D.C., England and Paris. Not only did they provide Walsh with correct time, but on their departure they gave him a receiver and the antenna. He was thus independent of Shearman, with whom personal relations had become less than cordial. They were, nevertheless, two highly respected citizens. Shearman's office was recognized as the centre for correct time where ship chronometers could be rated, and also as the centre for weather information within the Vancouver area.

Today the Vancouver 9 p.m. gun is fired daily by the Vancouver Board of Parks and Public Recreation having been reinstituted, after a period of silence during World War II.

Shearman had always dreamed of building a 10-foot reflecting telescope. He mentioned it to some of his associates in Vancouver and commented on the discussions in a letter to Stupart in 1911. In 1920 it came to the fore again in connection with the Vancouver exhibition. But instead of the hugh instrument, only a model was on display. In 1922 he invited Stupart to be Honorary Visitor to the Frye Observatory, to which Stupart replied, "I fear that it would be quite unwise for me as Government Meteorologist to become connected in such a way with an Astronomical Observatory; it appears to me that Dr. Plaskett [of the Dominion Astrophysical Observatory in Victoria] is the man who should be offered the position." Shearman had fondly hoped to emulate the work of another eminent amateur astronomer, Dr. Lewis Swift, who became director of an observatory on Echo Mountain near Los Angeles.

Denison expressed his doubts about Shearman's ability to complete such a project, and the discredit that might devolve upon the Meteorological Service as a result of a failure. Stupart, however, was not one to offend. And until Shearman might become involved to the extent of neglecting his current duties, there was no harm in his talk. Fifty years later the Hon. H.H. Stevens, now in his nineties, was asked if he recalled Shearman and his telescope plans. His reply in part reads, "I clearly recall Mr. Shearman and his contribution to Vancouver. Mr. Shearman maintained over a great many years the famous "9 o'clock gun". It was in fact the chief authority to all Vancouver people re the correct time and we all appreciated it. I know nothing about the "10-foot reflector". If he wanted it, then in my opinion it was O.K. He was a fine man and a great technician." (July 12, 1972.)

There were in fact two Shearman brothers. In a historical note concerning the Port Meteorological Office, one reads that T.S.H. Shearman "continued to manage the affairs of the Weather Office until 1915 when his brother E.B. Shearman took over his duties. The latter continued as official Weather Observer until his retirement in 1948, and was awarded the British Empire Medal in October 1947 in recognition of his long and faithful service. T.S.H. Shearman, an astronomer by profession, continued to act in an advisory capacity for a number of years after 1915. Then, due to poor health he passed away on December 21, 1944. E.B. Shearman died in Vancouver on November 15, 1955, at the age of 82."

Denison, though not academically trained, worked hard at his job and won recognition in the city of Victoria and throughout the whole province of B.C. and the adjoining States for his contribution to weather forecasting. His contribution to timekeeping became less important with the passing years. In 1930 the time ball service was discontinued because, as he reported, "radio time signals are now in almost general use".

Mr. Sydney Wood a wireless operator who knew the Gonzales Heights radio station and the adjacent Observatory, enquired from his former supervisor, Mr. George Gilbert, now 86, (1972) about his early days. Mr. Gilbert clearly recalled the time signal that was tapped by hand through the C.P.R. telegraph loop from the Observatory to the adjacent transmitter building, then retransmitted by hand over the air, the hour being identified by a long dash. The automatic sender, which was later attached to the pendulum, still required manual operation of the hour dash. At the powerful transmitter at Estevan Point, the signals were relayed by hand "so I suppose there was some inaccuracy along the way", said Mr. Wood.

Denison retired on December 31, 1935, in his seventieth year. He was succeeded by W.A. Thorn. An efficient time service was maintained within the Observatory by the wireless reception of time. Transmission of time from the Observatory had ceased to be useful, and in fact complaints had been registered concerning lack of accuracy. They were discontinued on August 13, 1940, when the Gonzales transmitter was moved to Gordon Head.

Ten years after his retirement, Denison died at the age of 79. His passing was the occasion of a very fine eulogy in the Victoria newspapers. "Mr. Denison was one of the best known meteorological scientists on the continent, and also was well known in England due to his research in the matter of weather cycles and his study of seismic disturbances. .... By his daily weather forecasts he became especially well known to Victorians."

Sir Sandford Fleming

SIR SANDFORD FLEMING (1827-1915)

When Sandford Fleming arrived in Canada from Scotland as a young man of 18 he had already acquired considerable training in mathematics and engineering, together with a capacity for hard work. After various jobs, he articled himself to a land-surveyor, S. Dennis, and at the age of 22 passed the qualifying exams and received, from the hand of Lord Elgin, his certificate as a provincial land surveyor.

The following year, 1850, he, with F.F. Passmore, laid the foundations for the Canadian Institute (later Royal Canadian Institute) in Toronto, a cultural society that has enjoyed great prestige through the years. From the very beginning, Fleming had the ability to draw together kindred spirits who served as a forum for the presentation and discussion of progressive ideas.

At the age of 26 he commenced a ten year association with the Northern Railway, first as assistant engineer, then as chief engineer. During this time he published his thoughts on a trans-Canada railway project. By reason of this he was selected by the Red River Community to present a memorial to the Colonial Secretary, the Duke of Newcastle. The trip to London, and the request for lines of communication to eastern Canada from the isolated Red River settlement, bore no immediate result.

On his return to Toronto in 1863 he found himself nominated by the united provinces of Upper Canada and Quebec, by the maritime provinces of Nova Scotia and New Brunswick, and by the Imperial Government, as the commissioner to oversee the survey of a route for the Intercolonial Railway, which would link Halifax and Quebec City. A three-man commission was thus entrusted to one individual. Following the survey he continued on with the Intercolonial as the chief engineer supervising its construction. His connection with this project spanned the years 1863-76, during which Confederation (1867) was accomplished. Because of his demonstrated ability he was invited, in fact prevailed upon, in 1871, to supervise the survey for the Canadian Pacific Railway. Five years of dual responsibility, plus a brief interval as chief engineer of the Newfoundland Railway, leaves little doubt of his status as an outstanding Canadian engineer. Small wonder, then, that his name appeared on the New Year's honours list for a C.M.G. in 1876.

Fleming's survey trip across Canada in 1872 is recorded by Rev. George M. Grant, the Secretary of the expedition in what was at one time a best seller, 'From Ocean to Ocean', (James Campbell & Son, Toronto, 1873) One brief excerpt is quoted from page 157, the date August 23, 1872. "The sun usually rose and set in so cloudless a sky on the prairies that the Chief (Fleming) had all along roughly determined the longitude of our camp and the local time in a simple way. His watch kept Montreal time, and he knew that the longitude of Montreal was 73°33'. Sunset last night was at 9:34 p.m. and sunrise this morning at 7:26 a.m., by his watch. That gave 14 hours and 8 minutes of sunlight: the half of that added to the hour of sunrise made 2:30 p.m., on his watch, to be mid-day. We were thus two hours and a half behind Montreal time, and as four minutes are equal to a degree of longitude, we learned that we were 37°30' west of Montreal, or in longitude 111°."

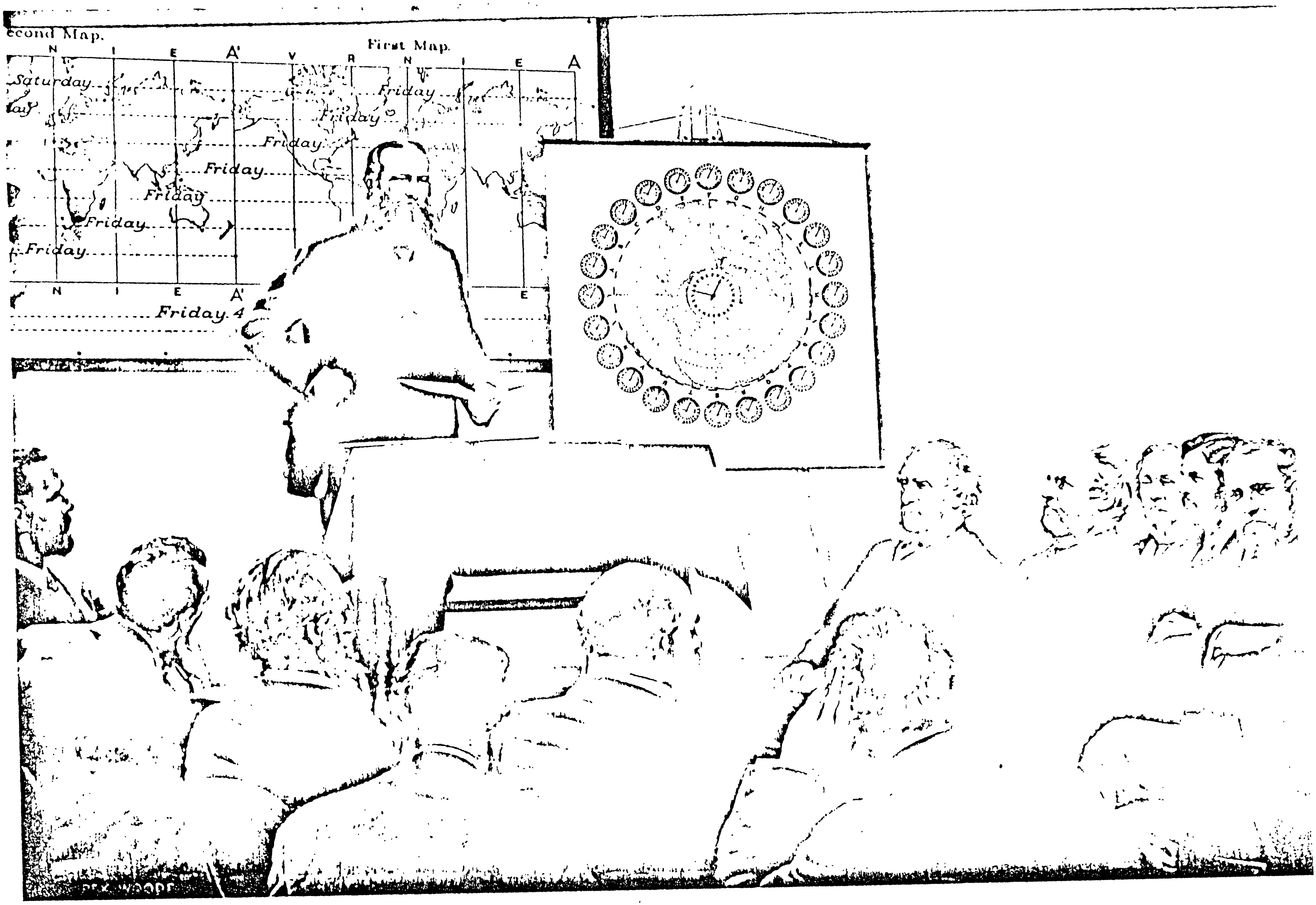
In 1880, at the age of 53, with the construction of the trans-Canada railway advanced as far as Winnipeg, he retired from active engineering. That same year he was elected Chancellor of Queen's University, a position to which he was re-elected time after time for the next 35 years. He now enjoyed the freedom to devote himself to the study and support of great causes that would benefit Canada and the Empire. The forum he used for his discussions were the scientific, engineering and cultural societies, such as the Canadian Institute, the Royal Society of Canada, the American Metrological Society, the American Society of Civil Engineers, and others of which he was either an Honourary Member, a Fellow or a Member.

The important cause, for which he is internationally recognized, is that of time reform. The matter came forcibly to his attention in 1876 when an error in printing p.m. for a.m. in a railway timetable in Ireland caused him to miss a train connection, with subsequent embarrassment to himself and his friends.

It should be mentioned that Charles F. Dowd (1826-1904), a distinguished graduate of Yale, Principal of Temple Grove Ladies Seminary, Saratoga Springs, New York, had written as early as 1869 championing a system of hour zones that would bring order out of chaos in the timetables of the American Railways, by reducing the multitude of local reckonings from community to community to an orderly array of four time zones in the United States. A full account of his work appears in the biography prepared by Charles N. Dowd M.D. (Knickerbocker Press New York 1930). In his article Astronomy in New Zealand, George A. Eiby states, "In 1868 the colonial government passed an act establishing standard time for the whole country. This was on the advice of Sir James Hector who had already drawn the attention of Canadians to the time difficulties that would arise on their transcontinental railway and had suggested time zones as a solution." (Sky and Telescope, 42, 18 (1971)). Cleveland Abbe (1838-1916), who is known as the Father of American Meteorology, presented his important paper on Standard Time in 1879 before the American Meteorological Society. He strongly recommended the adoption of a uniform time for the whole of the country, based on local mean solar time of the 90th meridian.

The proposal which had been advocated on a national or regional basis, was seen by Fleming to be one of broad international significance. In 1878 he was denied a hearing when he wished to present a prepared paper before the British Association for the Advancement of Science, because his ideas were considered as pure utopian. The following year, as a result of a paper presented to the Canadian Institute entitled "Time Reckoning and a Prime Meridian common to all Nations". a Memorial was sent from the Council of the Canadian Institute of Toronto to the Governor-General for submission to various Scientific Societies and to various Foreign Governments. Fig 34

In his reply to this Memorial, G.B. Airy, the Astronomer Royal, said, "I would suggest for consideration that an answer be given nearly of the following tenor: That Her Majesty's Government, recognizing in some degree the inconveniences described by the memorialists, are not able at present to compare with them the possible inconvenience which might arise from the interference of Government in such a matter. That it has been the custom of Her Majesty's Government to abstain from



THE BIRTH OF STANDARD TIME

Sandford Fleming [illegible] es Plan for Universal Time Reckoning at the Canac [illegible] titute, Toronto, February 8, 1879

From the original [illegible]

Fig. 34
Pg. 169

THE BIRTH OF STANDARD TIME

Sandford Fleming Outlines Plan for Universal Time Reckoning at the Canadian Institute, Toronto, February 8, 1879

Described as one of the four greatest Canadians of his day, Sir Sandford Fleming is best remembered as the Father of Standard Time, and least known as an unofficial Father of Confederation. Without him, Nova Scotia, New Brunswick and Prince Edward Island might have met alone at Charlottetown in 1864 to discuss confederation. He urged statesmen friends in Canada East (Quebec) and Canada West (Ontario) to "rub shoulders" with their Maritime counterparts, and arranged through D'Arcy McGee for a party to visit Saint John and Halifax. An invitation followed for the Canadas to go to Charlottetown, and within three years federation of the British provinces of North America as the Dominion of Canada was an accomplished fact. Said Fleming: "There is nothing like the brotherhood of knife and fork."

Sandford Fleming was born in Kirkcaldy, Scotland, January 7, 1827. He came to Canada at 18, taking six weeks to cross on the windjammer *Brilliant*. The year was 1845. Canada's Champlain and St. Lawrence Railway, covering 16 miles between Laprairie and St. Johns, Quebec, had been in existence less than 10 years, and still closed down in the winter. But railways were in his blood and he determined to be a civil engineer.

In Montreal in 1849 Fleming helped rescue a portrait of Queen Victoria from the burning Parliament Buildings, little realizing that in 1897 she would knight him for his many services. Shortly afterwards he designed Canada's first postage stamp, the 1851 three-penny beaver.

Fleming's long and distinguished career as a railway builder included almost identical jobs as engineer in charge of surveys and construction with the Northern Railway, 1852-63, and the Intercolonial Railway, 1863-76. He was government consultant 1871-1880 on Canadian Pacific Railway surveys. Of his Yellowhead Pass route through the Rockies which was later adopted by Canadian National Railways, he said "I simply followed the buffalo." In 1879 he proposed the Pacific cable which in 1902 linked Canada with Australia.

Fleming's interest in Standard Time was sparked in Ireland in 1876, when a railway timetable mix-up forced him to spend the night in a dreary station-house. During the long wait he vowed to do something about the confusion caused everywhere by differences in time. He kept his word, and time toda is so well ordered we take it for granted. In Fleming's day frustratio mounted as faster transportation and communication made existing time reckoning methods obsolete. There were 75 distinct times used by Nort American railroads alone. Cities varied by a few minutes and stations ha separate clocks for local time, for eastbound and westbound trains. Instruc tions were posted under each clock for the hapless traveller.

Fleming planned a system of 24 time zones, one for every hour the eart takes to revolve on its axis. Each would cover 15 degrees of the earth' surface. Time would be uniform in these segments but would change by on hour from one zone to the next. He chose Greenwich, England as the com mon or prime meridian.

By 1878 Fleming was ready to present his ideas to the British Associatic for the Advancement of Science, in Dublin, but his paper was shelved a being "of little consequence." This was only a temporary setback. In Toront in 1850 he had helped found the Canadian Institute which later include men like Sir Casimir Gzowski, Sir William Mulock and Sir Daniel Wilso On February 8, 1879, he addressed its members on "The Selection of Prime Meridian." Confederation Life's painting by Rex Woods depicts th historic meeting. The circular "Longitude and Time Reckoning" diagra shows 24 meridians proposed in connection with "Cosmopolitan Time. The map indicates "the progress and duration of the days of the wee around the globe."

Canada's governor-general circulated copies of Fleming's proposal inter nationally. North American railways adopted Standard Time in 1883, and 2 out of 25 nations followed suit at the International Prime Meridian Confer ence in Washington in 1884. The Universal Time System began January 1 1885 at Greenwich.

At 81, Sir Sandford spearheaded the erection of a memorial tower to th start of parliamentary government in Canada. It is located in Halifax wher he died in 1915 at the age of 88—one of Canada's most remarkable men.

Painted by Rex Woods for <u>Confederation Life</u> <u>Collectio</u>

interfering to introduce novelties in any question of social usage, until the spontaneous rise of such novelties has become so extensive as to make it desirable that regulations should be sanctioned by superior authority. That it does not appear that such extensive spontaneous call in reference to the subjects of the Memorial has yet arisen. That it appears desirable that the question should be extensively ventilated by the memorialists, and should be submitted by them to the principal Geographical and Hydrographical bodies, including (perhaps with others) the Royal Geographical Society, and the Dock Trustees, or other commercial bodies, at London, Liverpool and Glasgow." The letter was addressed to Sir Sam Hicks, Colonial Secretary.

Two main principles formed the basis of Fleming's discussion of time reform. "Whatever system might be adopted", he reported in his Presidential address before the Royal Society of Canada in 1890, "it was felt that it should be on the fundamental principle that there is only one time. It was moreover held to be that there should be only one reckoning of time common to all nations; and to secure a common reckoning, one established zero and one common unit of measurement became necessary."

These principles had motivated him when he attended the International Geographical Congress at Venice in 1881. Here it was proposed that the United States Government be invited to call a conference to consider the adoption of a zero meridian. The conference was convened in Washington in October 1884. L.J. Burpee, in his biography of Sandford Fleming (Oxford University Press 1915), writes as follows.

"Twenty-five independent nations were represented at the Conference, including practically all the countries of Europe, the South American Republics, Japan, Mexico, and Liberia. The Conference sat for about a month, discussing the question in all its bearings. At the outset Fleming submitted a series of recommendations with explanatory remarks, which were carefully considered. Other proposals were brought forward by the delegates of different nations. Finally the Conference adopted the following Resolutions, by a practically unanimous vote:

'I. That it is the opinion of this Congress that it is desirable to adopt a single prime meridian for all nations, in place of the multiplicity of initial meridians which now exist.

'II. That the Conference proposes to the Governments here represented the adoption of the meridian passing through the centre of the transit instrument at the Observatory of Greenwich as the initial meridian for longitude.

'III. That from this meridian longitude shall be counted in two directions up to 180 degrees, east longitude being plus and west longitude minus.

'IV. That the Conference proposes the adoption of a universal day for all purposes for which it may be found convenient, and which shall not interfere with the use of local or other standard time where desirable.

'V. That this universal day is to be a mean solar day; is to begin for all the world at the moment of mean midnight of the initial meridian, coinciding with the beginning of the civil day and date of that meridian; and is to be counted from zero up to twenty-four hours.

'VI. That the Conference expresses the hope that as soon as may be practicable the astronomical and nautical days will be arranged everywhere to begin at mean midnight.

'VII. That the Conference expresses the hope that the technical studies designed to regulate and extend the application of the decimal system to the division of angular space and of time shall be resumed so as to permit the extension of this application to all cases in which it presents real advantages.'

In the second Resolution, San Domingo alone voted in the negative; France and Brazil abstained from voting. In the fifth Resolution, Spain, Austria-Hungary, and Turkey voted in the negative. The principles embodied in the first and sixth Resolutions were adopted unanimously.

On January 1, 1885, the 24 o'clock system was adopted at the Greenwich Observatory, the seat of control for all the public clocks of Great Britain. In a circular issued by the Canadian Pacific Railway in June 1886, the 24-hour system was officially adopted for use on the company's lines. Despite the action of the Washington Conference, however, the nations were slow to take action in the matter of the adoption of a prime meridian common to all. As Fleming had foreseen, national jealousies stood in the way of the general acceptance of Greenwich. Nevertheless, the agitation had been helpful in creating a recognition everywhere of the importance of agreeing upon a universal prime meridian. It was with some degree of satisfaction that Fleming stated in another part of his address to the Royal Society of Canada in 1890, "Without taking into account Central Europe, where the reform is one the eve of adoption, the unification of time-reckoning has so far advanced that in Japan, Norway, Sweden, England, Scotland, Canada and the United States, all well regulated clocks strike the hours at the same moment (although locally the hours are distinguished by different numbers), and the minutes and seconds in all these countries are absolutely synchronous."

Adoption of Standard Time, as the new system was called, was greatly encouraged by the successful demonstration of its use by the railway companies of the United States and Canada who adopted it November 18, 1883. Many Canadian communities made the change at the same time, and no doubt the following notice in one form or another was to be seen in many places. " .... standard time, 17 minutes in advance of solar time, which will be adopted in the College commencing Monday next, the 19th inst. University College, Toronto, 16 Nov. 1883, President Daniel Wilson."

Not all Canadians favored the new idea. Major General D.R. Cameron, who had distinguished himself in the international boundary survey of the western interior in the 1870's and who was now Commandant at the Royal Military College, Kingston, fought a valiant rear guard action as he sought to stave off the passage of a bill through parliament that would legalize standard time. It was now 1891. A bill had been presented the previous year, but the following letter describes the situation.

"Ottawa, 23 June 1891

Robt. Sedgwick Esq.
Deputy Minister of Justice
Ottawa.

Dear Mr. Sedgwick:

We have had considerable correspondence from time to time about legalizing Standard Time and a Bill was introduced into the Senate last year by the Hon. Mr. MacInnes, but the Bill, however, being little understood was withdrawn.

A return is now before the House of Commons, which I think will be printed giving all the information and correspondence in connection therewith.

The Minister of Marine is now prepared to introduce the Bill as a Government measure but he wishes the Bill to be so prepared as to make it take effect only when adopted by the Governments of the different Provinces of Canada so as there will be no dispute of authorities, as it would require the authority of both the Dominion Legislature and the Local Legislatures to give it effect without any dispute.

I herewith enclose you the file on this subject and in that file you will see a copy of the Bill which was introduced by Mr. MacInnes entitled "An Act respecting the Reckoning of Time." The Minister requested me to consult with you, and make an addition to the Bill so as to provide for it taking effect only when the different Legislatures of the Provinces adopt the same system.

Would you kindly inform me whether you will have time to fix a section to this effect, so as I can have the Bill prepared, and also please look over the Bill and see if there is any portion of it which requires amendment or improvement.

The object to be attained is fully set forth in the papers herewith accompanying.

Yours truly,

Wm. Smith, Deputy Minister of Marine"

Before the Bill was submitted to Parliament, it was circulated as widely as possible in order to determine public reaction. Fleming, supported by Charles Carpmael of Toronto, gave the bill careful scrutiny, and submitted minor amendments. It apparently received first and second reading in August 1891, but was not passed.

An incident some two years later was reported in the Ottawa Free Press, and is reproduced here:

"Solar Time Governs. A decision of interest to every holder of a liquor license.

"London, Ontario, May 31 [1893] - Today Police Magistrate Parke gave a decision which is of interest to every holder of a liquor license in Ontario. In other words, it was His Worship's judgment in the test cases against C.W. Davis and Jas. James, who purposely kept their bars open till 10 o'clock solar time the other night, which is nearly half an hour later than standard time. The judgment was a short one. The magistrate simply said that all the authorities were in favor of solar time, and without some act to legislate standard time the other must govern. He therefore dismissed the case. The effect of the judgment will be to allow bars to remain open nearly half an hour later Saturday nights, as well as every other week night."

A note that same day from Fleming to the Deputy Minister of Marine, said in part, "There are other cases similar to this and no doubt in the future they will certainly arise and a statute is needed to govern in all such cases." However no further attempt has been made to prepare federal legislation, time being considered a matter for provincial jurisdiction.

Fleming prepared a "Memorandum on the movement for reckoning time on a scientific basis, by which the greatest possible degree of simplicity, accuracy, and uniformity will be obtainable in all countries throughout the world." It was communicated to the Committee on the Prime Meridian Conference by the Canadian Institute through the proper channels, and was subsequently distributed throughout the Empire. The principles of hour time zone and the 24-hour notation were now fully endorsed by the Astronomer Royal and his Committee, and were recommended to the colonies for their adoption.

Recommendation VI of the Washington Conference was also the subject of further action. The Astronomical and Physical Society of Toronto, forerunner of the Royal Astronomical Society of Canada, joined forces with the Canadian Institute in 1893 in a recommendation that the Astronomical, the Nautical and the Civil day be unified. The first two commenced at noon, except that the Nautical day was ending as the Astronomical day was commencing. Hence there was always the danger of confusion in reading the navigation tables, with resultant possibility of tragedy and loss. This recommendation fell on deaf or hostile ears, particularly in the U.S. Nautical Almanac Office. It was not until 1925 that the Astronomical day was adjusted to conform with the Greenwich civil day by changing zero hours of January 1, 1925 astronomical time to 12 hours.

Fleming followed with interest the adoption of the time zone system in all countries of the world, and his correspondence on the subject was voluminous. Lawrence J. Burpee, in his biography of this great Canadian, concludes the chapter on The Standard Time Movement with the following remarks.

"In introducing a paper by Fleming on 'Universal or Cosmic Time' the Canadian Institute paid the following tribute to the man who had laboured so long and faithfully in the interests of the movement:

To his own continued earnest and honourable labours in the cause Mr. Fleming has made no reference. This omission the Institute is constrained to notice in justice to Mr. Fleming and in justice to themselves. They may say what he has left unsaid, that his efforts have contributed in no small degree to the adoption of an initial Meridian common to all nations, and that he has unquestionably been the initiator and principal agent in the movement for reform in Time-Reckoning and in the establishment of the Universal day. The Institute cannot, perhaps, better express the debt of gratitude which the civilized world owes to Mr. Sandford Fleming in this connexion than by quoting from the accompanying paper from the pen of the distinguished Astronomer Royal of Russia, M. Otto Struve: It is through Mr. Fleming's indefatigable personal labours and writings that influential individuals and Scientific Societies and Institutes in America and Europe have been won over to the cause."

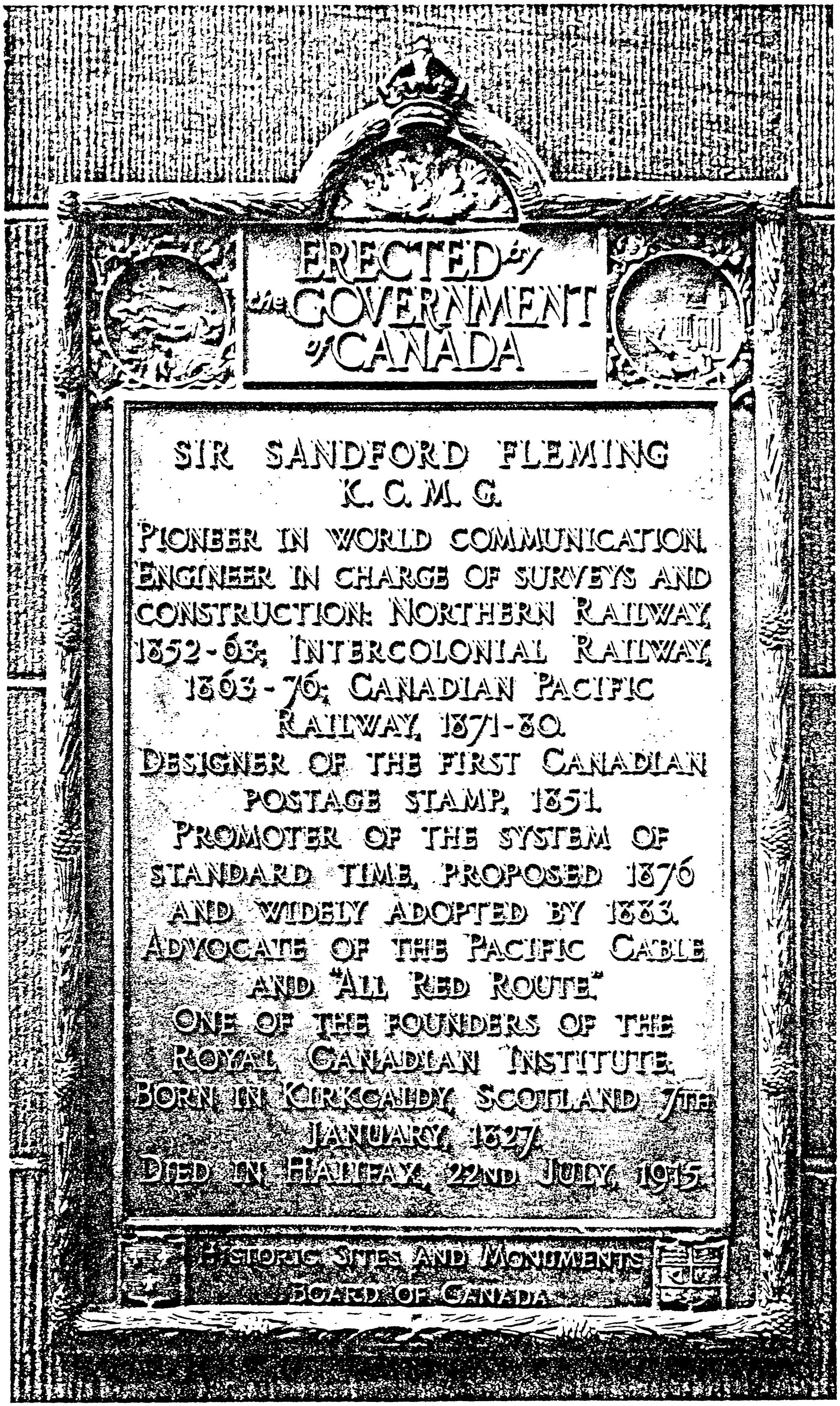


Fig. 35 Plaque mounted at the doorway of the Earth Physics Building,
Pg. 178 formerly Dominion Observatory. Courtesy Earth Physics Branch.

Because of his contribution to world understanding of improved timekeeping, Sandford Fleming was recognized in the Queen's Honors List of 1897 with the title of KCMG.

A bronze plaque to his memory is mounted in the foyer of the Earth Physics building, formerly Dominion Observatrory. Fig. 35

Ottawa

Cliff Street

Observatory

OTTAWA, CLIFF STREET OBSERVATORY

The story behind the building of an observatory at Ottawa has its beginning in the early years of Confederation. Two events are intimately associated with the story. One was the acquisition by the federal government in 1869 of the territory of Rupert's Land by the purchase of the rights from the Hudson Bay Company, and the other was the building of the Canadian Pacific Railway, in keeping with the promise to provide a link from British Columbia to the east in return for that colony joining Confederation.

The first observatory was a modest frame observing hut built in 1890 at the north end of lot 7 on Cliff Street. Piers on which the transit instruments were mounted remained for many years at the edge of the escarpment overlooking the Ottawa River at the north west corner of the Supreme Court building. It was superseded in 1905 with the inauguration of the Dominion Observatory on the Central Experimental Farm.

With the purchase of the rights from the Hudson Bay Company, there was made available for settlement in 1869 a vast area of rich fertile prairie land. It was necessary, in advance of the influx of settlers, to mark out the land, using a basic framework of meridians of longitude and parallels of latitude so that townships and individual farms could be properly identified.

Pembina was selected as the starting point. It is on the 49th parallel, the boundary line between western Canada and the United States from the Lake of the Woods to the Pacific Coast. Telegraphically its longitude was determined with respect to Chicago. The position of Chicago with respect to Greenwich had been determined previously, one measurement having been made by E.D. Ashe of Quebec City in 1857.

Responsibility for the survey was vested in the Minister of Public Works in 1869. Two years later the Dominion Lands Branch was formed and attached to the Department of the Secretary of State. Then in 1873 the management and control of the Dominion Lands was transferred to the newly formed Department of the Interior.

From Pembina, a distance 10 miles west was carefully measured and the first initial (or Winnipeg) meridian was marked out; its position was established as 97°27'28" west. From here successive initial meridians, designated as the 2nd, 3rd, 4th, 5th and 6th initial meridians were identified at 102°, 106°, 110°, 114° and 118°. Also the second initial meridian east was identified at 94°, so that guidelines for the grid extended across the western plains from the Lake of the Woods to the Peace River area. The subdivision into large blocks, townships and individual farm holdings required the services of a large number of surveyors for several years.

Field astronomical work involved observations for latitude for the purpose of checking long distances measured with the chain. Theodolites of 10-inch aperture, capable of a resolution of five seconds of arc were very effective in extending the survey. Checks in longitude were not attempted until the presence of telegraphic communication rendered precise determinations possible.

In British Columbia, a strip of land 20 miles wide on each side of the projected railway and parallel thereto, was given to the federal administration by the province. Because of the mountainous

Fig. 36 Edouard G. Deville, Surveyor General of
Pg. 181 Dominion lands. March, 1914.
Courtesy Public Archives

Slide 40

Fig. 37 Dr. William Frederick King (1854-1916).
Pg. 181

nature of the terrain it could not be surveyed by extending the lines of the prairie network. Instead it was necessary to run a detailed azimuth survey along the length of the line, and determine astronomically the latitude and longitude of a few positions so that the whole line could be related to the prairie network.

Three men who were largely responsible for the success of this venture, who rose to prominence as Canadian surveyors, and who were instrumental in establishing an observatory at Ottawa were E.G. Deville (1849-1924) W.F. King (1854-1916) and O.J. Klotz (1852-1923).

The oldest of the three, Edouard Gaston Deville, was born in France, educated at the French Naval School at Brest, and after six years of hydrographic work with the French Navy, retired with the rank of Captain and came to Canada in 1874. As a surveyor in the Province of Quebec he first came to notice in this narrative in 1875 when he accompanied E.D. Ashe of the Quebec Time Ball Observatory. The longitude of four places along the Ottawa River were determined by telegraph connections with Quebec. Five years later (1880), having qualified as a Provincial Land Surveyor (PLS), a Dominion Land Surveyor (DLS), and a Dominion Topographical Surveyor (DTS) he joined the western surveys. By reason of his experience and ability he was appointed in 1881 as Inspector of Surveys, in 1882 as Chief Inspector of Surveys, and in 1885 as Surveyor General on the retirement of Lindsay A. Russell. This office he held with distinction till 1922 when he was appointed Director General of Surveys. Fig. 36

William Frederick King, the youngest of the trio, came to Canada from England at the age of eight. His brilliant academic career Fig. 37

was interrupted at the end of his third year at the University of Toronto, when in 1872, at the age of 18, he was appointed as astronomical assistant to the boundary survey. At this time the 49th parallel between the Lake of the Woods and the Rocky Mountains was being identified. Two years later he returned to Toronto, and on graduation six months later was awarded the gold medal in mathematics. In 1876, he qualified as both a Dominion Land Surveyor (DLS) and a Dominion Topographical Surveyor (DTS), being the first candidate to pass the DTS qualifying exam. In 1875 and 1876 he was astronomical assistant on the Special Survey of the Northwest Territories (that part of the Territories which later became Saskatchewan and Alberta), and from 1877 to 1881 was in charge of the astronomical section. The Special Survey was that important section which was responsible for the initial meridians and base lines on which the remainder of the survey was based. He collaborated with Deville in revising the Manual of Surveys, most of the tables being computed by King. In 1881, along with Deville, he was appointed Inspector of Surveys, and five years later became Chief Inspector. In 1890 he was appointed Chief Astronomer, an indication that astronomy was a recognized branch of the Department of the Interior. In 1905 he was appointed Director of the Dominion Observatory, and in 1909 received the additional appointment of Superintendent of the Geodetic Survey of Canada. Commencing in 1892 he had numerous appointments as H.M. Commissioner for various sections of the International Boundary, and during 1903-07 served additionally on the International Waterways Commission.

Otto Julius Klotz was born in Preston, Ontario, and was a scholarship pupil both in public school and in high school. Mathematics, Fig. 38

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

Sept 11/85

MEMORANDUM **NOTE DE SERVICE**

Dear Mr. Thomson,

We have recently come across this photo of Dr. Klotz, which may be of interest to you.

Sincerely,

Adrian Camfield

Canada

Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

MEMORANDUM | **NOTE DE SERVICE**

85/04/23

Dear Mr. Thomson,

Our photographer Richard DeLaunais has been very busy preparing slides for meetings this month, but I have asked him to find a photo of Otto Klotz for you. In the meantime, the attached copy is from Meldrum Stewart's obituary of Dr. Klotz.

Sincerely,

Adrian Camfield

Canada

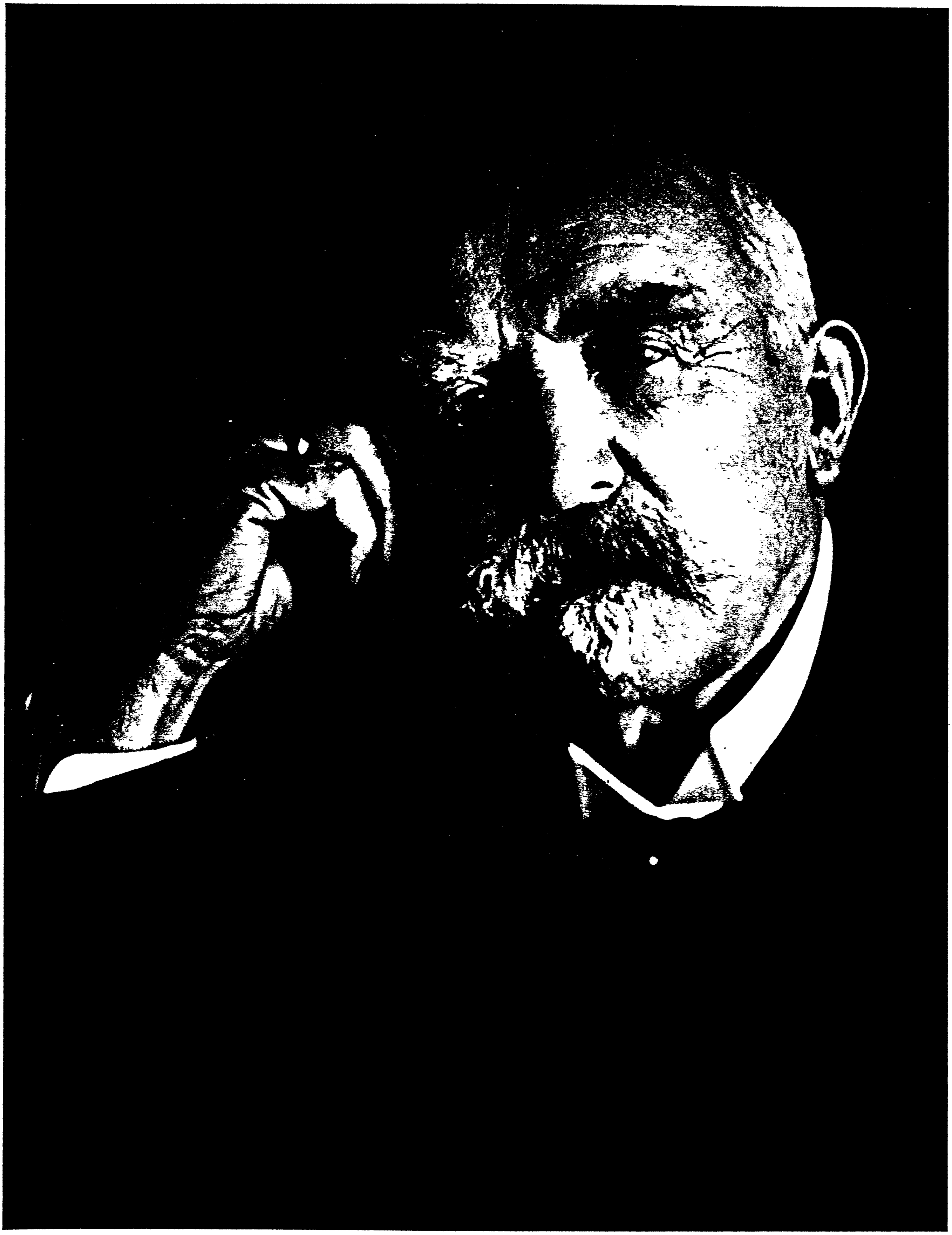


PLATE I

OTTO JULIUS KLOTZ, 1852-1923

(In the Office of the Director, Dominion Observatory, Ottawa)

Journal of the Royal Astronomical Society of Canada, 1924

Fig 38
Page 182

PLATE II

1871 1878

OTTO JULIUS KLOTZ

Journal of the Royal Astronomical Society of Canada, 1924 astronomy and science were his main interests, which he studied at the University of Michigan at Ann Arbor, graduating in 1872. He practised for a few years as a private surveyor, qualifying in 1877 for his DTS. Two years later he was appointed as a contract surveyor for the Canadian Government, in which capacity he had several interesting assignments. He was engaged for a while in base line work, the highest class of surveys in the northwest, King being his immediate supervisor. In 1884, when the Hudson Bay Route was being examined, Klotz was commissioned to report on the land approach to York Factory. His adverse report, based on the shallow waters surrounding the proposed harbor, undoubtedly had some influence in turning official attention to Churchill as the rail terminus. Boundary problems engaged him along the north shore of Lake Erie, and the coast of Labrador. But the assignment which had perhaps the greatest impact on the future of astronomy in Canada was the determination in 1885-86 by astronomical methods of the latitude and longitude of certain points along the Canadian Pacific Railway in British Columbia. He was in charge of the operation, with Thomas Drummond as his astronomical assistant. Wm. Ogilvie was responsible for the azimuth survey. Klotz, classified as an astronomer, was pleased, in later years, to note that this was the first occasion that the title of Astronomer had been given to an employee of the government of Canada. Klotz, in 1892, assisted in the transatlantic Greenwich-Montreal longitude determination, and a decade later extended the transpacific longitude determinations to Australia. He succeeded King as Director of the Dominion Observatory at Ottawa in 1917.

When Klotz commenced his work in British Columbia early in 1885, the railway was not completed, and the telegraph line had not yet been extended to the coast. The United States Coast and Geodetic Survey had extended the telegraphic network of longitude determinations to Seattle. This then became the base station from which to measure the longitudes of Victoria and Kamloops, and subsequently other locations in B.C. The last spike of the railway was driven at Craigellachie, B.C. on Nov. 7, 1885. And in Klotz's words, "the lesser metallic girdle", the telegraph, was completed three days previously. During the next two years, therefore, the telegraphic longitudes were extended eastward to Winnipeg and Port Arthur (Thunder Bay). And there is some evidence that a telegraphic exchange was made between Montreal and Winnipeg in 1888.

Prior to his appointment as Inspector of Surveys in June 1881, King had been engaged as astronomical assistant in the verification of the position of those principal lines which were laid out as controls for the survey. He was in charge of the western part of the field work, and collaborated with the Chief, Mr. A.L. Russell, DLS, whose location was the base station at Winnipeg. In spite of the frustrations with the less than perfect telegraph line, a total of 21 standard survey astronomical stations had been established by 1881.

During the next three years, Deville moved to Ottawa and King had the supervision of all the field work in western Canada. They were busy years, especially 1883, due in part to the rapid progress of the CPR and the influx of settlers. By 1885 the activity had subsided. But from the standpoint of astronomy in Canada it was a most eventful year because the work along the British Columbia railway belt effectively demonstrated the usefulness of astronomical techniques to surveying and to map making.

King was well aware of the limitations of this method. "These astronomical determinations" he wrote in 1906, in his official report as Chief Astronomer to the Deputy Minister of the Department of the Interior, "serve a useful purpose in the correction of maps, when the scale of these is not too large. For the control and checking of topographical surveys they are deficient. This is due to the fact that the astronomical and geographical coordinates of the same place are not necessarily, nor usually the same. The application of astronomy to topographical purposes proceeds on the assumption that the earth is a true spheroid and that the vertical line at a place (the direction of which it is the part of latitude and longitude observations to determine) is a true normal to it. The assumption is only approximately true: the irregularities of the earth, both above and beneath the surface, by their attractions, cause local deviations of the plumb line , so that the astronomical positions, though accurate in themselves within a few feet, may show a discrepancy in comparison with survey measurements of very considerable amounts.

"There is still a wide field for astronomical determinations in Canada, both in correcting general maps compiled from local surveys not coordinated, and in affording new points of departure for geographical surveys in unsurveyed regions. They cannot serve as a control for topographical surveys of any degree of minuteness of detail. This is the function of the trigonometrical survey."

Klotz, too, was aware of this problem, and as early as 1885, in his presidential address to the Association of Dominion Land Surveyors discussed the advantages of a triangulation survey all over Canada.

King was highly appreciative of the contribution of the telegraph companies. In his annual report of 1904 as Chief Astronomer, he wrote, "Thanks are due to the telegraph companies, Canadian Pacific Railway, Great Northwestern, Canada Atlantic, and Grant Trunk, for their cooperation in this work by affording free use of their lines for the exchange of time, and to the officials of the companies for their cordial assistance in carrying out the arrangements."

The success of the work along the B.C. railway belt established the importance of astronomy as the handmaid of the surveyor. It also stressed the need for a fixed observatory where time could be maintained and compared with the time as measured at a field location anywhere in Canada, thus determining the difference in longitude. Klotz and Drummond established Kamloops as a temporary base station during 1885 and 1886. Prior to this Winnipeg had been used, and it was to be used again for the field seasons of 1887 and 1888. Early in 1887 Deville, King and Klotz presented a joint submission to the Deputy Minister, Mr. A.M. Burgess, requesting that an observatory be established at Ottawa. Burgess agreed, and so did the Minister, the Hon. Thomas White. King and Klotz were permitted to visit Boston, Cambridge, New York and Washington with a view to acquiring a large transit. They also visited observatories at Ann Arbor, Michigan; Madison, Wisconsin; and Northfield, Minnesota; to study their equipment.

Charles Carpmael, Director of the Meteorological Observatory at Toronto was quick to take action when he heard of plans for an Ottawa Observatory. In a letter of April 13, 1887 to the Hon. Geo. E. Foster, M.P., Minister of Marine and Fisheries, he stated, "If this step is to be taken simply with the idea of having a station from which to determine longitudes, I would call to your attention the fact that there are already two observatories in the Dominion whose longitudes have been telegraphically determined, and which are thoroughly equipt with instruments necessary at a base station, and also possess competent observers. These are the McGill College Observatory, Montreal, and the Observatory at Toronto. Both the Observatories are under your department, that at Montreal, partly, and that at Toronto completely under your control. I, and I am sure also Prof. McLeod of Montreal, would willingly assist in the determinations of such longitudes as may be required, so that there is no need to wait until a base station has been fixed at Ottawa before making accurate telegraphic determinations. Of course if there is any other reason for establishing an observatory at Ottawa I have nothing to say, but if it is solely for the purpose named, it seems to me that the existing observatories might be utilized." Carpmael was anxious that federal support of astronomy should not become diluted. His proposal, however, was not acted upon because Deville, King and Klotz were unanimous in their views about a base station in Ottawa. King had set up a temporary observing hut in his garden in 1887 to test the Russell alt-azimuth which he was to use in the field. Klotz also built one in his garden in Preston, Ontario, to gain experience with a zenith telescope.

As a result of their visit to the United States, King and Klotz placed an order for some new and modern equipment, which arrived in Winnipeg early in 1888. A transit of 3-inch aperture, 34-inch focal length, made by Thomas Cooke and Sons, was mounted in the new observing hut on Princess Street. A Brashear 8½-inch reflector with equatorial mount was made ready for occultation observations. A sidereal clock with electrical attachments was carefully placed in the basement of the Clarendon Hotel. But Winnipeg was intended to be used as a base station temporarily, and the acquisition of the equipment added weight to the argument for a permanent observatory in Ottawa.

Klotz's diary recounts the realization of this objective in the entry for June 24, 1890. "Next I saw Mr. King and with him inspected our new observatory here, a slight improvement over any temporary ones." It was a frame building at the north end of Lot 7, Cliff Street, on the edge of the high bank overlooking the Ottawa river. The transit instrument it contained became the reference meridian for the survey of Canada.

Figs. 39 40, 41.

This same diary has an entry on Feb. 11, 1889 which reads, "A new office has been created in our branch of the Department, and that is Chief Astronomer - with W.F. King as incumbent. He is competent for the position." In his historical note on the Dominion Observatory, (J. RASC 13, 1, (1919)) Klotz writes, "On June 30, 1890, by order-in-council, a new office was created - Chief Astronomer - and W.F. King, Chief Inspector of Surveys, was appointed thereto at a salary of $1800 per annum." It would appear that more than a year had elapsed from the date of the appointment to the confirmation of the position.

In 1892 the government of Canada cooperated with the Imperial government in a determination by transatlantic cable of the difference in longitude between Greenwich and Montreal, which was carried out under the direction of the Astronomer Royal. Otto Klotz of the Department of the Interior and C.H. McLeod of McGill University were the two Canadian

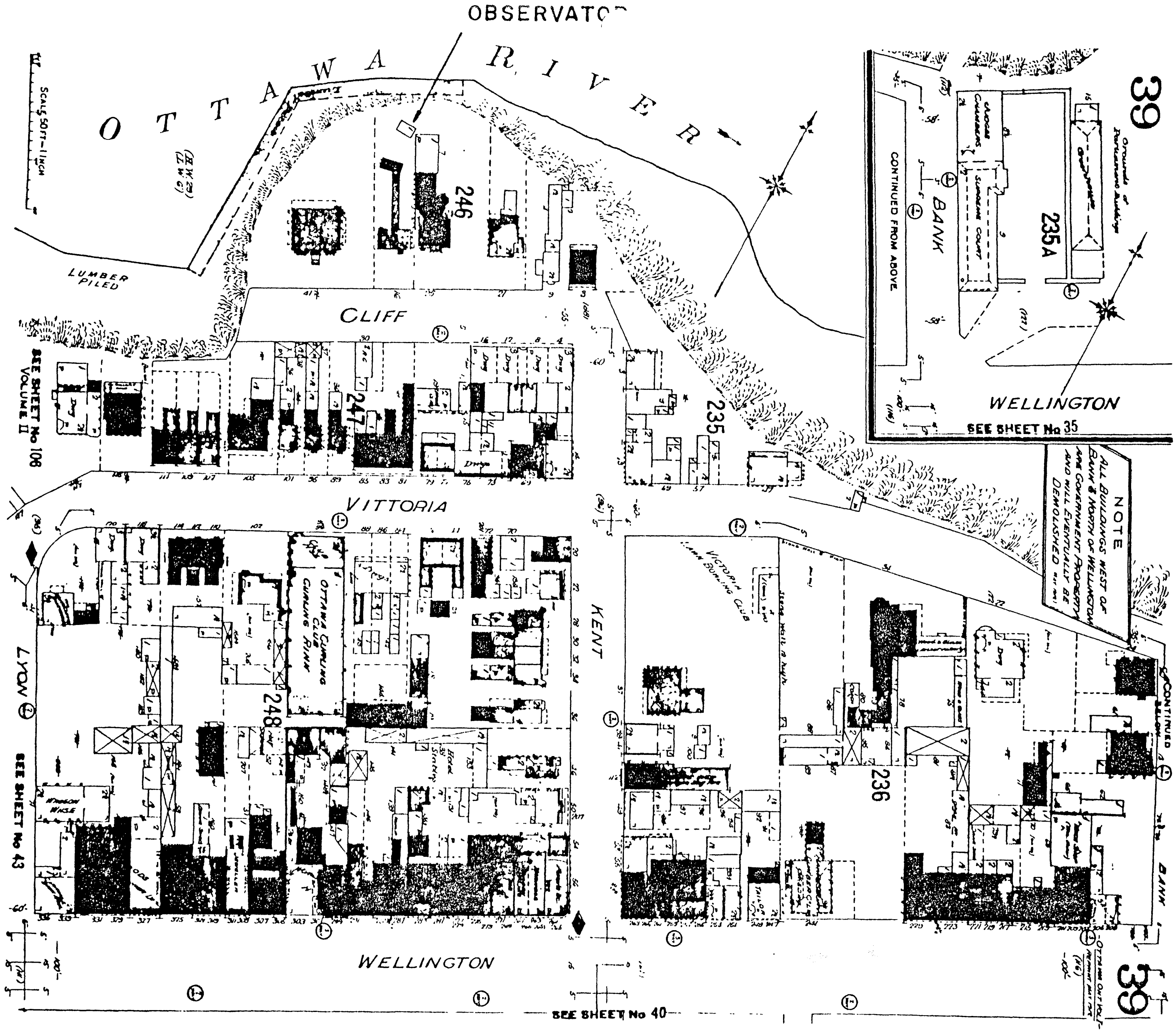


Fig. 39 Street plan showing the location of the Cliff Street Observatory.
Pg. 188 Ottawa Insurance Atlas, 1912. Courtesy Public Archives, Ottawa.

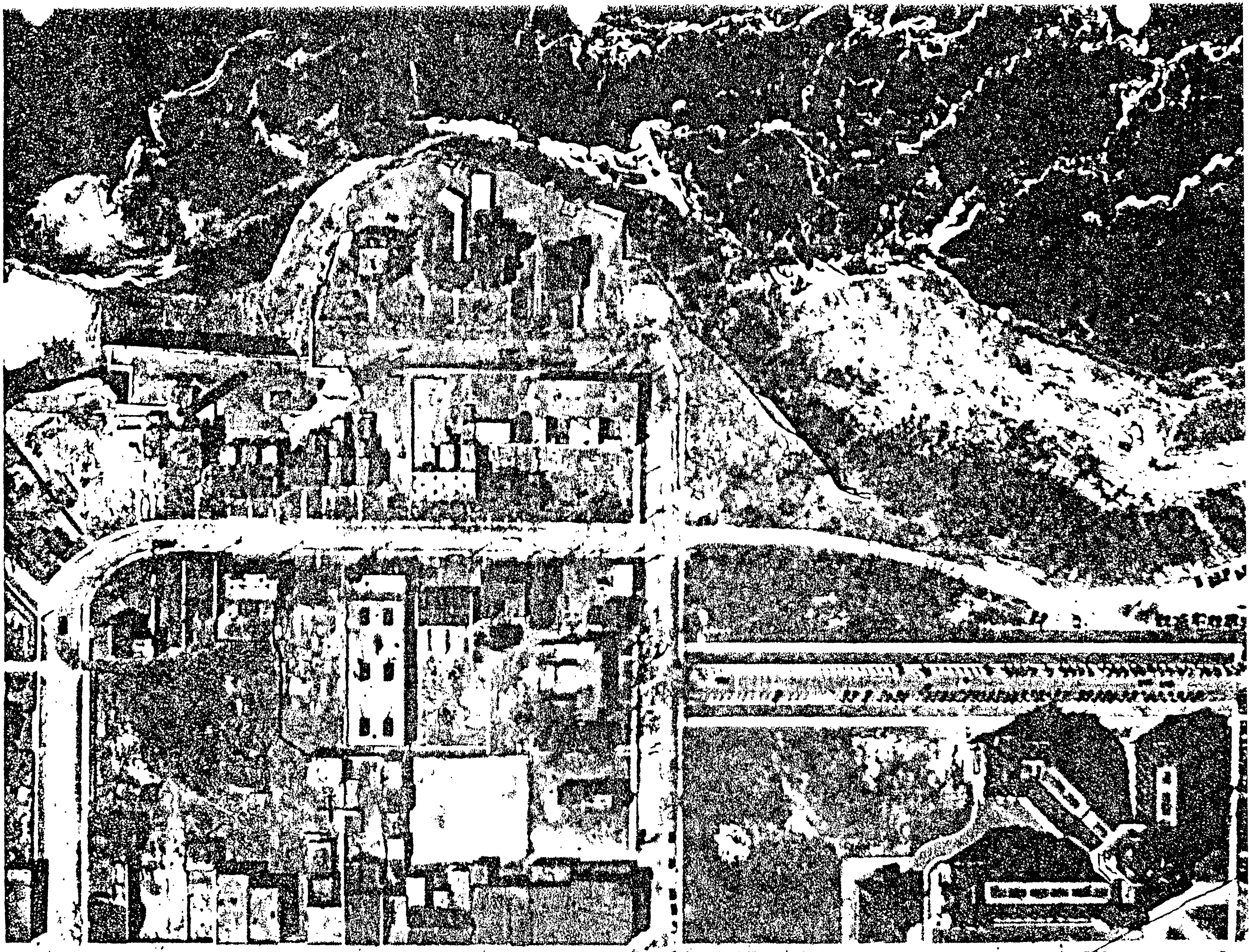


Fig. 40 Pg. 188 Aerial photograph, taken in May 1933, which shows the little observatory perched on the edge of the precipice overlooking the Ottawa River. Government property to the lower left has

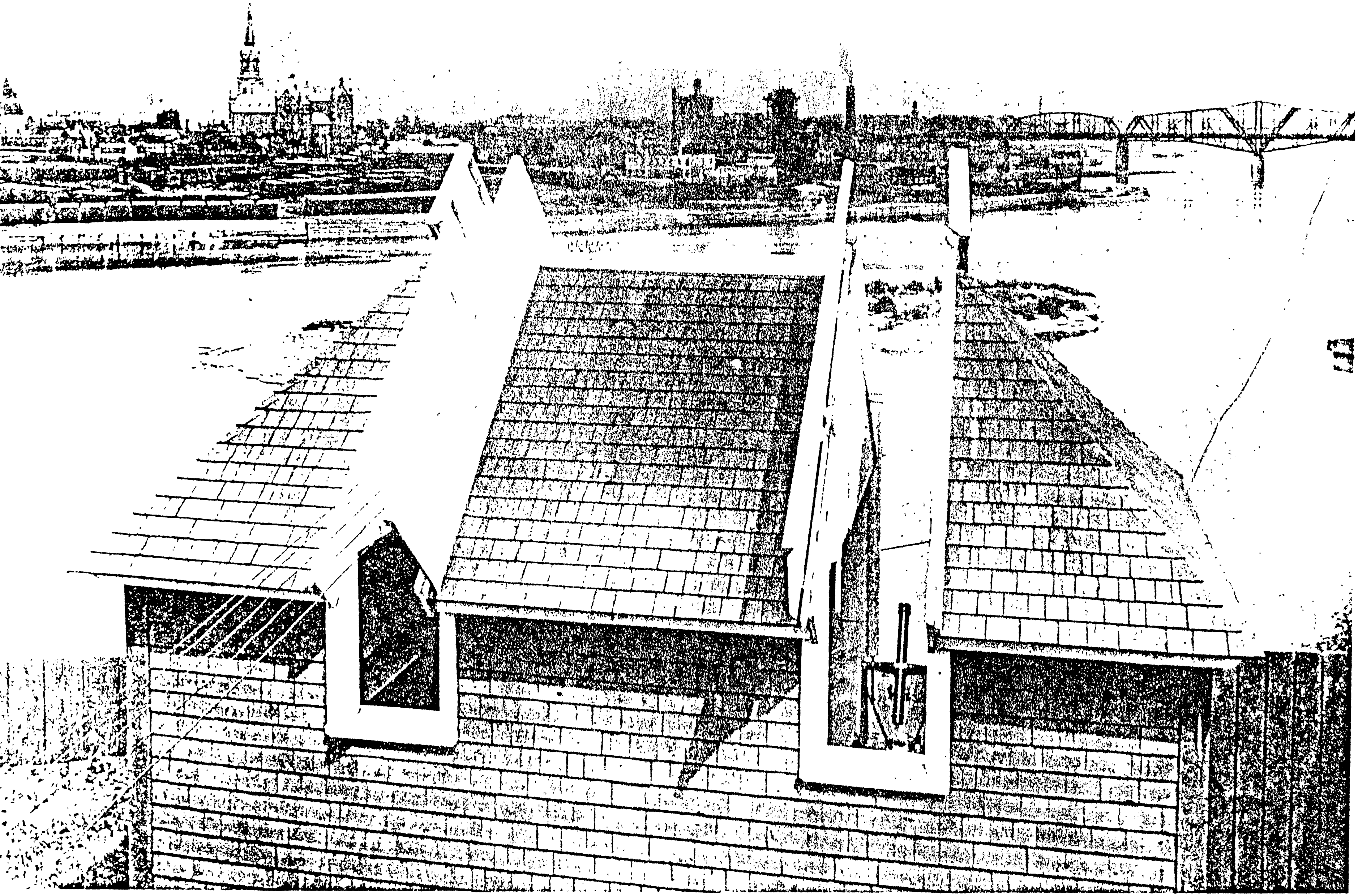


Fig. 41 The new observatory, Cliff Street, Ottawa, built in 1912 on the same site as the old observatory. The Alexandra bridge from Ottawa to Hull, Quebec, is seen in the background. Courtesy Public Archives, Ottawa.

Pg. 188

observers who collaborated with Turner and Hollis of Greenwich in making astronomical observations for time.

This same year King was named H.M. Boundary Commissioner, to collaborate with his U.S. counterpart T.C. Mendenhall, later succeeded by W.W. Duffield, in the survey of the Canada-Alaska boundary. The three field seasons 1893 to 1895 were completely taken up with this problem, Klotz being in charge of one of the survey parties.

In 1896, astronomical activity was resumed to the extent that Ottawa was connected with Montreal by King at Cliff Street and C.H. McLeod at McGill. King and Klotz then extended the connection to Winnipeg, thus linking the western survey to Greenwich. Port Stanley on Lake Erie was also connected with Ottawa to serve as a reference station for international boundary purposes.

Klotz had reason to remember 1896 because it was then that he became a permanent (inside) staff member of the Department of the Interior, and moved his family to Ottawa from Preston, Ontario. For several years he had contemplated the change from the temporary status of a contract surveyor. But for the benefit of his children he preferred the open surroundings of his home town. His financial position as a member of the outside service was better, though it lacked the security and the pension benefits of the inside service. Ottawa had other attractions. Not only was it the hub of political activity, it was also the place where Klotz enjoyed the stimulation arising from daily contact with his peers. Preston, by contrast, was a quiet back water which gave him a feeling of cultural isolation. His natural outgoing nature had already drawn him into the leadership of the national organization of the

Dominion Land Surveyors, and he was always interested in the conversation of those who could discuss current advances in science. So he came to Ottawa with the title of Astronomer. Klotz was a good public speaker, and one who took an interest in community affairs. He served on various committees, and for three consecutive terms he was returned as chairman of the Ottawa Public Library Board.

The observatory originally conceived by Deville, King, and Klotz was a modest site which might serve as a base station whose longitude would be determined with certainty. From here telegraphic longitudes could be extended to all parts of the Dominion served by the telegraph. In due course a large transit could be acquired and applied to the study of star positions, thus contributing to the international requirement for more precise information. The Cliff Street observatory answered this basic need. The equipment it contained is revealed in an inventory taken under the following unusual circumstances recorded by Klotz (J. RASC 13, 1, (1919)). "What equipment we had in our old wooden observatory on Cliff Street is found from the following list made on the removal of the instruments on the night of the big fire in Hull and Ottawa, April 26, 1900: 2 switchboards; 1 watch chronometer; 1 old chronometer No. 81; 1 new Dent chronometer; striding level in case; old and new Cooke transits; galvanometer; relays; chronograph; Siemens switchboard, and instrument lamps." There is no mention of fire damage. Instead astronomic work was resumed and several places, including Vancouver, were connected in longitude with Ottawa that summer.

Fig. 42

"In the summer of 1902", King states in his official report of Nov. 11, 1904, "as the new Pacific cable was approaching completion, I

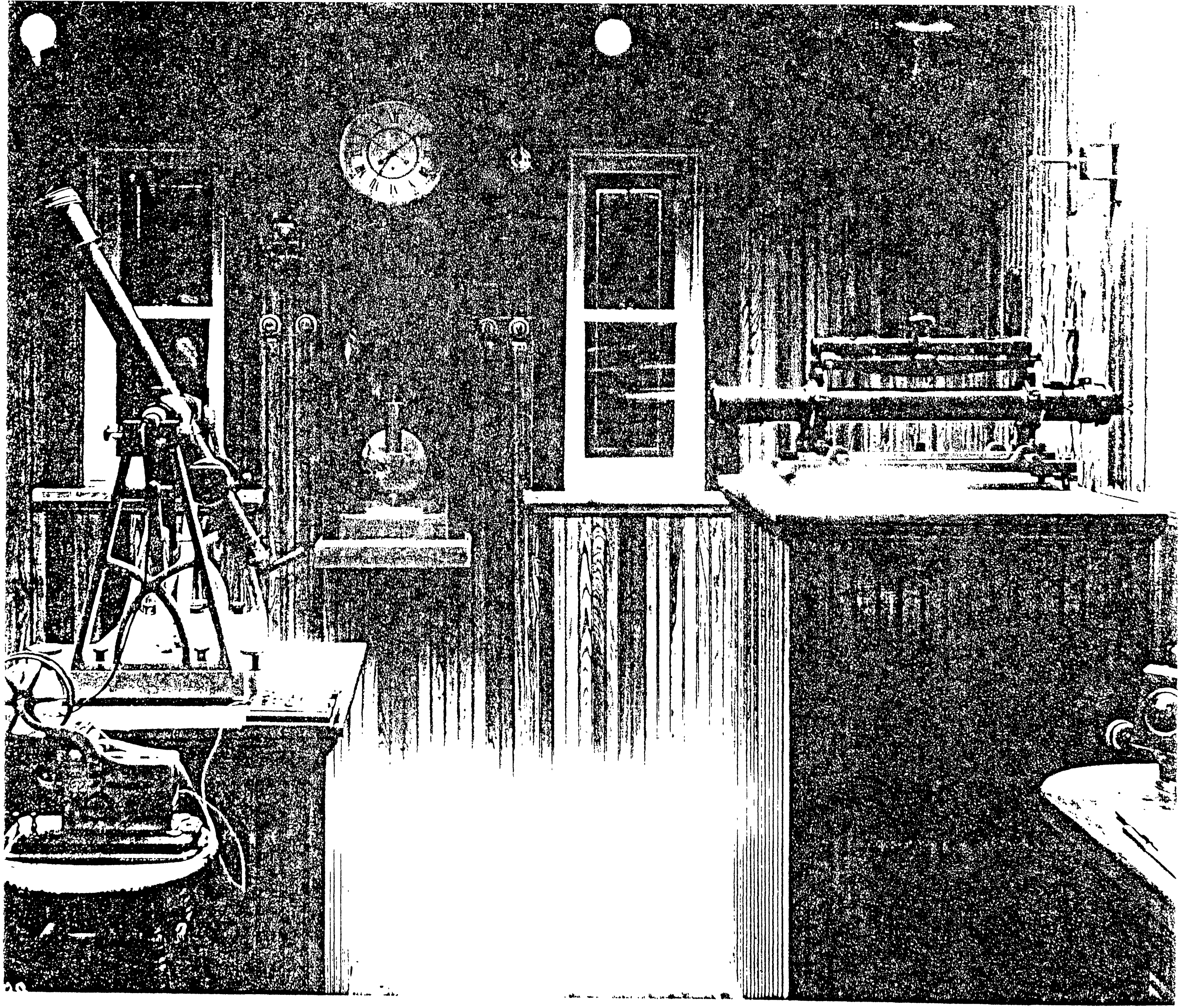


Fig. 42
Fg. 190

Interior of the old observatory, Cliff Street, Ottawa, built in 1890 on the edge of the precipice overlooking the Ottawa River, showing the transit instrument, colimator and observing clock.

pointed out to the Minister that an opportunity would thereby be afforded to extend our chain of longitudes from Vancouver (which had been connected with Ottawa and Montreal in 1896) across the Pacific to Australia and New Zealand, and that the value to shipping of accurate positions on the Pacific would be even greater than on the Atlantic, while the completion of the first longitude circuit of the globe would be itself a notable achievement, which would be to the credit of Canada."

The work was authorized and Klotz was placed in charge. He and his assistant, F.W.O. Werry, occupied alternate stations in the link: Vancouver to Fanning Island, Suva, Fiji, to Norfolk Island, to Queensland (Southport, Moreton Bay). Southport served as a temporary base station from which time was compared by telegraph with stations at Brisbane and Sydney. Werry left Ottawa Feb. 27, 1903, and the first satisfactory exchange between Southport and Sydney, New South Wales, occurred September 27. Thus "for the first time", said Klotz in his report, "longitude from the west clasped hands with longitude from the east, and the first astronomic girdle of the world was completed." The achievement was even more noteworthy from the fact that "the chain of successive differences of longitude carried from Greenwich through Canada was connected at Sydney with that carried eastward from Greenwich through Europe, India, etc., with a closing discrepancy in the circuit of the globe of only one-fifteenth of a second of time [about 84 feet]. As there are some twenty links in the whole chain, and the determination of the difference of longitude of each link consists of the comparison of time between its extremeties, one can get some idea of the extreme accuracy of modern observations."

In concluding his report of the transpacific longitudes, Klotz writes: "I wish here to express thanks for the hearty cooperation of the Chief Electrician of the Pacific cable and of the superintendents at all stations; [and of the authorities in Queensland, New South Wales and New Zealand who] kindly placed the use of the respective telegraph lines at my disposal for the nightly clock exchanges. .... In short, wherever and whenever any assistance was required it was readily and cheerfully extended."

Mention was also made of the speed with which news could now be sent from one part of the world to another. A single cable girdling the earth would require only about two seconds. But communication was made by several sections, part of which was cable, part land line. This necessitated repetition by manual transmission, causing delay. However an example of the speed was given in the report of a cricket game in Australia which was sold in bulletins on the streets of London fourteen minutes later. Klotz said that Puck is now left far behind when Shakespeare lets him say: "I'll put a girdle round the earth in forty minutes."

The Cliff Street Observatory continued in use as a test site for another three decades after the new Observatory was built on the Experimental Farm. The old wooden hut was replaced with a new structure about 1912, and a cement flat on the west side was used for setting up surveying instruments. An azimuth mark was painted on the Alexandra interprovincial bridge near the Hull end. When the Cliff Street site yielded to the Supreme Court building, the observing piers remained in plain view for another four decades, being removed in 1974, together with

Fig. 43

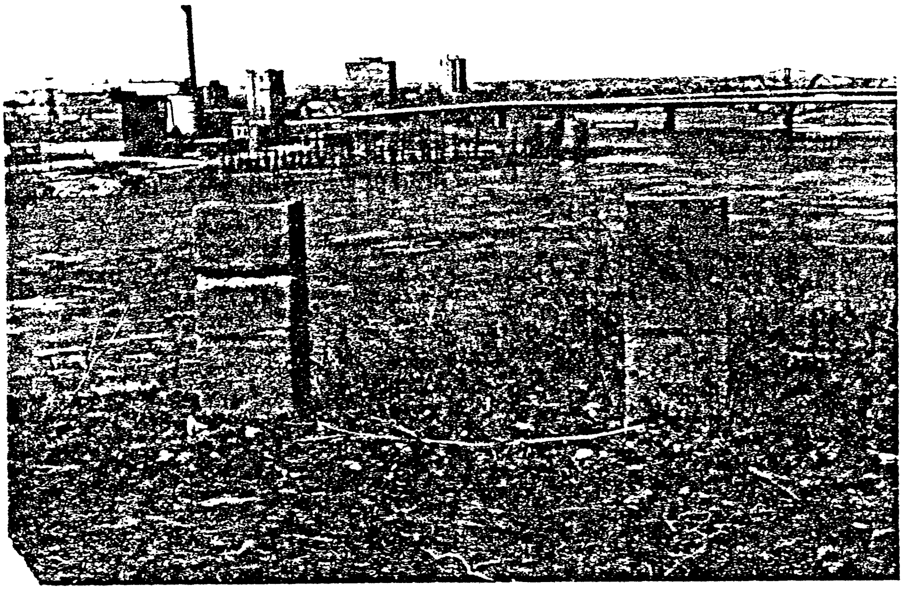


Fig 43. Pg. 192 Piers of the Cliff Street Observatory which were finally removed in 1974 to make way for a new parkway at the base of the cliff.

parts of the escarpment, as a safety measure in preparation for a bicycle pathway at a lower level.

The Dominion Observatory is built

Fig. 44 Pg. 193 The Dominion Observatory, 1905 to 1970. The building is now used by the administrative staff and library of the Earth Physics Branch, Department of Energy, Mines and Resources. Dourtesy Earth Physics Branch, E.M.R.

THE DOMINION OBSERVATORY

It was a great step forward when the Cliff Street observatory was built in 1890. Henceforth Ottawa would be recognized as the custodian of the prime meridian from which positions in all other parts of Canada would be measured. But it was another six years before the longitude determination from Greenwich to McGill was extended to Cliff Street, because the Chief Astronomer and his staff were occupied with the Alaska boundary problem.

When astronomical work was resumed in 1896, it became apparent that the accommodation was but a stop gap. The observatory was a small frame shed, the primary clocks were in the old Supreme Court building and the offices were in the Thistle Building at 26 Wellington. The operations were scattered over three quarters of a mile. A proper observatory was required where instruments could be mounted, tested and put into service, where astronomical observations could be made and where the Chief Astronomer and his staff would have adequate office space. With improved accommodation it would become possible to extend the range of operation from the utilitarian applications of surveying and time-keeping into broad avenues of astronomical research. Canada would then take her place among the more advanced nations. It was time for a change.

Fortunately for W.F. King there was a sympathetic ear. The Honourable Clifford Sifton had become Minister of the Interior with the change of government in 1896. Two years later King submitted to him a proposal for a modest observatory, including with the memorandum the details collected by Klotz of over 300 observatories in other parts of world. Sifton asked what other observatories there were in Canada, and was told of the one in Montreal and the one in Toronto. Their work, said King, would not interfere with that contemplated in Ottawa.

From here the plans grew. The original proposal for a 10-inch equatorial evolved into a 15-inch, the mechanical parts of which were built by Warner and Swasey of Clevland, while the optics, grating, etc., were made by J.A. Brashear of Allegheny. The small building which would have fitted on the knoll back of the parliament building overlooking the Ottawa River, became, instead, the spacious observatory on the high ground of the Experimental Farm. Otto Klotz submitted a plan in which the front of the building formed a straight line. King's plan had a right angle. As a compromise the architect adopted an angle 150 degrees between the two wings, and that was the way it was built. The first sod Fig
was turned in mid summer 1902, and in April 1905 the staff moved in, vacating the quarters which they had occupied in the Thistle Building for the previous 9 years.

The following is a summary of the cost of the observatory, including the transit house, north and south azimuth mark buildings, a small observatory for stellar photometric work, a magnetic hut, the Director's house and a machine shop, as well as laying out and improvements to the grounds.

Observatory and auxiliary buildings	$180,000
Instrumental equipment	100,000
Library, 9000 volumes	30,000
Total investment, Dominion Observatory	$310,000

While the building was under construction, and the sum, large in those days, was being spent, King prepared the following memorandum for the Honourable Mr. Sifton.

"As large expense is being incurred for the erection and outfitting of the Dominion Observatory, and as the sole justification for public expenditure is resulting public benefit, the following remarks upon the object of the observatory, with special reference to its utility, are submitted.

"1. Primarily, the equipment of the Dominion Observatory is designed for the carrying out of definite lines of observation and investigation of a scientific character. These observations will not be astronomical only, but meteorological, seismological, spectroscopic, etc.

"Such observations are for the general advancement of science, and, if conducted on a systematic plan, are of the highest value, though this value computed in dollars and cents may be remote. The absence of direct return from astronomical investigations calls for the aid of Government in a greater degree than do most other branches of science. State aid is given to astronomy by all civilized nations, and it is fitting that Canada should take part in the development of this branch of science.

"2. The advantage to a nation in supporting such a science as astronomy is not confined to the ultimate results. In the very course of the work the men who do it derive special training, not only in the observing itself, but in the practical application of many branches of science which are closely bound up with modern astronomy.

"This tends to develop a class of men of special training and knowledge who will be useful to the country, wherever accurate observation and investigation is required. For instance, explorations, geodetic work, etc., call for men of this stamp whose trained intelligence enables them to adapt their methods to overcoming the peculiar difficulties which they encounter.

"3. A branch of the work of the Observatory is the determination of longitudes. The determinations which have already been made under this office have proved useful in the construction of maps, the correction of surveys, etc. They have from time to time been asked for by various departments of the public service. Under the organization which the completion of the observatory will render possible, they can, it is believed, be made more rapidly and economically.

"4. Another branch of the work will be the transmission of accurate time to the city and the public buildings.

"5. Arrangements will be made for testing chronometers, a service frequently required by many departments, but for which there are now few facilities. Minor instruments can also be tested, such as sextants, aneroid barometers, etc.

"6. An indirect advantage will be the public interest which is hoped to arouse in astronomy and science generally by the exhibition of the instruments to visitors at stated times. In many countries, above all the United States, large contributions to scientific objects have been made by private persons. There seems to be no reason why similar benefactions should not be made in Canada, if public interest were directed towards these objects.

Respectfully submitted,

(Signed) W.F. King,

Chief Astronomer.

Minister of the Interior,

City."

In his official report as Chief Astronomer and Boundary Commissioner, Department of the Interior, November 11, 1904, King states:

"The new observatory, which will, it is expected, be ready for occupation in a few months, will afford office accommodation for the astronomical staff and that of the International Boundary Surveys. In the dome, the fifteen-inch equatorial telescope has just been erected. The installation of the clocks and of numerous minor instruments will shortly be made. Provision for meridian instruments has not yet been made. These call for a small separate building, the immediate erection of which is demanded, for the determination of the time is the essential prerequisite to all astronomical work.

"A feature worthy of mention of the future work of the observatory is the transmission of accurate time to the parliament and department buildings in the city. For this object an appropriation was made by parliament at its last session. It is proposed to distribute the time by electricity, with a master-clock situated in the observatory, and a clock synchronized by this in each of the buildings where time is to be furnished. These secondary clocks will each drive by electricity as many dials as are desired.

"A small number of dials, operated by a system of this kind, has been, as already mentioned, in operation for some time. A brief description of the system may not be out of place here.

"In the basement of the Supreme Court Building are set up two clocks, one regulated to sidereal and one to mean time.

"The sidereal clock is connected by wire with a chronograph placed in the transit shed on Cliff Street, alongside the transit instrument. This enables star transits to be recorded upon the chronograph, and thereby the error of the sidereal clock to be determined.

"The mean time and sidereal clocks are both connected by wire with the Langevin Block and this building.

"Through the wires an impulse is given at each beat of the mean time pendulum to the pendulums of two clocks, one in each of the buildings mentioned. These impulses force the pendulums to beat synchronously with the master clock. The system by which this is effected is the invention of the late Professor A. Cornu, and the mechanism in use, including the master and the two controlled clocks, was made by Borrel, of Paris. Each controlled clock carries a bar magnet at the lower end of its pendulum. This magnet passes, when the pendulum moves to the right through a solenoid which carries the controlling current. When the pendulum swings to the left, the magnet passes through a copper cylinder, which has the purpose of damping the oscillations, and thereby rendering the controlling impulse paramount over the natural period of the pendulum.

"The two controlled clocks each drive, by independent circuits, a number of dials operated each minute by an electromagnet.

"As has been stated, the sidereal clock is connected also by wire with this building. To avoid multiplicity of wires through the city, the same wires as those carrying the synchronizing current from the mean time clock are used to carry the beat of the sidereal clock. This is effected without confusion of signals by the use of a 'diplex' arrangement. The wires here come to a switchboard, which is provided with an ammeter for testing the strength of the currents, and with a Morse recorder, by which the beats of the two clocks can be recorded on the tape, and thereby a comparison made.

"On the switchboard there is also a switch by means of which a current can be sent in either direction to regulate the mean time master clock in the basement of the Supreme Court building. This clock is provided with a permanent magnet on the pendulum, which swings with it over an electromagnet placed below. The passage of a current in a direction to make the electromagnet attract the permanent magnet accelerates the pendulum; if in the opposite direction, retards it.

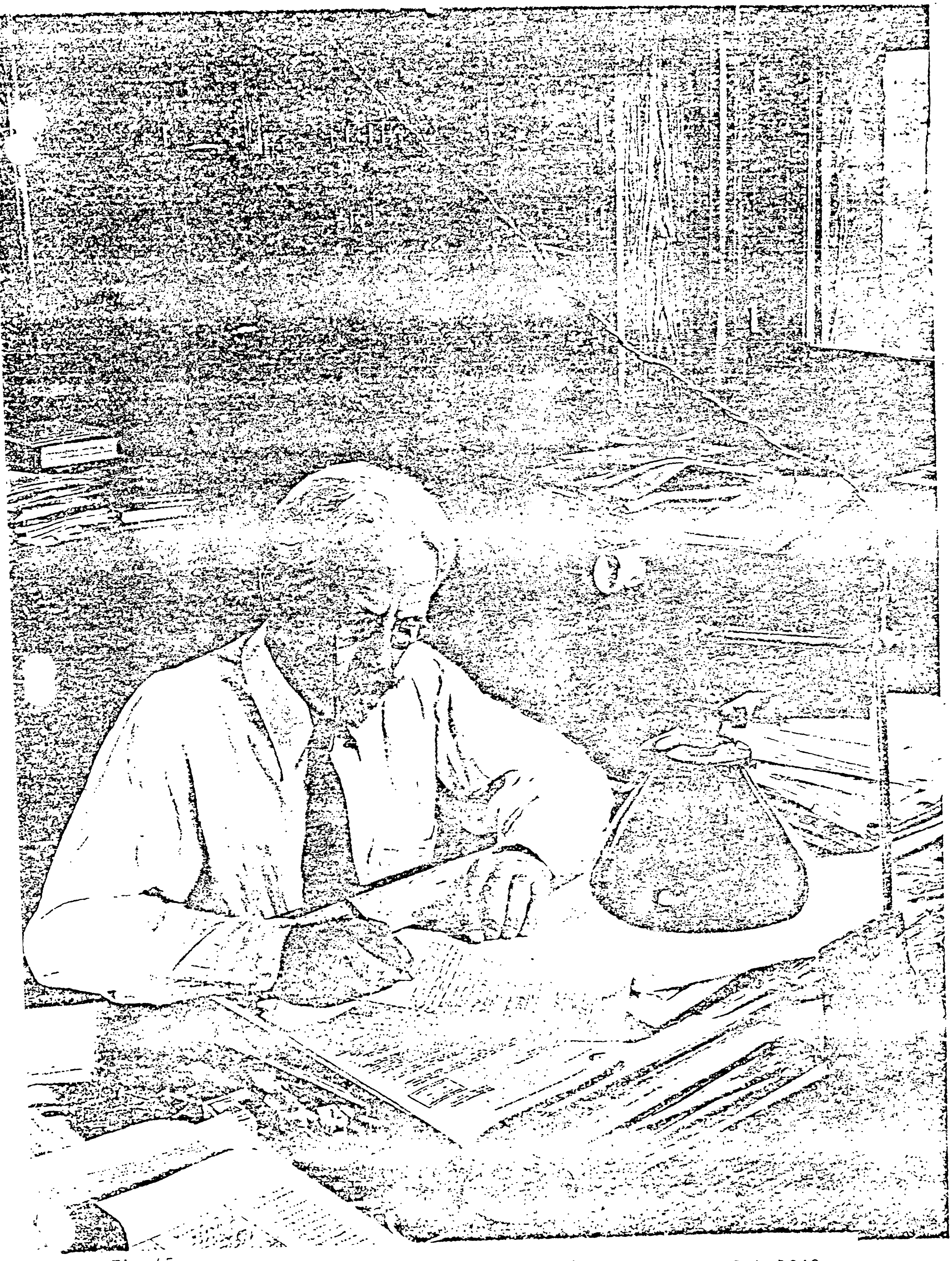
"Provision is also made for the receipt of an hourly signal from the clock in the Langevin Block.

"This apparatus enables all the operations to be conducted in the office, except the observations themselves, and thereby obviates as much as possible the inconvenience of having observing station, clock room and office so far apart. The observer takes his observations at night, brings his chronograph record sheet to the office in the morning, and there works out his observations. This gives the error of the sidereal clock. A comparison is then made by means of the switchboard between the sidereal and the mean time clock. If the mean time clock is found to be in error, the small correction necessary is made by turning the switch to the right or left.

"This service was put in experimentally. It has proved generally satisfactory, though it will receive certain modifications when the completion of the new building renders possible a more comprehensive scheme."

In 1902, a few weeks before the contract was awarded for the construction of the new observatory, Robert Meldrum Stewart (1878-1954), Fig. 45 winner of the Gold Medal in Mathematics and Physics at the University of Toronto, joined the staff. He had much to do with the development of the embryo time service described in King's report. When the move was made to the new building, his appointment became permanent, and he was made Superintendent of the Time Service. In 1924, following the death of Otto Klotz, he became the third Director of the Dominion Observatory, and served in this office until his retirement in 1946.

During his 19 years as Superintendent, he accomplished the difficult task of installing and 'de-bugging' the meridian circle, and establishing an observational program to improve catalogue positions of those stars which were particularly useful to Canadian surveyors; and he saw the introduction of radio time signals which freed the surveyor from the constraints imposed by the telegraph line, and which permitted the direct intercomparison of the time as determined by star observations at various observatories around the world.



. 44 Fig 45
193 Pg. 201 R. Meldrum Stewart M.A. (1878-1954). Photo by Malak 1943.

During his two decades as Director he saw the pendulum timekeeper at its best, and contributed his talents to the design of a Time Machine which mechanically produced correct mean time from the master sidereal pendulum. The rapid development of the quartz crystal oscillator had commenced to supplant the pendulum by the end of World War II, and six years after Mr. Stewart's retirement, the pendulum clock at the observatory was retired. Doubtless his scientific curiosity and understanding would have permitted him to accept the atomic age.

The inauguration of the Dominion Observatory was recorded in the following manner. "In April 1905, [nearly three years after the first sod was turned] the Chief Astronomer and his staff moved from their old quarters in the Thistle Block to the Observatory. On April 25, 1905, the press visited the Observatory in the evening, was entertained, and the next day the Dominion Astronomical Observatory became known throughout Canada. Dr. W.F. King became its Director, holding in addition as heretofore the title of Chief Astronomer of the Department of the Interior." With these words Otto Klotz concludes his story of the founding of the Observatory (J. RASC, 13, 1, (1919)). In April, 1911, Klotz was named Assistant Chief Astronomer.

Deville, who had been instrumental in forming the astronomical section within the Surveys Branch, culminating in the Cliff Street Observatory, now witnessed the inauguration of an independent and thriving branch. It was the parting of the ways. He saw the observatory controlled clocks installed in many of the government offices, but never was one permitted to grace the walls of his office. R.H. Field and

A.M. Narraway, who both served under Deville, recalled the independence of the Surveyor General. He had a new transit installed at Cliff Street, and the pendulum clock which was used for testing surveyor's timepieces, and which was verified by astronomic observations often more than a week apart, provided him with his own independent source of time.

Clocks of the Time Service

CLOCKS OF THE TIME SERVICE

The new building, located on high ground to the south west of Ottawa, provided ample space for all the functions for which the director, W.F. King was responsible. R.M. Stewart, who was appointed superintendent of the Time Service, was particularly pleased to have a clock room for the primary clocks, a time room for the secondary "work" pendulums with all their relays and outgoing circuits, and office space for study and research.

The clock room was located in the very centre of the basement where there would be the least disturbance from traffic passing around the building. Double doors insured thermal control. Uniform temperature was maintained by a thermostatically controlled heater. A fan behind the heater kept the air of the room well mixed. Various improvements in the thermal control culminated in a Callendar Recorder in the time room with a platinum sensing device in the clock room. Control of the ambient temperature to about one tenth of a degree centigrade was maintained.

Four piers were built, each on its own footing and independent of the walls or floor of the clock room. On them the four primary timekeepers were mounted. They were arranged in pairs at the two ends of the room, a sidereal and mean time pendulum constituting a pair, and so disposed that the planes of oscillation of the two pendulums were at right angles, to obviate any mutual effect.

The Howard clock, which had been purchased in 1900 for $500 and which had served as the sidereal clock in the basement of the Supreme Court building, was moved to the new clock room to become the primary sidereal timekeeper. A Riefler pendulum served as standby. These two clocks were adjusted as nearly as possible to zero rate and then left undisturbed in the expectation that any residual rate, as determined by star transits, would remain small and uniform.

Each morning the practice was maintained of computing the correct value of mean time from the best known value of sidereal time. And a switch was thrown to the left or right on the control panel of the time room to advance or retard the mean time primary the required amount, just as it had been done from the office in the Thistle Building. Now, however, a new and improved method of advance and retard was employed. Two small pendulums were mounted, one on each side of the mean time primary, and close enough that one or other could be attached to the main pendulum. One was suspended in the normal manner with its centre of mass below the point of support. Its much shorter natural period caused the main pendulum to swing a little faster. The other small pendulum was suspended below its centre of mass, and its attachment caused the main one to swing more slowly. The amount of gain or loss amounted to about 0.01 second per second.

The Cornu method of holding secondary pendulums in synchronism (page 199) had been replaced by the Riefler system. R.M. Stewart describes it as follows. "In each of the synchronized clocks was a "synchronizing" electromagnet situated below and to one side of the end of the pendulum rod; attached to the pendulum was a small armature of soft iron, which would be attracted to the electromagnet whenever current flowed through the latter. A current controlled by the primary clock was arranged to

(Fig 44)
SIZE 100%

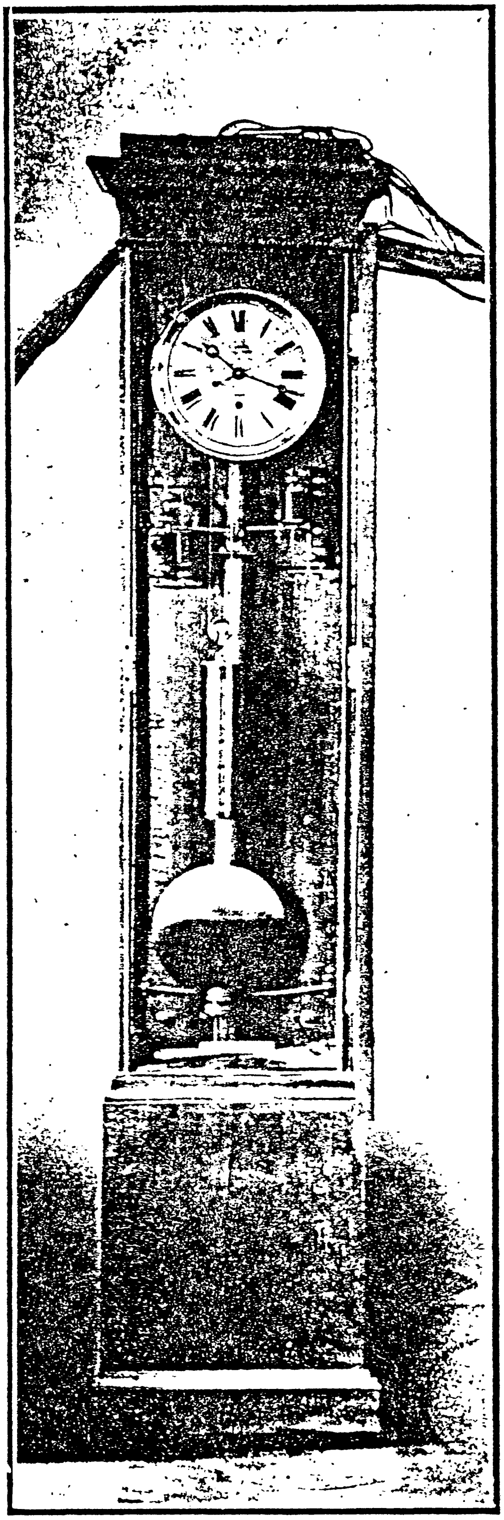


Fig.46 A secondary clock showing the synchronizing system introduced
Pg. 206 by R.M. Stewart in 1913. At the upper end of the pendulum is a tray. Two small weights on light chains may be lowered onto the tray or held suspended to make the clock gain or lose. Courtesy NRC Duplication.

flow through the synchronized magnet every alternate second; thus the pendulum of the synchronized clock was forced to swing in synchronism with that of the primary."

The system, however, could not withstand an interruption in the line. The secondary clocks, generally, would not retain a steady rate independently, but would soon get out of phase. Then when the line was restored the clock would invariably stop and the dials dependent upon the clock would also stop. Where the line was free of interruption, such as in the confines of the observatory, the system worked satisfactorily for many years. It is the method by which the Howard, which today adorns the upstairs foyer of the Physics building, M-36, of the National Research Council of Canada and which is adjusted to a mean time rate, is held in step with the cesium standard. The relatively long lines from the observatory to the clocks in the government buildings were frequently interrupted, and so were not suitable for the Riefler method.

A unique system for holding a clock in synchronism with its primary was introduced by Stewart in 1913. It consisted of a tray Fig. 46
mounted near the upper end of the pendulum, and two small weights which could be lowered onto or held free from the tray. When the weights rested on the tray, the centre of gravity of the pendulum was raised, the period of swing reduced and the clock would gain. Conversely when the weights were held free the clock would run slow. Should the power to the control magnets fail, one weight was held free and the other rode the tray, and in this situation the pendulum was regulated as nearly as possible to zero rate. A synchronizing pulse from the master pendulum once a minute determined whether the weights would ride or be held free

for the ensuing minute. The secondary master, whose rate could vary by 6 or 8 seconds a day due to thermal fluctuations, could be held to the time of the primary to within about a hundredth of a second. The synchronization line to the clocks in the government buildings downtown was activated once an hour, and this maintained all the minute dials in the government offices within a few hundredths of a second. When the dials advanced only once per minute, or once per half minute, both of which systems were used in the government offices, this precision was quite satisfactory.

In November of 1905, a new model of the Riefler clock was acquired and installed as the primary sidereal clock of the observatory. R75, as it was numbered, incorporated the new Riefler concept of a nickel-steel pendulum, a free escapement, and an electrical self winding mechanism, all enclosed in an airtight glass cylinder. The self winding mechanism was in the form of a gravity arm centred on the axis of the escapement wheel and with a ratchet attachment to the teeth of the wheel. It rode down with the turning of the wheel till it touched an electrical contact, whereupon it was flipped to its upper position. Pressure inside the cylinder was maintained at 725 mm of mercury, slightly below barometric pressure. A few volts of battery power could keep the clock in operation for many months, while a second pair of wires through the vacuum seal operated a relay from the pendulum contacts. The Howard clock was adjusted to mean time and subsequently became the mean time primary.

R75, though it marked a great advance in reliability of performance, was apparently sensitive to small thermal fluctuations, and

Stewart went to great pains to provide a better environment, such as a special wooden enclosure with thermostatically controlled air flow.

In 1922 a second Riefler, R412, was ordered, and placed in service. The two complemented each other, and brought to light the fact that an improved environment was required which would be more spacious, free from the effects of vibration from motors, and capable of satisfactory temperature regulation. There was also need for a third precision pendulum, because with two only, it was not easy to determine which one was developing a faulty rate.

In March, 1923, something was wrong with one of the two Rieflers. Failing a third precision pendulum, a Nardin sidereal chronometer was used on an all night test, which revealed that the new clock, R412 was irregular. A day later R412 stopped due to a tight bearing on the hour hand wheel, and R75 became the primary standard temporarily. Two years later R75 stopped due to a failure in the winding mechanism. Each time a failure occurred in one of these clocks it was necessary to break the vacuum seal and later to restore the seal.

The new clock vault was built "under the north lawn of the observatory and east of the coelostat, from which the door leading down to the vault opened. The outside dimensions of the vault were approximately 15 feet by 19 feet, with a height of 11 feet, the top of the roof being two feet below the surface of the ground. The walls and ceiling are double with a 4-inch air space. A 3-foot hall divides the vault into two parts, and each of these parts is divided into two rooms. Massive concrete piers, separated from the floor, are placed to support the clocks, and on each pier a half inch steel plate is bolted to give a firm and even surface for the holding of the clock brackets... The temperature control in the hall is by bimetallic thermostat and in each room is a petroleum-mercury thermostat. The heating unit in the hall is a 660-watt heater and the rooms are heated by carbon lamps", (from an unpublished report by C.C. Smith, 1930). The temperature of the vault was maintained at 25°C, which was higher than the ground temperature during the heat of summer. Fans kept the air circulated in each of the four rooms and the hall. Tile around the vault drained into the nearby collector pipe, which occasionally became clogged from tree roots. When this occurred, the vault was subjected to the inconvenience of several inches of water on the floor.

The vault was completed in 1927, R75 was installed in 1928 and R412 the following year.

A Shortt synchronome clock, master and slave, numbered S29, was obtained in January 1930. The master, or free pendulum, was installed Fig. 47
in the vault while the slave was mounted in the time room. This remarkable clock incorporated a further step toward the ideal in that no work was required of the free pendulum. It was sealed in a container that was evacuated to about 32 mm of mercury. A slight adjustment in the vacuum could be made to adjust the rate. Every thirty seconds it received an impulse which was triggered by the slave and which restored the arc for another 30 seconds of free swinging. The impulse was in the form of a gravity arm terminated by a roller which rolled down a curved slope attached to the pendulum. When the arm dropped to the bottom of its travel it closed a contact which immediately restored it to the ready.

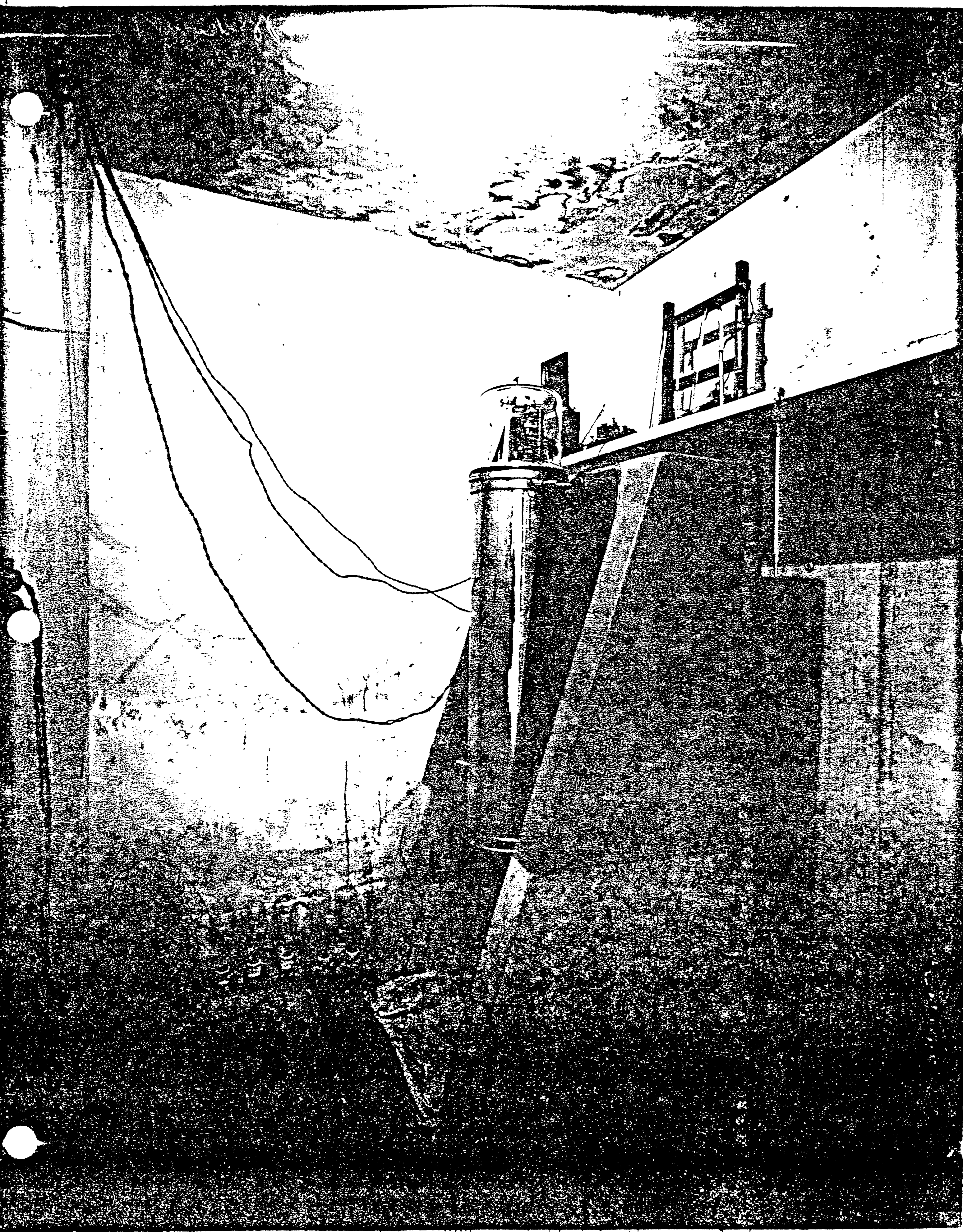


Fig. 47 Synchronome master pendulum, S29, installed in the new clock
Pg. 209 vault in 1930, was the primary time standard at the Dominion Observatory for two decades. Courtesy Earth Physics Branch.

SIZE 75%

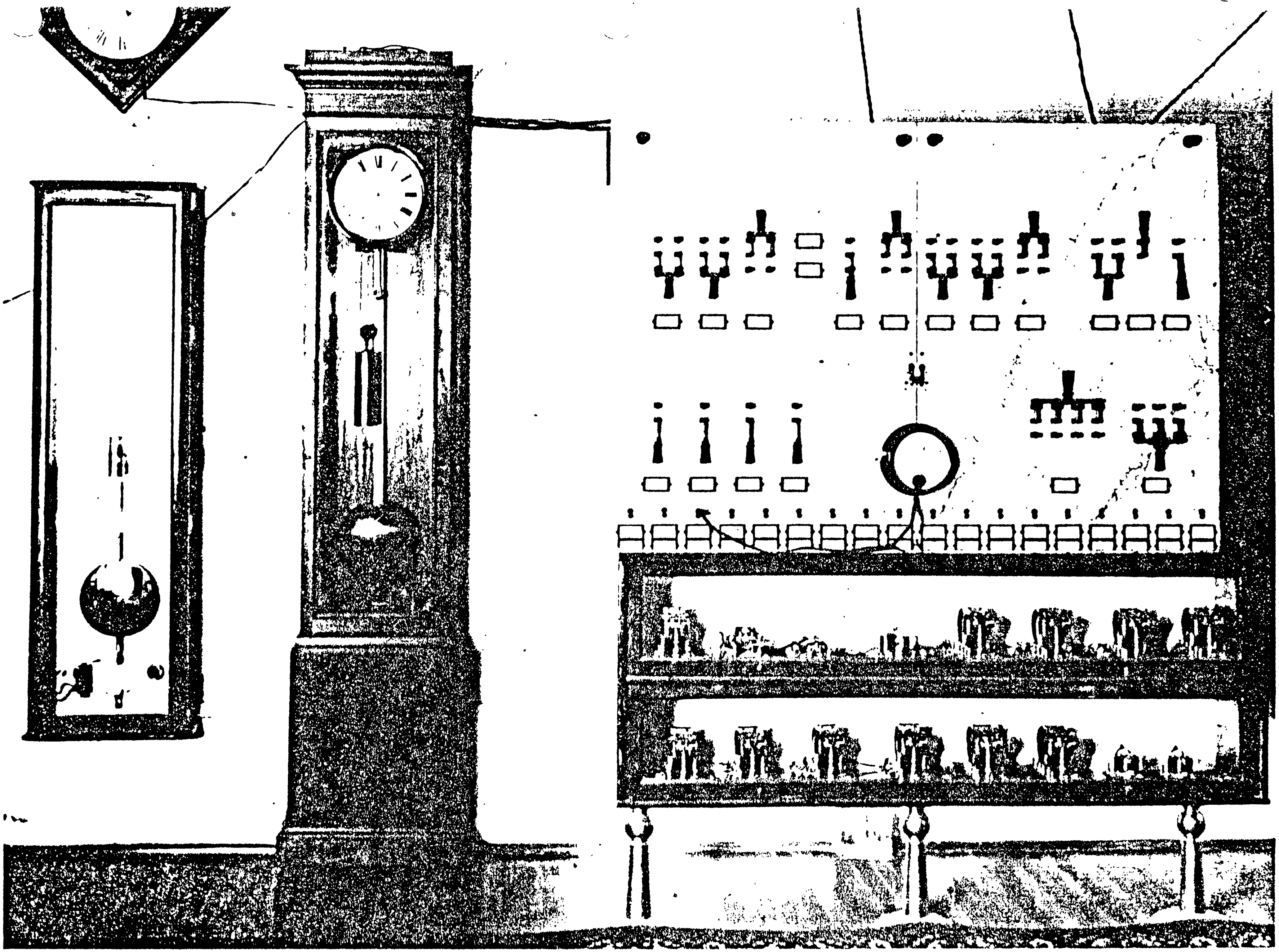


Fig. 48
Pg. 210

The time room of the Dominion Observatory, showing the secondary pendulums, sidereal and mean time, with electro magnets at the base of each to keep them in synchronism with their respective primary pendulums in the clock room. The marble control panel is on the right, and below it are the relays which distributed the time pulses. Courtesy Earth Physics Branch, E.M.R.

ROTAI

The slave was rated to lose 6 seconds per day or approximately 4 milliseconds per minute. In addition to the regular half minute impulse which it received in the same manner as the free pendulum, the slave also was given an accelerating impulse of 0.004 second when it had dropped sufficiently far behind the free pendulum. This pulse was formed by the same contact which restored the gravity arm of the free pendulum to the ready. The current passed around the coils of an electromagnet adjacent to the slave pendulum. The armature of the electromagnet carried a tongue which could engage the bent top of a long leaf spring carried on the slave pendulum. The spring was then flexed as the pendulum continued its motion, and on the return the spring was carried away and the armature freed. Alternate half minutes the slave would not have retarded enough, and the armature of the electromagnet would merely give a harmless tap to the top of the leaf spring. Thus the slave was able to reproduce the excellent performance of the free pendulum.

The time room on the main floor contained the secondary pendulums, Fig. 48
both mean time and sidereal, which were required for the operation of the time service. The various circuits radiated from a marble control panel, at the base of which were two glass faced shelves containing the necessary relays. Above the shelves was a row of 18 jacks into which could be plugged the cord from a test meter mounted centrally on the panel. A variety of switches made it possible to change the control from one pendulum to another.

In 1905, the downtown time service included four government buildings, East Block, West Block, House of Commons, and Langevin Block. Secondary master clocks in each building controlled a number of dials, the power for the output of each clock being maintained by a 24 volt bank of B2 Edison cells. A Holtzer and Cabot motor generator at each site was used each week to charge the cells. Other services supplied from the time room included seconds pulses to the chronograph for transit work; pulses to the seismograph shutters; signals by the telegraph line to the Great Northwestern (later CN) and Canadian Pacific telegraph rooms; minute pulses for the tower clock and mean time dials in the observatory. Gradually the service was extended to other government buildings, as the following table indicates.

Growth of the time system from 1905 to 1930

	Primary Clocks	Secondary Master Clocks	Seconds Dials	Program Clocks	Tower Clocks	Minute Dials
1905	4	6	0	0	1	214
1911	4	8	6	1	2	283
1915	4	9	9	1	2	333
1920	4	9	14	1	2	351
1926	4	15	18	1	2	561
1930	5	16	18	1	3	682

The program clock was in the form of a punched tape controlled by one of the secondary mean time pendulums of the time room. It controlled the hourly pulse to the seismic recorders, the daily signal to the telegraph companies, and other services of a repetitive nature. The three tower clocks of 1930 were located at the observatory, the Post Office, and the Peace Tower. Also by 1930, clock beats could be switched onto the telephone line for the benefit of jewellers, surveyors, and others who might call in for the correct time.

On December 1, 1905, connection was made with the time ball on Parliament Hill, which gave the signal for the firing of the noonday gun. Formerly this was controlled from McGill. Very little has been recorded about the operation of the Ottawa time ball, and a search has failed to unearth a picture of it.

Several people were queried about it, and the following is a letter dated June 2, 1971, from Mr. Jesse Ketchum of Toronto. "Re time signals in Ottawa 1900 to 1905. During this period, time was given to the Great Northwestern Telegraphs who transmitted it to the Canadian Atlantic Railways and the New York Central Railways. This was given on the telegraph wires as a long dash then a space and a dash and a space until just before the hour, when a double length space preceded the closing of the signal to indicate the noon hour. We received the signal from the observatory, and also sent a signal to the man who fired the "noon gun". I was then an apprentice telegraph operator, and assisted over all the floor wherever needed. On many occasions when the chief was otherwise involved, he would tell me to watch for the signal and fire the gun. I well remember slipping one time and thus delaying the signal for part of a second. I was much afraid he would report me to the authorities, and went up to see him. But he showed me a huge watch he carried and told me he never relied too much on our signal, but shot the gun as timed by his watch. ... The gun was on the grounds just a few yards south and east of the East Block, and we boys often went there to watch."

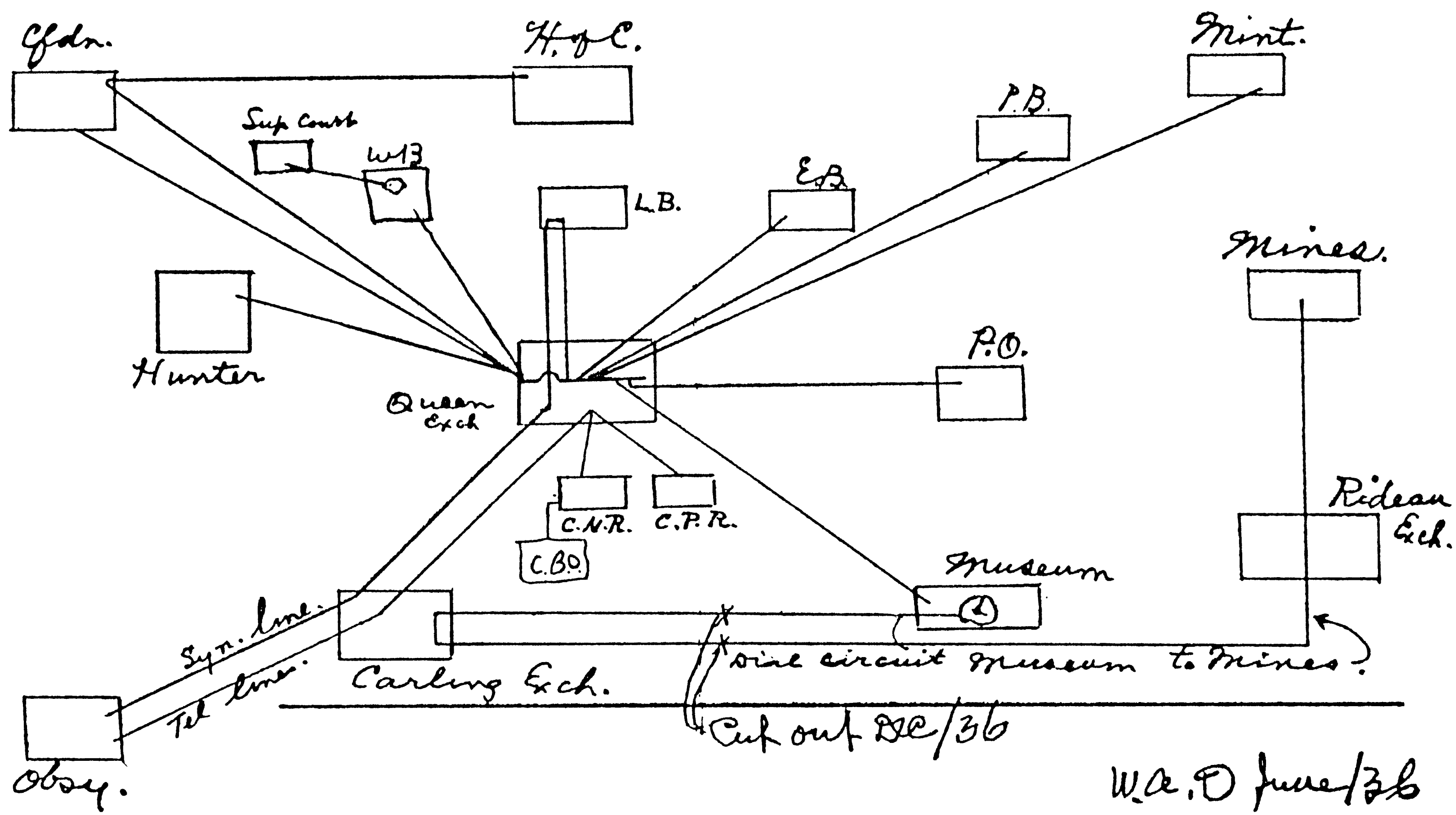
In a second note dated December 20, 1971, Mr. Ketchum said, "Now, with your reminding me that the Chateau Laurier was built since I worked there [built 1912], I can place the time ball and also the gun, which in my time was on the west side of the canal.... ... The gun was fired by a signal which the G.N.W. received from the observatory. I put the plug in to actuate the signal for several years. It is a good thing to give your old forgettory a shake up and make it remember, especially the more interesting things that occurred years ago."

In a phone conversation with W.M. Cory, Q.C., shortly before he passed away in 1971, he recalled that the time ball was situated near the gun. It was a brass ball, 15 to 18 inches in diameter, mounted on an iron mast about 20 feet high. The ball had a drop of about 8 feet, and when it was released the gunman pulled the cord which fired the noon day gun. Just prior to World War I, the gun was on the east side of the canal, pointing west, perhaps where it is located today.

When the Centre Block of the Parliament buildings was destroyed by fire in February 3, 1916, the connection to the time ball was damaged and never restored.

The growth of the public service in Ottawa was marked by the construction of new buildings and the consequent expansion of the observatory controlled time service. In a diagram prepared by W.A. Dier in 1936, just prior to his retirement, clock lines are indicated to twelve government buildings, ten of which had secondary master pendulums. Dials in the Mines Branch on Sussex Drive were controlled by the clock in the Museum at McLeod & Metcalfe, and those in the former Supreme Court by the clock in the West Block. Also, not shown, was the Archives (now the Canadian War Museum) whose clocks were controlled from the Mint next door. Fig. 49

Within the next few years a new Supreme Court and a Justice Building were erected on Wellington Street, a Postal Terminal on Besserer, Pg. 213 from the Dominion Observ ry through Bell Telephone exchanges to the government office ɔuildings.



Key to symbols: Queen Exch, Carling Exch and Rideau Exch are Bell Telephone exchange offices. The Queen Exchange served the central core of Ottawa and hence most of the government buildings. Cfdn - Confederation; H of C - House of Commons; Mint - Royal Canadian Mint; Sup. Court - Supreme Court (subsequently demolished and relocated to the west two blocks); WB - West Block; L.B. - Langevin Block. E.B. - East Block; P.B. - Printing Bureau (subsequently re-located in Hull); Hunter - Hunter Building; P.O. - Post Office (present site of War Memorial); Mines - Mines Branch formerly on Sussex at George Street; C.N.R. and C.P.R. -

and a Post Office on Sparks Street, each one equipped with dials and a secondary master pendulum attached to the observatory synchronisation system. At maximum there were about 750 dials in government buildings, the maintenance of which occupied much of the time of a technician and a watchmaker. This does not include the 100 or more dials of Centre Block, Parliament Hill, which were maintained by the resident engineer.

It is interesting to look back four decades and recall the devotion to duty of W.A. (Wally) Dier. His training as a telegraph operator provided him with the basic skills required to extend the clock service into new locations; his genial nature made him a good public relations officer; and his dedication caused him to drop in to inspect his clocks any time he happened to be in the downtown area. He was particularly concerned that the clock in the privy Council Chamber in the East Block registered correct time.

There was no immediate successor to Wally Dier on his retirement in 1936, and the writer was assigned this responsibility for several months till the appointment, in June 1937, of an electrical engineer, V.E. (Ted) Hollinsworth. The dials in the old Supreme Court building were controlled by the clock in the West Block. I was mystified by the appearance of an electrical relay which was housed in a rather elegant manner behind glass doors, this relay being a repeater from the clock in the adjacent West Block, and the control for the local dials. Only in the research for this story has it come to light that this relay was located in the original clock room of the time service!

During the postwar years, Ted Hollinsworth, who had spent several years in private industry after graduating from the University of Toronto, supervised the work of three successive technicians, Guy Lemieux, Walter Hewson, and Stanley B. Sim. The original watchmaker, J. Murray Walker, had retired, and was followed in succession by J. Hector and W. Foisy. By now some of the clock installations were almost beyond repair and were replaced by frequency dials which operated directly from the mains. The East Block was the first building to be changed when it was redecorated a year or two after the war. Some of the newer government buildings, such as the Forest Products Lab. on the Montreal Road, the Bureau of Statistics at Tunney's Pasture, and the National Research Council laboratories on the Montreal Road, had coordinated dials in each building installed by one of the several companies which provided such equipment. The servicing became the responsibility of the Department of Public Works, and was usually awarded as a contract to the supplier. By the end of the 1950's, the observatory had divested itself of the maintenance of clocks and dials in the public buildings, and Wm. Foisy became attached to the Surveys and Mapping Branch of the department. The hourly synchronization pulse continued in service for the benefit of the Bank of Canada and the clocks of the Centre Block of Parliament Hill, including the Peace Tower.

Fig. 50

When the timekeeping facilities of the observatory and NRC were amalgamated in 1970 to form the Time and Frequency section of the Physics Division, the hourly synchronization line was discontinued. A special line to the Centre Block of Parliament Hill has maintained the continuous seconds pulses with a voice announcement of time each minute. The service is used to check the clock of the Peace Tower, and also to provide a time mark on Hansard records. Other lines are leased by Bell Telephone, the RCMP, the Department of Communications, and the two CBC outlets CBO and CBOT.

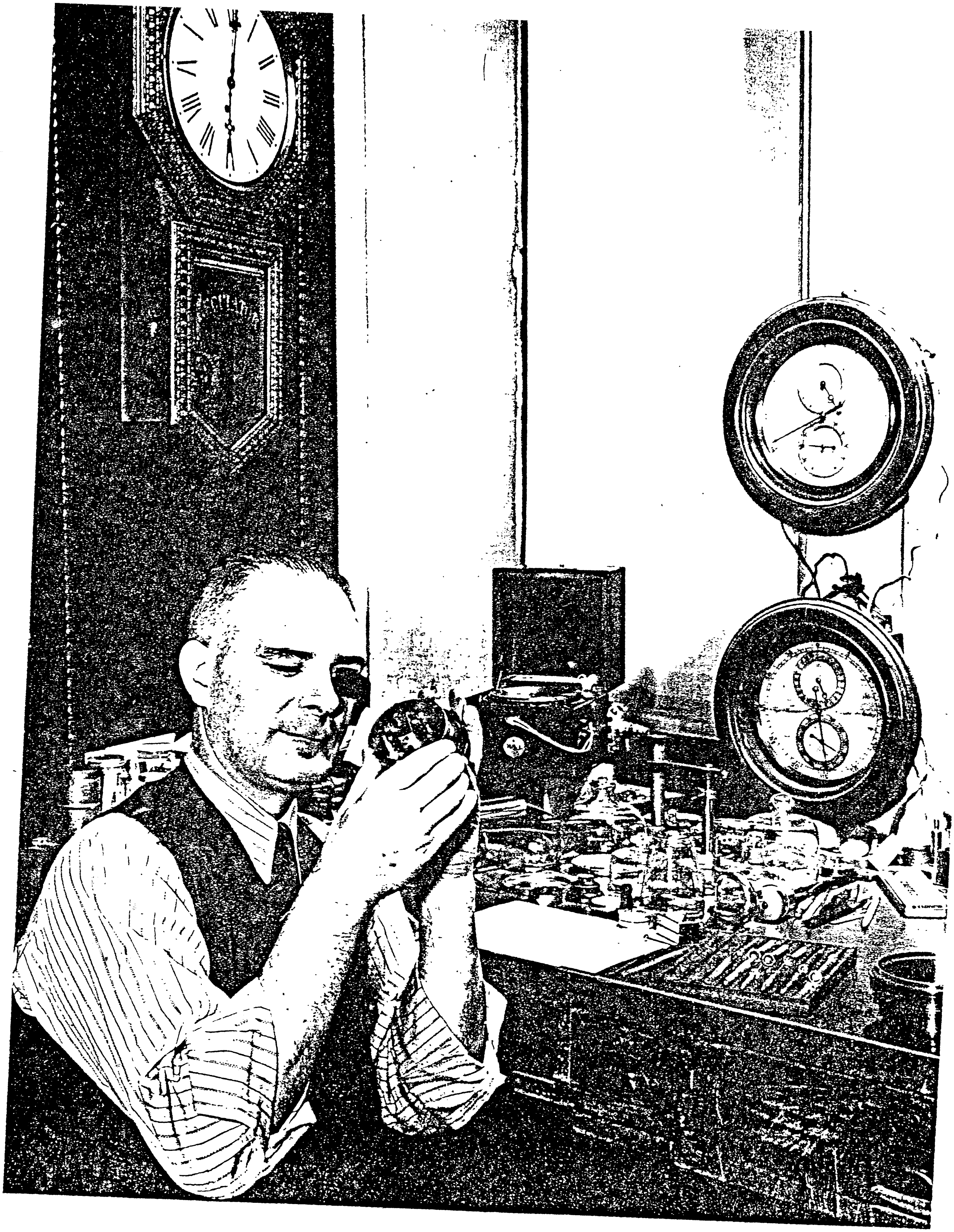


Fig. 50
Pg. 215 J. Hector, watchmaker at the Dominion Observatory from the mid 1930's till 1948. Both sidereal and mean time seconds dials were required to check the rates of chronometers used by survey parties. Photo by Malak 1943.

Size 65%

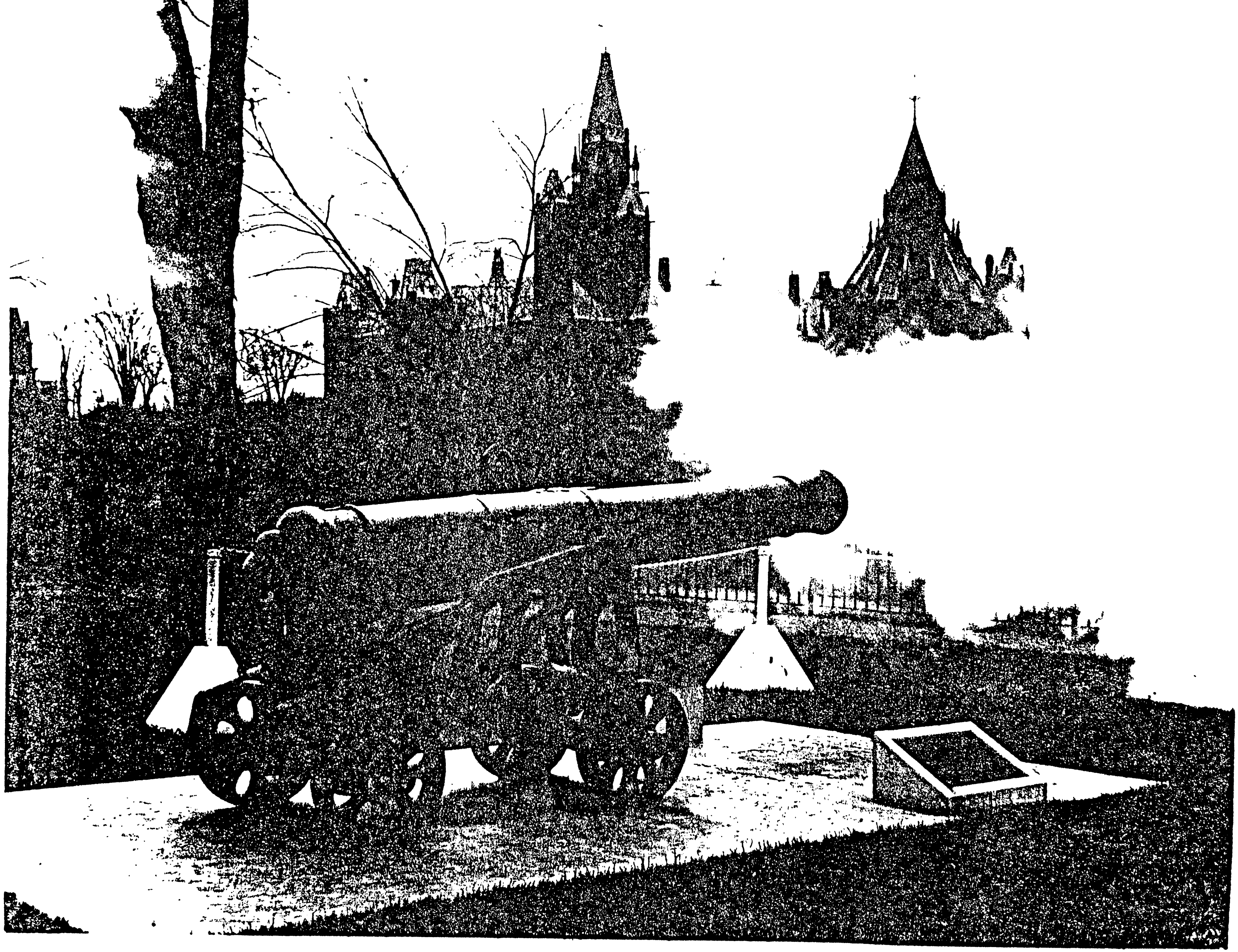


Fig. 51 The noon day gun, Ottawa. The clock of the Peace Tower reads 12 noon

The noonday gun used to be timed from the gun man's watch which he checked daily. His request, "Time for the gun" was heard over the time room phone each morning in plenty of time for him to proceed to the gun site and prepare the charge. Today the gunner has a special receiver tuned to CHU with which he can have the correct time, complete with voice announcement, at his elbow. Fig. 51

The Time Signal Machine

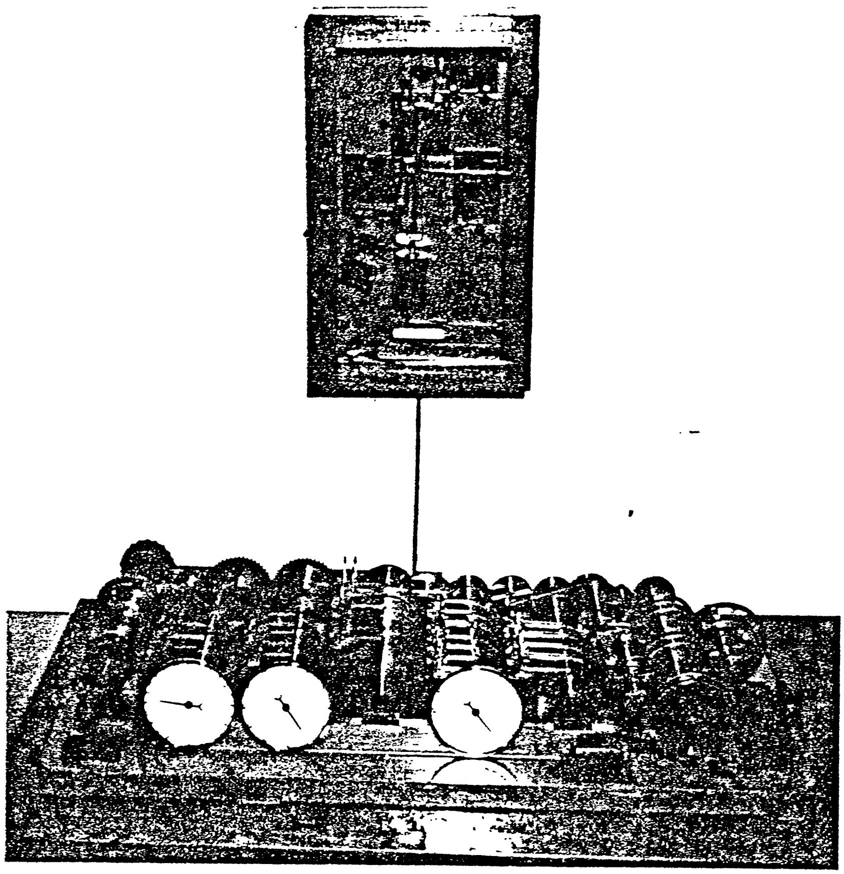


Fig. 52 The Time Signal Machine showing the details of the half
Pg. 217 seconds pendulum. Courtesy Earth Physics Branch, E.M.R.

THE TIME SIGNAL MACHINE

The Shortt clock was of such high repute that as soon as the capabilities of the Ottawa clock, S29, were demonstrated, R.M. Stewart commenced the fulfilment of a dream. He envisioned a mechanical device which would deliver mean time pulses, and yet be controlled by a sidereal source. It would therefore be required to identify the coincidence interval of 365.2422 mean time seconds, which is equal to 366.2422 sidereal seconds, and use this as a means of keeping itself in step with the sidereal primary. He was successful.

In principle this is what he did. By combining the gear ratios 79:130, 70:123, and 57:120, he arrived at a value of 60:365.2422. Hence, from a shaft which rotated once in 60 seconds, another shaft was made to rotate once during the coincidence interval. It is important to note that if the rate of the time machine were slow, the coincidence interval would be longer. Also it should be noted that the observed rate of S29, which amounted to several hundredths of a second a day, was added in to the above gear reduction. Hence the interval of 365.2422 mean time seconds was modified to make it equal to 366.2422 seconds of the best known value of S29 as determined by star observations. The rate of S29, which was added in, was recorded on an accumulating counter wheel and its value could be checked against the observed ΔT. Fig. 52

By another route, the coincidence interval was also achieved. In this method two relays, one from the time machine, and one from S29 operated side by side. When they were in exact synchronism, a current through the contacts of the two of them operated a third electromagnet which sensed whether or not the time machine shaft had completed its rotation. In the case of the two relays, if the one representing the time machine was running slow, it would be overtaken more rapidly by the sidereal relay, and the coincidence interval would be shorter; if the time machine impulses were faster it would take longer for the sidereal pulses to overtake them, and the coincidence interval would be longer.

The two methods of determining the coincidence interval produced opposite results, thereby exaggerating or doubling the effect of the gain or loss of the time machine.

The indicator on the time machine was a figure-of-eight cam on the output of the 365.2422 shaft. Adjacent to it was the electromagnet which was activated when the two relays came into synchronism. An arm from the electromagnet forced the figure-of-eight cam into the horizontal position, bringing it back if it had over run, or advancing it if it were lagging. The same impulse unlatched a contact wheel and through a differential gear attachment caused it to rotate forward or back an amount equivalent to the error in the position of the figure-of-eight cam. This error was then applied as a correction to the half seconds pendulum which controlled the escapement of the time machine.

The half seconds pendulum was mounted on the wall directly above the machine. It was only about one quarter the length of a seconds pendulum, and so required little space. The rod was of invar, and the bob of brass. A short sleeve of zinc was supported on an adjustable stirrup at the bottom of the invar rod, and the brass bob sat at its mid point on the zinc sleeve, thus attaining a good measure of thermal compensation.

a nickel steel alloy with a low coefficient of expansion

The rate of the pendulum was adjusted in the conventional manner by a screw at the base which raised or lowered the bob. A short auxiliary pendulum, supported in the same manner as the main pendulum, by a flexible piece of steel spring held in the jaws of the same clamp, provided the maintaining impulse each second. It was picked up just beyond dead centre of the swing, carried out and back, and released at dead centre. The over ride on the return trip was controlled by the armature of an electromagnet which was activated by the contact between the pendulum and its auxiliary.

An arm extending to the left from the top of the bob pushed a toggle switch back and forth as the pendulum passed through the centre of its swing in each direction. The toggle switch gave the impulse to the escapement relay of the time machine.

On an extension to the pendulum above the centre of support was a cone shaped cup. Into it could be lowered a piece of brass of the same shape when the sensing mechanism indicated that the time machine was in advance and had to be retarded. If the weight were large enough so that it balanced the weight of the bob, then intuitively one can see that the period would become infinite, and the pendulum would tend to rotate like a wheel. The small weight was made of the correct size to increase the period and retard the pendulum the required amount. The advance was accomplished in a manner similar to the accelerating impulse given to the S29 slave. A long leaf spring, which extended upward from the pendulum bob, was engaged by the armature of an electromagnet and depressed as the swing continued to the right. On the return of the pendulum to the left the spring was released. The spring was depressed on successive swings till the proper advance had been achieved.

In the two operations of advance and retard, the correction amounted to 0.0007 second per second, so that even during the interval that the correction was being applied, the length of the second delivered by the time machine differed from a true mean time second by less than a thousandth of a second. The total correction seldom exceeded one hundredth of a second.

The time machine was weight driven, and the weight was wound automatically. In keeping with the latest design of pendulum clock, the act of winding increased slightly the torque on the train of gears. The weight of some 300 pounds was applied to the slow moving end, and the winding drum had a capacity of about a week. As one might expect, the heavy duty gears gave way to progressively lighter duty ones as the drive progressed from the slow motion of one revolution per day to the more rapid motion of one revolution per minute.

The output of the time machine was contained on five shafts on which were notched discs. Fingers which rode on the discs, and which dropped into the notches, made the required contacts. The five shafts had rotational periods of once per day, once per hour, once per five minutes, and two at once per minute. The slower moving discs acted as gates through which the signals from the faster moving ones acted. For instance a disc on the day shaft provided the opening once each day for the signal to the C.N. telegraph office. The signal awaited an opening provided by a disc on the hour shaft, and the actual signal was given by two carefully coded discs on one of the minute shafts. A similar process was followed for the signal to the C.P. telegraph an hour later. A synchronizing pulse to the secondary control pendulums in the downtown

Fig. 53

Fig. 53. .B. Nugent with his hand at the 5-minute shaft of the Time
Pg. 220 ignal Machine. Photo by Malak 1943.

65%

government buildings went out each hour, and involved only the hour and the minute shafts.

CHU seconds pulses were initiated by the half seconds pendulum itself in order to avoid the slight eccentricity which was almost impossible to avoid when mounting a disc on a shaft. The omissions, which included the 29th pulse, and a coded sequence at the end of each minute of a 5-minute sequence, involved a disc on the five minute shaft. Also, the long dash on the hour, followed by the call sign C-H-U, delivered in morse code twice in the first minute of the hour, involved a coded disc on the hour shaft as well as a minute disc with the morse symbols.

A 24 hour dial with hour hand was mounted on the end of the day shaft, a 60 minute dial on the hour shaft, and a 60 second dial on the end of one of the minute shafts. At a glance, then, one could read the time. The control was the escapement relay which was operated as a uniform off-on impulse directly from the pendulum toggle switch. The escapement relay also controlled the rate at which the intricate system of gears transformed from mean time to a coincidence interval, involving the ratio of 60:365.2422. It is not known for sure when Stewart commenced working on the design, but it is estimated that its construction monopolized an accumulated total of two years of machine shop time. The result was an ingenious combination of gears, and a monument to the skill of the machinist, L.P. Christenson and his assistant A. Bird.

There were two time machines, one always at the ready in case the other required servicing. Each was mounted on a heavy cast iron base, which in turn was mounted on an oak bench. The two benches occupied adjacent walls in one corner of the time room. Glass dust covers protected both time machines and both pendulums. The cabinet space under each bench contained relays, wiring terminals, and the winding motor. Each machine was independently synchronized with respect to S29, and there was the possibility of one drifting away from the other. To warn that such might be happening, they were interconnected to an alarm bell which sounded if they differed in output by more than 0.015 second.

The time machines were set in operation in 1938, and for more than a decade they served their intended purpose. Each time machine was capable of controlling the complete mean time requirements within the observatory such as seconds dials, minute dials, the tower clock in the dome, and shutters for the seismic recorders. In addition they controlled all the mean time output, including the synchronization pulse for the government buildings, the continuous signals for CHU, the individually coded signals for each of the two telegraph companies, the noon signal for the CBC, and the special seasonal signals relayed to the Monitoring Station for the benefit of survey parties, and to the Department of National Defence for navigation on the North Atlantic.

V.E. Hollinsworth, was responsible for wiring up the circuits and adjusting the discs on their shafts. His shortness of stature worked to his advantage in that he was able to get right inside the cabinets under the time machines to work on the wiring. His engineering skill, together with the inventive genius of J.P. Henderson, was in no small way responsible for promptly bringing the time machines into successful operation. Henderson (1891-), who will be formally introduced on page 290 kept a diary during his active career at the observatory (1919-1956). He has made it available and it has been a valuable source of information.

An assessment of the time machines, published in 1948, is still a valid statement, and is reproduced here. "Defects of this system are due to the following considerations:

"1. The daily rate of S29, which is a little more than a tenth of a second a day losing, has to be accounted for mechanically by the time signal machine. The mechanism for doing this can be set only to the nearest hundredth of a second. Frequent adjustments have to be made in order to keep the clock correction indicated by the time signal machine the same as the correction indicated by star observations.

"2. The moment of coincidence between the half seconds pendulum and S29 may occur during a period when the slave seconds are irregular following the half minute maintaining impulse. Or it may occur while the 0.004 second accelerating impulse is being administered to the slave. These two defects combined may mean that the time of the half seconds pendulum before and after a correction may differ by as much as 0.01 second.

"3. The half seconds pendulum may, itself, have a variable rate because its protective case is merely dust proof and does not provide temperature or pressure control. The pendulum is compensated for temperature only.

"4. The time signal machine operates with an escapement, and the resulting banging, starting and stopping, is not now considered to be good for the mechanism or for the personnel who are obliged to work in the same room. A proposed improvement is to have the time signal machine operated by a controlled frequency motor, the primary control being a crystal clock. It is readily adaptable to the greater precision of a crystal control.

"The above mentioned defects should not be overemphasized. A pendulum timekeeper has the advantage of long uninterrupted service, a distinction towards which the crystal timekeeper is progressing. It is perhaps worth repeating that in the present system of timekeeping at the Dominion Observatory, the actual star observations constitute the weakest link.

"The accuracy of the time signal machine is only slightly less than that of S29. And since the variations in the seconds beats of S29 from hour to hour are normally less than 0.01 second, the short period fluctuations in the time signal machine seldom exceed 0.01 second. From day to day the rate of S29 varied slowly between 0.13 and 0.16 second per day during 1947 but the overall rate was about 0.148 second. The short period fluctions of 0.01 second or less are of too small an order to be detected by surveyors and other government or private field parties, though the errors will be incorporated in their results. Nor are they of concern to the average Canadian who hears the CBC signal at one o'clock eastern time each day. They are, however, too large for present day laboratory measurements unless the measurements can be made over an extended period of time." (Jr. RASC, 42, 105, 1948).

In retrospect, there were moments of humor attached to the maintenance of the time machines. Once, when the contacts of the fingers of TMI were being serviced, the escapement ratchet was accidentally lifted. Immediately the gear train started to accelerate out of control. The contact fingers danced on their discs like the fingers of a pianist until the heavy drive weight came to an abrupt stop at the bottom of its run. Two days were required to restore all the discs to their proper orientations.

An opportunity to try a 60-cycle crystal controlled motor on one of the time machines came in 1949 when S29 was accidentally stopped. For a while the time room enjoyed a delightful freedom from one of the half seconds thump, thump. The circuitry had been available and tested, but lacked official approval. Now the superior short term precision of the crystal oscillator could be demonstrated. Two months later, a relay failed, the time machine drifted in error a matter of eleven seconds, and the CBC, with the same error, was embarrassed. An entry in the diary of J.P. Henderson for November 29, 1949 reads, "Time Machine #2 put back on S29. Now both machines are on S29 - so many failures of crystal - all parts of relays have given troubles." In spite of this pessimistic remark, Henderson actually held more firmly to the following statement which appeared in the quarterly report of the time service division in July of 1947, "When pendulum clocks are in use, long periods, hours or days, are required to determine rates. When crystal equipment is available, equally accurate rate comparisons may be made in a few seconds. This also applies to radio signals used to correlate the time services of different countries."

C.C. Smith also had an appreciation for the electronic contribution to timekeeping. In 1936, when he looked forward to the acquisition of a second Synchronome to occupy the fourth room in the clock vault, he added the statement, "The crystal clocks [of the Department of Marine and Fisheries, and of the Canadian Radio Broadcasting Commission] are giving valuable data on the rate of S29."

A second Synchronome was never acquired by the Dominion Observatory. Instead, on April 17, 1942, a General Radio Frequency

Standard arrived. The basic frequency was derived from a quartz crystal bar cut to resonate at 50 kilohertz. This was stepped down by multivibrators to one kilohertz which controlled a synchronometer whose output could be read by interpolation to the millisecond. And because the contact could be brought into synchronization with radio signals from Washington, Rugby, etc. the difference to the thousandth of a second between them and CHU was readily established. April 1942, therefore, marked the birth of the observatory crystal clock which was designated Co.

Stewart never lost his faith in the pendulum as the ideal oscillator. With the assistance of Hollinsworth he pursued his research, even after his retirement in 1946, applying the principles of thermal control, thermal compensation and photoelectric pick-off. He was one of the last survivors of his generation. The pendulum had already been superseded by the quartz crystal frequency standard at Greenwich and Washington, and by 1950 it happened at Ottawa.

In October 1951 the arrival of two Muirhead timing devices, designed to operate from 1000 hertz supply, rendered the time signal machines obsolete except for that portion which generated the coded signals for the CN and CP telegraphs. They were converted to synchronous drive, and for a while operated in parallel with the Muirheads. Later they were dismantled and the space was made available for more racks of electronic equipment. Two compact time signal machines were constructed, using only the required shafts and discs and contact arms to generate the coded time signals. They are still operating and the information is still fed to the CN telegraph office. The line to the CP telegraph was discontinued when the move was made from the Observatory to NRC in 1970.

Astronomical Equipment of the Time Service

ASTRONOMICAL EQUIPMENT OF THE TIME SERVICE

The primary function of the Ottawa observatory, when it was first established on Cliff Street, was to determine the time from transit observations of stars, and to compare the local time with that observed at field stations in order to measure the difference in longitude. As soon as it became operative in 1896, its own position with respect to Greenwich was established by extending the measurement from Montreal to Ottawa. The Cliff Street Observatory thus became the primary meridian for the determination of longitudes in Canada, and when the Dominion Observatory was inaugurated on the corner of the Experimental Farm to the south west of Ottawa in 1905, the Canadian prime meridian was moved there. The transit annex of the Observatory was not completed until a couple of years later, during which interval a temporary transit hut was occupied to the east of the Observatory building, and its observing pier defined the prime meridian. Then when the transit annex was completed and the meridian circle telescope placed in operation, the prime meridian was relocated as the north south line through its optical axis, originally determined as $5^h\ 02^m\ 51\overset{s}{.}983$.

The transit instrument, which was designed by Roemer of Denmark in 1704, is a relatively small telescope mounted on a horizontal east west axis so that it has freedom of motion in one plane only, the plane of the meridian. It can normally be pointed in any direction along the meridian, from north to south, and then depends upon earth rotation for motion from west to east. A star on which the telescope has been set will be seen to drift across the field of view, the nearer the equator the greater its apparent speed. The earth will have made one complete rotation on its axis when the same star is seen to pass again through the centre of line of sight, 24 hours later. Due account of course must be made for procession and proper motion. Precession is the steady change due to motion of the coordinate system, and proper motion is the change due to the star's own motion.

A great deal of preliminary work must be done before the stars can be used to determine the time. Hours of painstaking observing are required to "map" the sky, to determine the positions of a representative group of stars within the slowly changing coordinate system described by the equator and the vernal equinox. A star catalogue in use today is thus the result of the accumulated effort of many dedicated individuals who have spent the quiet watches of the night following the majestic parade star by star, measuring the elevation and marking down the time of transit of each one.

The transit instruments used in the early survey of the Canadian west were equipped with vertical threads, or similar markings on a glass reticule, and the star would be observed to pass each thread during its transit. Illumination of the threads was provided by a small amount of light introduced through one end of the hollow axis and reflected towards the eyepiece by a prism or small mirror. Otherwise the threads would not be seen. For a bright star the light could be bright, but for fainter stars the light had to be dimmed but only to the point where the threads or lines were still visible. As a result, transit observations of stars by eye were limited to the brighter stars.

A clock or chronometer or watch - some form of time piece - is an essential tool for the astronomer, so that he can determine the time of transit of each star. Timing the actual transit of stars whose positions have been well established, enables him conversely to measure the error of the clock, and therefore establish correct local time.

Learning to use a transit telescope has been described by Otto Klotz, who had his introduction into its mysteries when he was named astronomer in charge of the longitude and latitude work along the Railway Belt in British Columbia. The time piece was a box chronometer beating half seconds, and the transit had five threads. Transit observations were made by the "eye and ear" method. It was the duty of the astronomer to count to himself the seconds and half seconds that he could hear, holding the watch to his ear, and at the same time he would watch the star as it passed behind each thread in succession, and record the time.

"How well I recollect", wrote Klotz, "how the prespiration ran down my face and neck while observing transits at Seattle, my first station [June 1885]. Picking up the beat of the chronometer; carrying it mentally forward while watching the transit; hurriedly jotting down the beat, still carrying on the counting, for to look at the chronometer would probably mean the loss of catching the transit of the next thread, was strenuous work. ... With continued observations some composure was attained, and the transits were found to take place not only at the beats and midway, but at other divisions." Later that same season he could report, "Composed I sat at the eyepiece. The [chronometer] beats were slowly (apparently) running their course and the mind could easily, yet unconsciously subdivide the time intervals, ... the tenth of an interval or twentieth of a second ... [occasionally being] estimated." Klotz continued his story. "To test the accuracy of the longitudes determined by the eye and ear method, one of the stations was many years afterwards occupied by another observer supplied with the most modern outfit; Cooke transit with transit micrometer; chronometer with electric attachment, and chronograph; observing seven stars instead of just five for one position of the clamp, besides using more zenith stars and fewer equatorials than formerly. The longitude obtained agreed within a few hundredths of a second with that of the eye and ear method." (J. RASC, 13, 288, (1919).) This was perhaps a reference to the remarkable work of Wm. Ogilvie on the Alaska boundary during the winter of 1887-88, followed by F.A. McDiarmid in 1906, in which the difference as marked on the ground was only 218 ft. (Men and Meridians by Don Thomson, Vol. 2, pg. 196). At the age of sixty-six, when these words were penned, Klotz looked back with some pride on the results obtained under the more rugged conditions he experienced as a younger man.

The first improvement in meridian observing came with the invention in 1850 by W.C. Bond, Harvard College Observatory, of the Spring-Governor, a gravity driven drum chronograph on which the beats of the clock together with the electrical impulses transmitted by the key in the hand of observer were recorded. With this convenient recording device the observer watched the star approach each thread, and at the mid point of transit of the thread pressed the key. Bond described the advantages of his device. "In three most important requisites it has unquestionably the advantage over any of the plans hiterto used; - it is more accurate in its results; it is superior in the point of convenience, and in this respect recommends itself to the observer, relieving him from much labor, and contributing to the ease and comparative comfort with which the work can be prosecuted; lastly, the time necessary for completing an observation is greatly shortened ..." (Annals of Harvard College Observatory, Vol. 1, Part II, pg. V.)

The next big advance in observing technique was the travelling wire micrometer designed by Repsold towards the end of the 19th century. Described also as the impersonal micrometer, it was hailed as the device which would free the observer of his personal equation. He would no longer be guilty of consistently pressing his observing key a little early or a little late compared to another observer. Always at the beginning and end of a field season the field man was required to observe along with the base station astronomer, each using his own transit, to measure this systematic difference. Now that was no longer required. A single wire, or closely spaced pair of wires, was fastened to a slide which could be made to move in an east west direction by a screw terminated at each end by a small hand wheel. The eyepiece was carried on the same slide so that the moveable wires appeared always in the centre of the field of view. Now the astronomer watched as each star moved into the field of view. Then when the star was properly bisected by the wire, or was at the bisection position between the pair of wires, he would turn the hand wheels so as to hold the star at that attitude till it had moved across the field of transit. The hand wheels also drove a commutator wheel against which a brush made contact with each of the strips embedded in the wheel. These contacts were recorded along with the clock beats on the drum chronograph to mark the time that the star was in various positions during transit. They effectively gave the time, according to the local observing clock, that the star was on the meridian.

R.M. Stewart was one of those who thought that he had a small and fairly constant personal equation with the old fixed wire method. In a series of tests to measure the personal equation between himself and F.A. McDiarmid, he used an instrument equipped with a glass reticule while the other was equipped with a transit micrometer. The difference between the two averaged out to about 0.35 seconds. Then Stewart ran another series of observations in which he himself alternated in the use of the two transit instruments. To his surprise several nights work showed the same difference of 0.35 second in his clock corrections, convincing him completely that he had a large personal equation with the fixed reticule, and that the transit micrometer eliminated from the results most of the effects of the observer's personal equation.

There was still the tendency for the observer to lead or lag systematically as he followed the centre of the star across the field. This was overcome in the field type of transit (the Cooke or Heyde) by reversing it on its pivots at the mid point of the transit. Then the star would be seen to enter and leave through the same optical side of the instrument, and also the apparent direction of motion of the star would be reversed. The first effect, i.e. using the same side of the little telescope to observe the entrance and departure of the star, cancelled the effect of any collimation error. The second effect, namely reversing the direction, meant that the contacts from the commutator wheel were the same in reverse order, except for the width of the contact strips. The first and last contact were therefore equally distant from the time of mid transit, and so were the second and second last, and so on.

The larger meridian circle, whose reversal on its pivots required upwards of half an hour, and in fact was routinely done only once or twice a year, was equipped with a dove prism in the optical path of the eyepiece. Turning the prism through 90 degrees reversed the optics by 180 degrees, and gave the impression of the star reversing its direction of motion, though of course the micrometer hand wheels had to continue to turn in the same direction.

Great care was taken to measure and account for the personal equation, especially during the world longitude campaign of 1933. A machine was built to simulate a star moving at three different speeds which could be selected by the observer, one speed to simulate a fast moving star of 0 degrees declination, one for a mid declination of 45 degrees and one for a slower moving polar at 72 degrees. Contacts were made by the machine as the star (small light bulb behind a pin hole) was driven from right to left and then back again. These were compared to the contacts recorded by the eyepiece micrometer.

Some doubt seems to exist concerning the validity of the personal equation machine. C.C. Smith noted that in the 1933 observations in Vancouver he and H.S. Swinburn had a relative personal equation of -0.10 second as revealed consistently by the clock corrections each one observed. The personal equation machine gave a value of only -0.03 second. It was hardly to be expected that the machine could simulate actual conditions of observing. The Ottawa machine was placed in the south azimuth hut 150 feet away and viewed through a collimating lens. All the viewing therefore was done with the telescope in a horizontal position. One might have thought that the Vancouver measurements would have been more favourable since both observers used broken type transit instruments with a fixed viewing position at the level of the pivot. However, the two transits differed in both aperture and focal length, the one being a Cooke of 3 inches aperture and 3 feet focal length, while the other was a Heyde of 2 inches aperture and about 21 inches focal length, and the machine was mounted for use only with the Cooke. In the post World War II years when several observers made use of the Cooke for time determinations, at the Observatory no attempt was made to measure and apply a personal equation. More weight was given to the internal consistency as revealed by the individual stars, and to the fit of the night's work in the final clock curve.

The story of the small reversible transit will be continued later. When plans were formulated in the minds of King and Klotz for a Dominion Observatory in which provision would be made for research, a logical avenue of research was that of positional or fundamental astronomy. Canada has a very long international boundary with the United States, half of which is an east west line defined by the 49th parallel of latitude. Its position had been delineated astronomically, using stars whose positions were not too well defined. So it was desirable to incorporate in the new building a larger transit, equipped with accurate measuring facilities so that an accurate catalogue of these latitude stars could be made. It was recognized, of course, that improved star positions were also of practical value in the measurement of longitude, azimuth and time. The time was required in the local government buildings, the telegraph and telephone companies, and also throughout the local community. Beyond the local advantages of a good time service, a program of fundamental astronomy would provide reference stars for research in astrophysics and stellar photography, yield evidence concerning variations of latitude, longitude and time, and of course provide the information from which to derive proper motions of the individual stars.

The meridian circle, purchased from Troughton and Simms, arrived in October in 1907, but not until January 1911 was it finally placed in operation. A description by R.M. Stewart in his annual report of 1908 is as follows: "The telescope is of six inches aperture and about seven feet focal length; the field contains six vertical threads and two horizontal ones, in addition to the moveable micrometer threads; the right ascension micrometer is supplied with the Repsold automatic registering device. The field illumination is provided for by an annular reflector in the axis; bright wire illumination is effected by four small electric lamps inside the tube near the eye end. (This was later changed to dark wire illumination with a small lamp near the objective.) There are two circles [36 inches in diameter], each graduated to every five minutes, one being fixed in position on the axis, the other moveable . They are read by four microscopes each, two pointer-microscopes (one for each circle) being provided for reading to the nearest five-minute division. There is an end-thrust bearing at each end of the axis, one being fixed, while the other is tightened by two nuts pressing against coil springs; this ensures the constancy of the position of the telescope with respect to the standards, so that the division marks may always be in focus in the reading microscopes. There are two collimating telescopes each of four inches aperture and about four and a half feet focal length. For reversing the telescope a reversing carriage is provided, which runs on rails between the piers. The level is read by nadir observations on a circular mercury trough with the usual [Bohenberger] collimating eyepiece." A platform mounted on top of the reversing carriage served as a stand from which the observer could look down through the telescope to see the micrometer wires reflected back from the mercury basin.

It was indeed a splendid instrument. More than three years, however, were to elapse before it was finally ready for operation in January 1911. The large graduated circles were returned to the maker because they were warped slightly in transit. The circle reading microscopes had to be remounted because they were unstable. The pivots turned out to be soft and had to be renewed, and the counterpoises had to be completely remodelled. Iron shutters, which had been installed originally to cover the slots of the transit room, warped so badly they no longer kept out the rain or snow, and had to be replaced with wooden shutters. Perhaps worst of all, the cement piers had to be completely rebuilt so that they penetrated more deeply below the frost line and also that they were protected with adequate drainage. All this was done under the watchful eye of Mr. Stewart.

Finally, with everything in readiness, the collimation piers and the azimuth mark piers completed, and the meridian circle almost completely rebuilt, the first program was prepared. In this unpublished report of 1930, C.C. Smith wrote: "With the purpose of confining the Fig. 54
observations to those stars chiefly which were being used, or likely to be used, in latitude and longitude observations for geographical positions in northern latitudes, a list comprising 3162 stars was compiled suitable for latitude observations. This list comprised, with some exceptions, the following stars:-

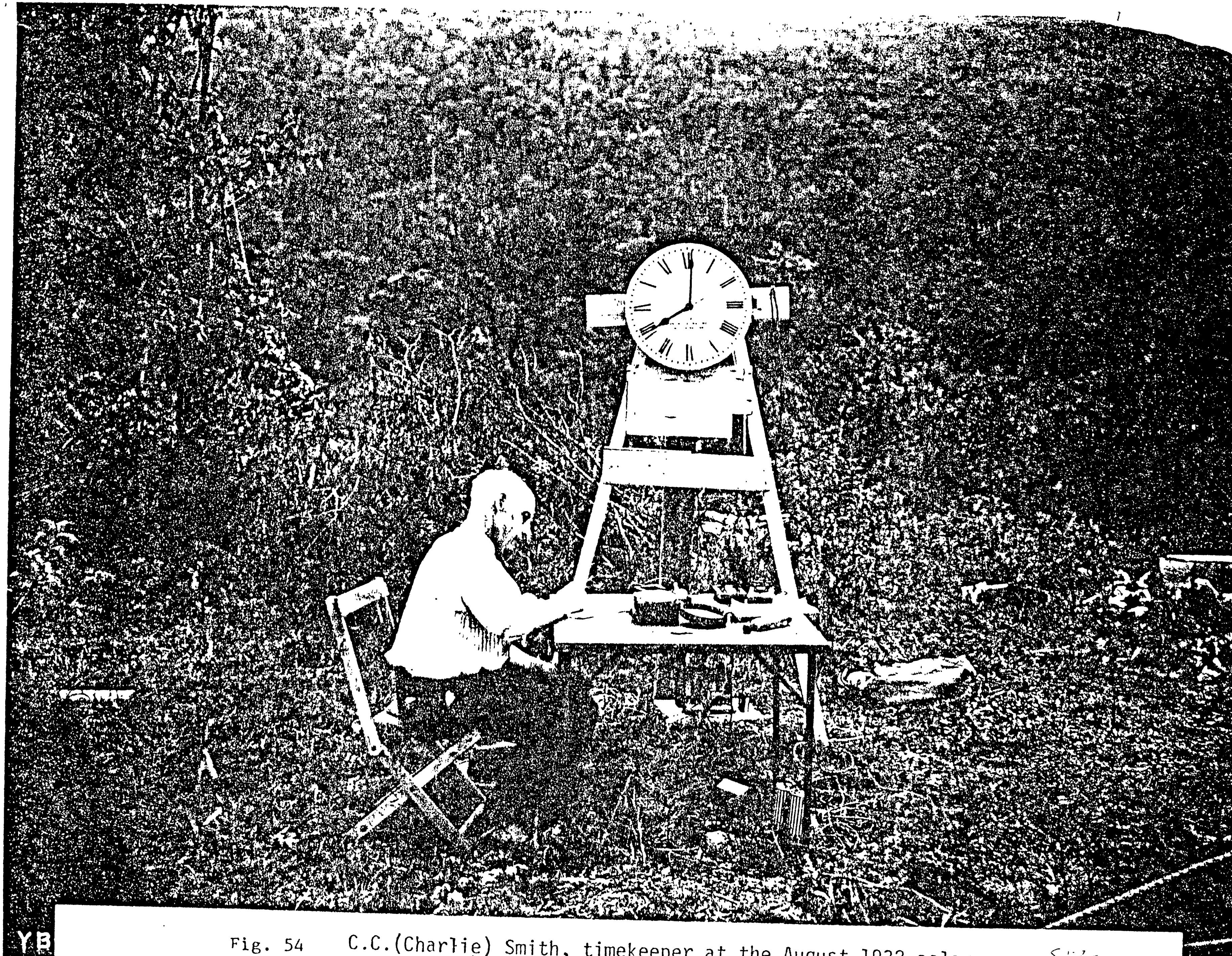


Fig. 54 C.C.(Charlie) Smith, timekeeper at the August 1932 solar eclipse camp established by the Dominion Observatory at St. Alexis-des-Monts, P.Q. Courtesy Public Archives of Canada.
Pg. 236

(a) All those north of 20° declination, and many between 10° and 20° in Boss' Preliminary General Catalogue for 1900.

(b) All those between the same limits of declination in Ambronn's Sternverzeichnis for 1900.

(c) Such additional stars as had at any time been used by this observatory in latitude observations.

"The exceptions were stars fainter than magnitude 7.5, and close unequal doubles considered unsuitable for measurement. The list included 255 standard stars, 180 fundamental stars and 21 azimuth stars to be observed.

"Each meridian circle observation required the following operations, - setting the telescope ready for the appearance of the star, reading the circle microscopes, observing the star in right ascension and in zenith distance, reading the temperature, and, in addition the necessary readings for collimation, level, nadir and azimuth. Each observation required in computation 33 operations in right ascension and 36 operations in declination, and the final discussion of the results, which can only be done after the whole program is completely observed, is involved and lengthy. A total of 28,000 observations were made of the stars on this list. Incidentally that has required over one and one-half million computations. Let anyone who lacks patience and demands immediate results beware of undertaking meridian observations on a list of stars. The observations were completed in 1923.

"The values of the micrometer screws and the series of observations necessary for the determination of pivot errors, were made in 1910, 1912 and 1916, and the readings for the corrections to the declination circle graduations in 1920. This latter series of measurements required a total of 22,000 readings. In Greenwich and Paris Observatories, where similar observations have been carried on for over two centuries, the multitudinous observations necessary for defining star positions have ceased to be terrifying. Actually, to one who enjoys measuring, the work is not distasteful and the results are of great interest and are necessary."

C.C. Smith was away from the observatory between 1912 and 1919, and W.S. McClenahan was on military duty for three years. The observing team was for a while reduced to three persons, R.M. Stewart, D.B. Nugent, and R.J. McDiarmid. To these five men goes the credit for taking observations and doing a great part of the computing. Others who assisted in the computation were W.C. Jacques, E.C. Arbogast and A.H. Swinburn, while Dave Robertson assisted in reading the chronograph records.

"By the time the Latitude Program was completed", continued Smith, "the meridian circle and its accessory equipment were in excellent condition; the different constants of the instrument had been almost all well determined and the experience gained was of very considerable benefit.

"At the meeting of the International Astronomical Union at Rome in 1922, it had been recommended by the Commission of Meridian Astronomy that such observatories as had the suitable equipment should undertake the fundamental observation of part of a list of 3064 fundamental stars published in the Connaissance des Temps for the year 1914. It was decided, therefore, that the Ottawa meridian circle could render this service to astronomy and that it was our duty to do our part as one of the national observatories of the world in taking on the observing of such of these stars as could be most profitably observed here. The stars on the Ottawa list are known as the Backlund-Hough stars [so called after the two astronomers whose work was used to compile the Connaissance Des Temps list] and comprise a list of 1368 stars. In addition to these there are, of course, the 180 clock stars, 21 azimuth stars, the sun, moon and planets."

The intention was to observe these stars twice in each clamp and then to interchange the eyepiece and object glass and repeat, a total of eight observations. The first half of the program was completed in 1935 and the second half commenced.

Several events combined to reduce the scope of the plan that had been so well conceived. C.C. Smith retired at the end of 1937, and the program was deprived of one of its most enthusiastic observers. 1937 saw the publication of Benjamin Boss' General Catalogue of the positions and proper motions of 33 342 stars. It seemed as if the job had been done, and general interest in positional astronomy tended to flag. The Ottawa program was reduced in scope by dropping observations of the sun, moon and planets. The position of the ecliptic, and hence of the stellar coordinate system, could no longer be derived from the Ottawa observations. Instead the stellar positions were determined with reference to the framework of standard stars. By the outbreak of World War II, R.J. McDiarmid and H.S. Swinburn alone remained to continue the meridian circle program, while W.S. McClenahan was responsible for time determinations using the broken type Cooke transit.

C.C. (Charlie) Smith (1873-1940) was a competent scientist who preferred to work on the practical or observational problems of his profession. He had come to the Observatory in 1908. During his seven years absence he was successfully self employed as a surveyor at the west coast. Sports of all kinds interested him, but he found time only for golf and curling. His love for music often found him at his piano in the small hours of the morning as he relaxed after a session of observing. Occasionally his rich base voice could be heard coming through the open shutters of the transit room in song as he waited in the darkness for the next star to appear. It is not certain whether Charlie ever carried an expensive watch, but he did carry an inexpensive one. He claimed that when at work he was surrounded by the finest of timekeepers, and when he was at play he wasn't too concerned about exact time. He lived to enjoy only two and a half years of retirement, and passed away while playing golf.

D.B. (Bert) Nugent, who succeeded C.C. Smith as chief of the Fig. 52
time service, had joined the staff in 1907 and made a notable contribution as an observer during the pioneer days, and throughout the first program of the meridian circle. In 1923 he was assigned the duty of working up the clock corrections from the meridian circle transit observations, and supervising the maintenance of the primary clocks of the Observatory as well as the downtown time service. Of a retiring nature, he nonetheless enjoyed curling and horseshoe pitching with the staff, and was active in the Masonic Order and in his church.

By the time D.B. Nugent became head of the division in 1938, he was not enjoying very good health. Six years later, on the advice of his doctor, he took early retirement at the age of 63. He lived to enjoy several years of leisure, being 76 when he died.

W.S. (Bill) McClenahan, (1892-1968), who succeeded D.B. Nugent, Fig. 55
was one of those individuals who seemed to be good at everything he

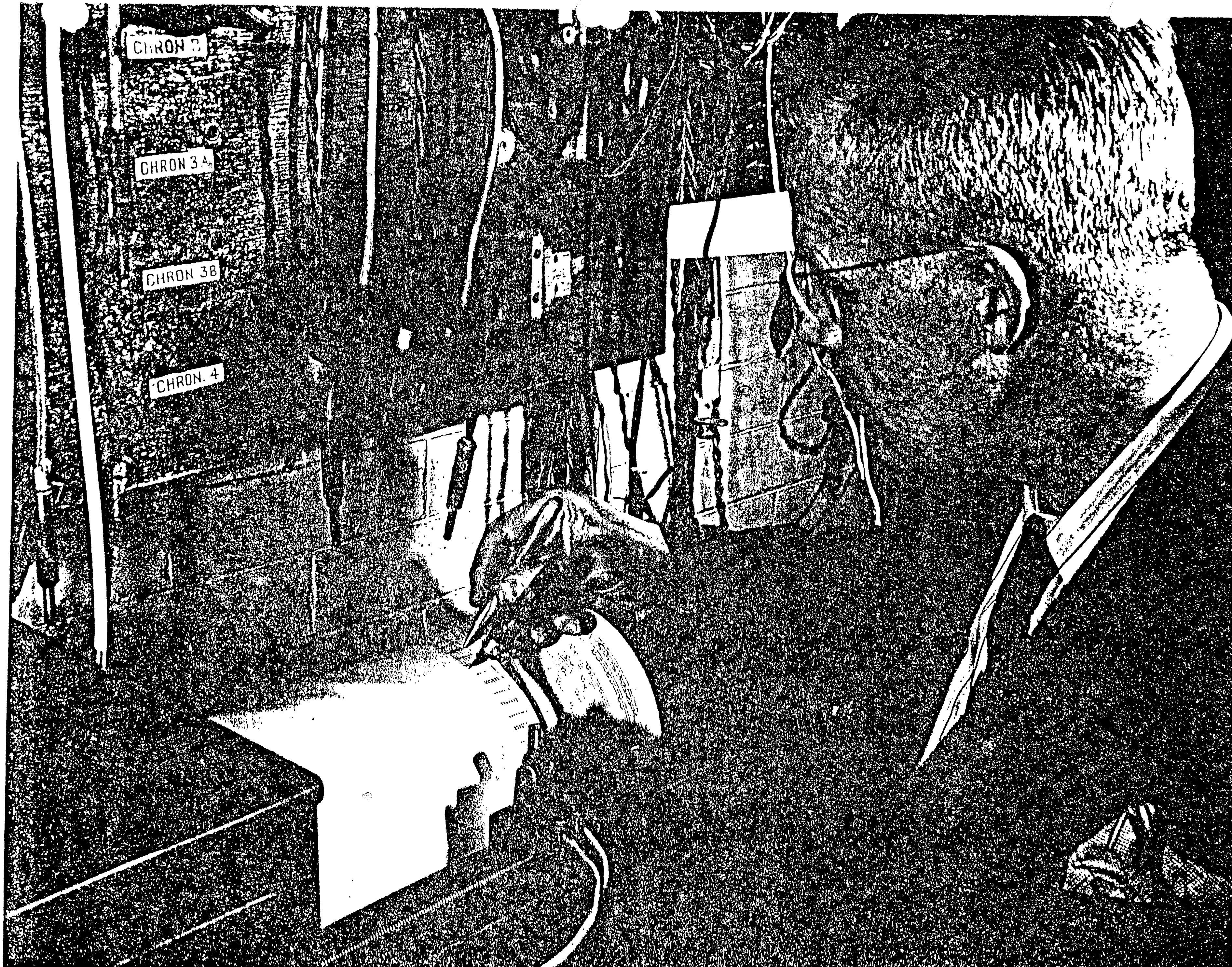


Fig. 55 W.S. McClenahan, marking time on the drum chronograph prior to
Pg. 240 taking an observation with the transit instrument. Photo by

27

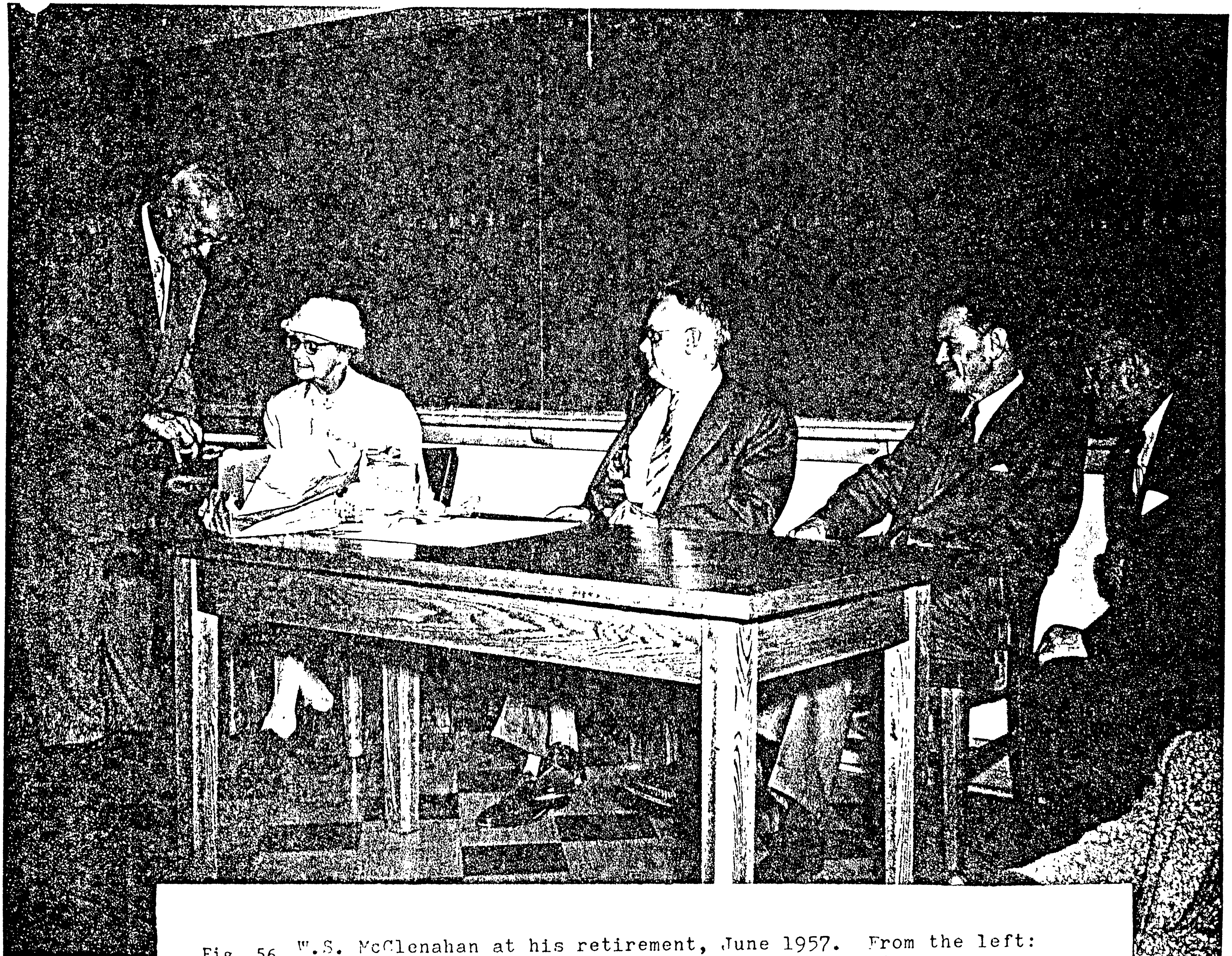


Fig. 56 W.S. McClenahan at his retirement, June 1957. From the left:
Pg. 241 W.S. McClenahan, Mrs McClenahan, Dr. C.S. Beals (Dominion Astronomer), Dr. Marc Boyer (Deputy Minister of the Department of Mines & Technical Surveys), Dr. Don W. Thomson (Secretary to

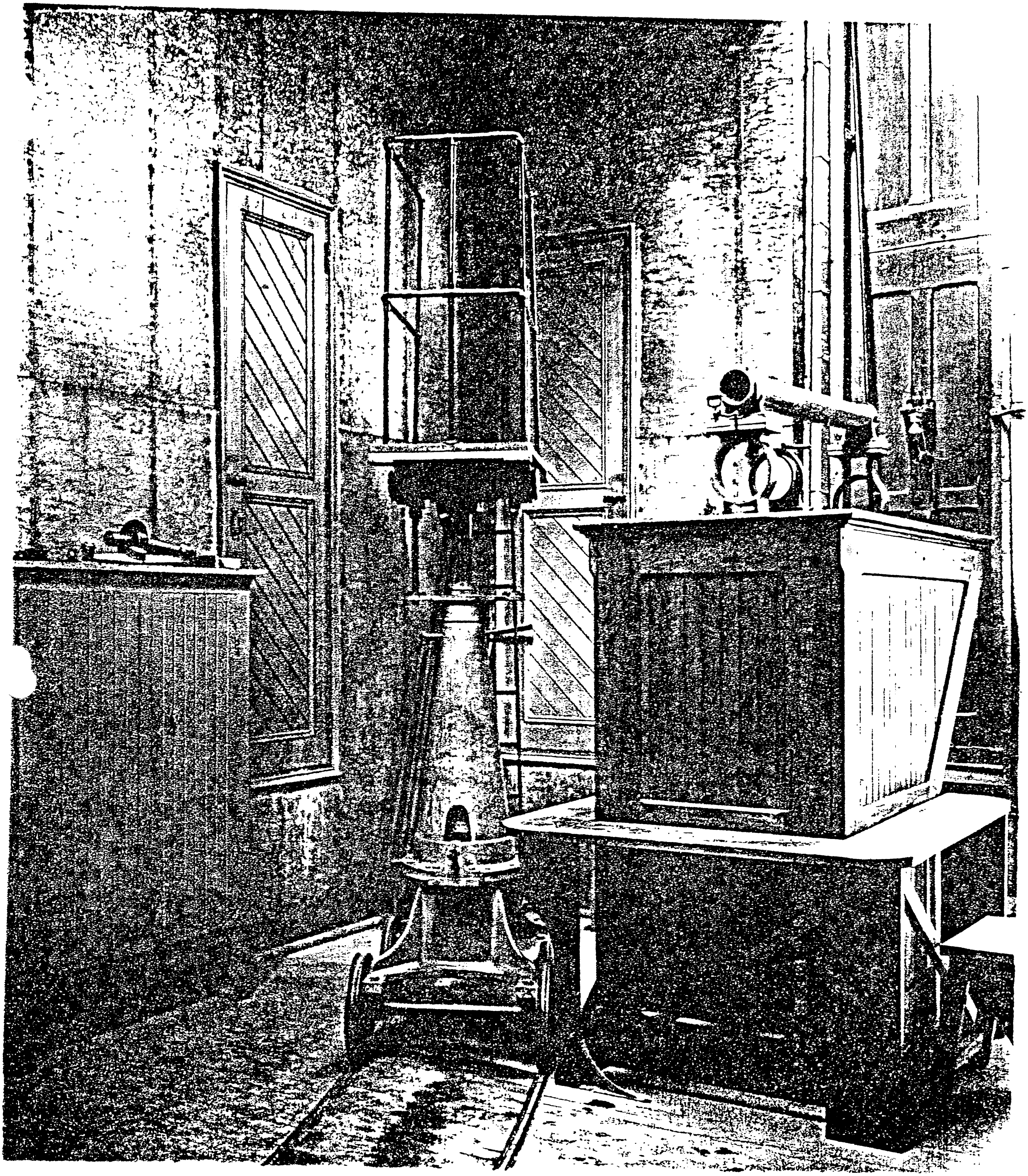


Fig. 57 The hoist for reversing the meridian circle telescope
Pg. 241 is stowed out of the way when not in use. The platform on top makes it a viewing stand for looking down through the telescope to determine the nadir with the help of the mercury basin. Courtesy Earth Physics Branch, EMR.

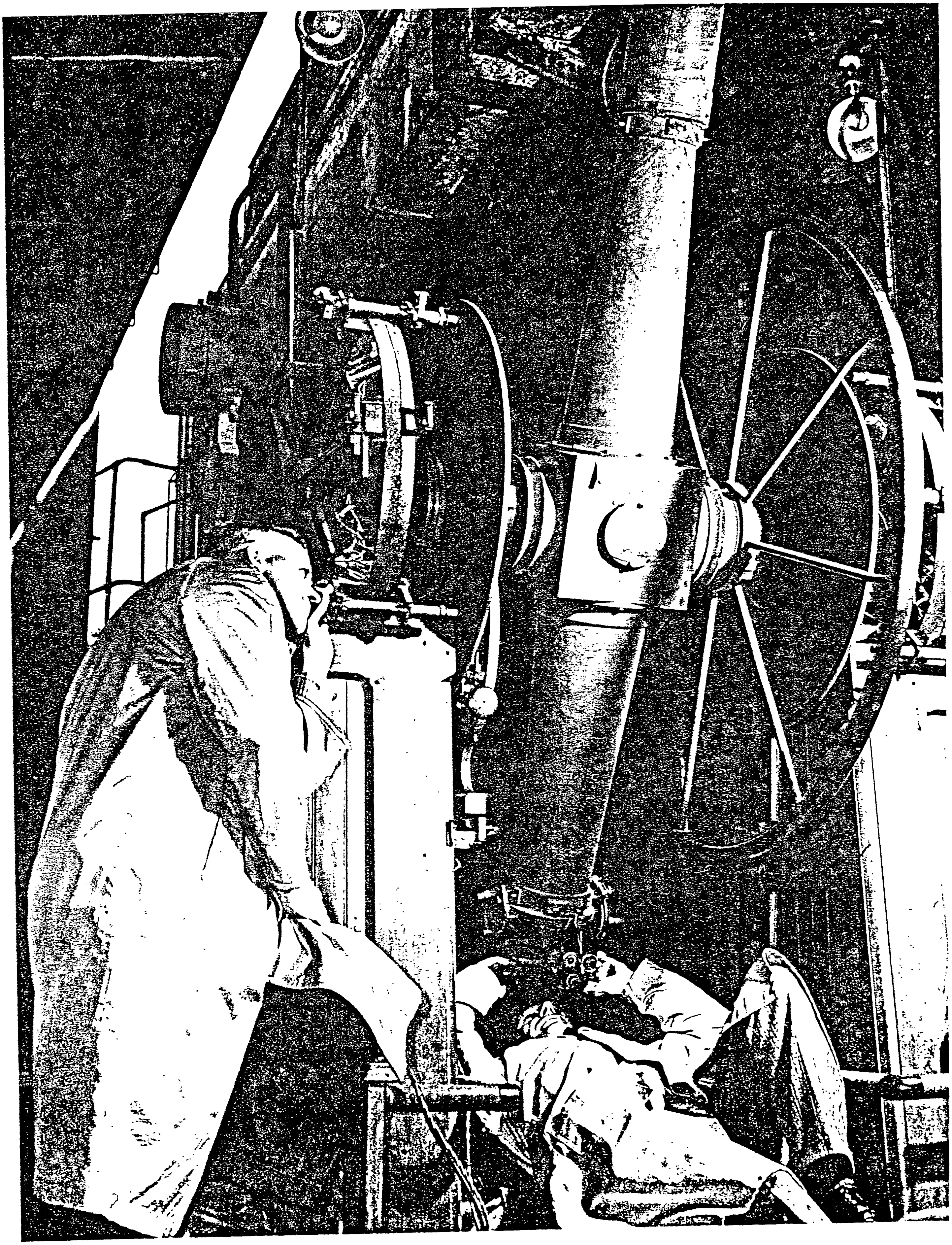


Fig. 58
Pg. 241

Dr. R.J. McDiarmid, on the observing couch, has his hands on the micrometer wheels of the meridian circle eyepiece. W.S. McLenahan is at one of the four microscopes used to record the instrument setting. The microscopes were later replaced b

SIZE 75%

undertook. He enjoyed sports, and could have excelled in baseball or hockey had he so desired. Also he was abreast of the developments in his chosen field of astrometry, and kept careful notes of what he read and studied. As a group leader he gave one the impression that he was standing back to give encouragement. Yet the aim of those who worked with him was always to try and do as well. Fig. 56

The reversal of the meridian circle on its pivots involved moving the hoist into position, carefully cranking the telescope up, moving the hoist with its load into the clear so that the telescope could be turned horizontally through 180 degrees, then carefully returning the telescope to its pivots. Usually two persons did the job. Bill McClenahan has the distinction of observing a set of stars, reversing the meridian circle, single handedly, and then accumulating a second set. This can only be done on a long winter night, because the reading of the instrumental constants, added to the time required for transit observations, means that a single set is about 4½ hours duration. Fig. 57

The meridian circle transit was used for the determination of astronomical time up to the beginning of 1935, after which reliance for timekeeping was placed on the broken Cooke. The meridian circle, because of its greater focal length, gave results which were much more consistent from star to star on any one night. But due to the reversal at mid transit of the smaller transit, and the consequent cancelling of the collimation error, and also due to the reading of the striding level at both settings for each star, the Cooke yielded more consistent night to night clock corrections. This was well demonstrated by several years during which both instruments were used. Fig. 58

During its half century of operation, the meridian circle was applied to six observational programs. It had been the original intention to complete the discussion of each program and make the results available for international use soon after the conclusion of observing. Staff limitations, depression, and war, all contributed to frustrate this intention. Not till war was over and new staff was available under the leadership of W.S. McClenahan, were the original observations dating back to 1911 published. Considerable credit is due to the assistance given by E.G. Woolsey and R.W. Tanner. Also electronic methods of data reduction permitted computations to be kept abreast of the observations during the last decade and a half so that final discussion and publication was accomplished within two years.

Several improvements were incorporated in the meridian circle in the postwar years. The mercury reflector was floated in a basin of mercury to reduce vibrations when the nadir was being read. 35 mm cameras of local design replaced the microscopes for circle registration, and E.G. Woolsey designed a projection machine for measuring the film. A reversible motor with toggle switch control replaced the hand crank to the sector gear for close adjustment of the declination setting. The micrometer adjustment in declination remained the same, namely a fine vertical adjustment of the eyepiece assembly by means of a hand wheel to bring the star within the horizontal wires of the eyepiece.

The mirror transit telescope, intended as a successor to the meridian circle, was to be completely impersonal with photographic registration of stars and of instrumental settings, remote servo control, and on-line punch card facilities for all the routine calculations. Fig. 59

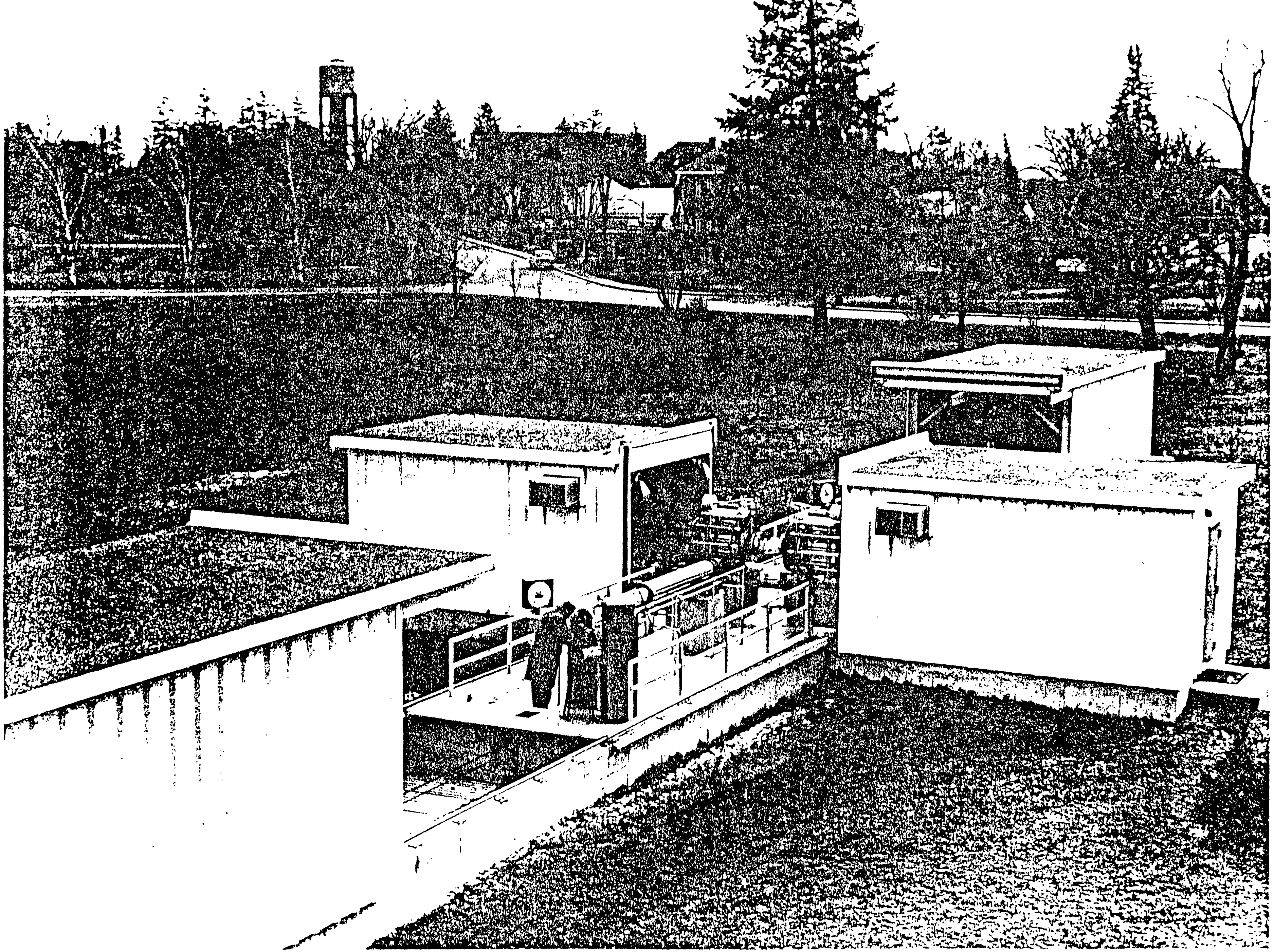


Fig. 59 The mirror transit telescope involved an optical flat in a central position from which star light was reflected into one of two horizontal telescopes located to the north and south. The observer is shown at the eye end of the north telescope.
Pg. 242

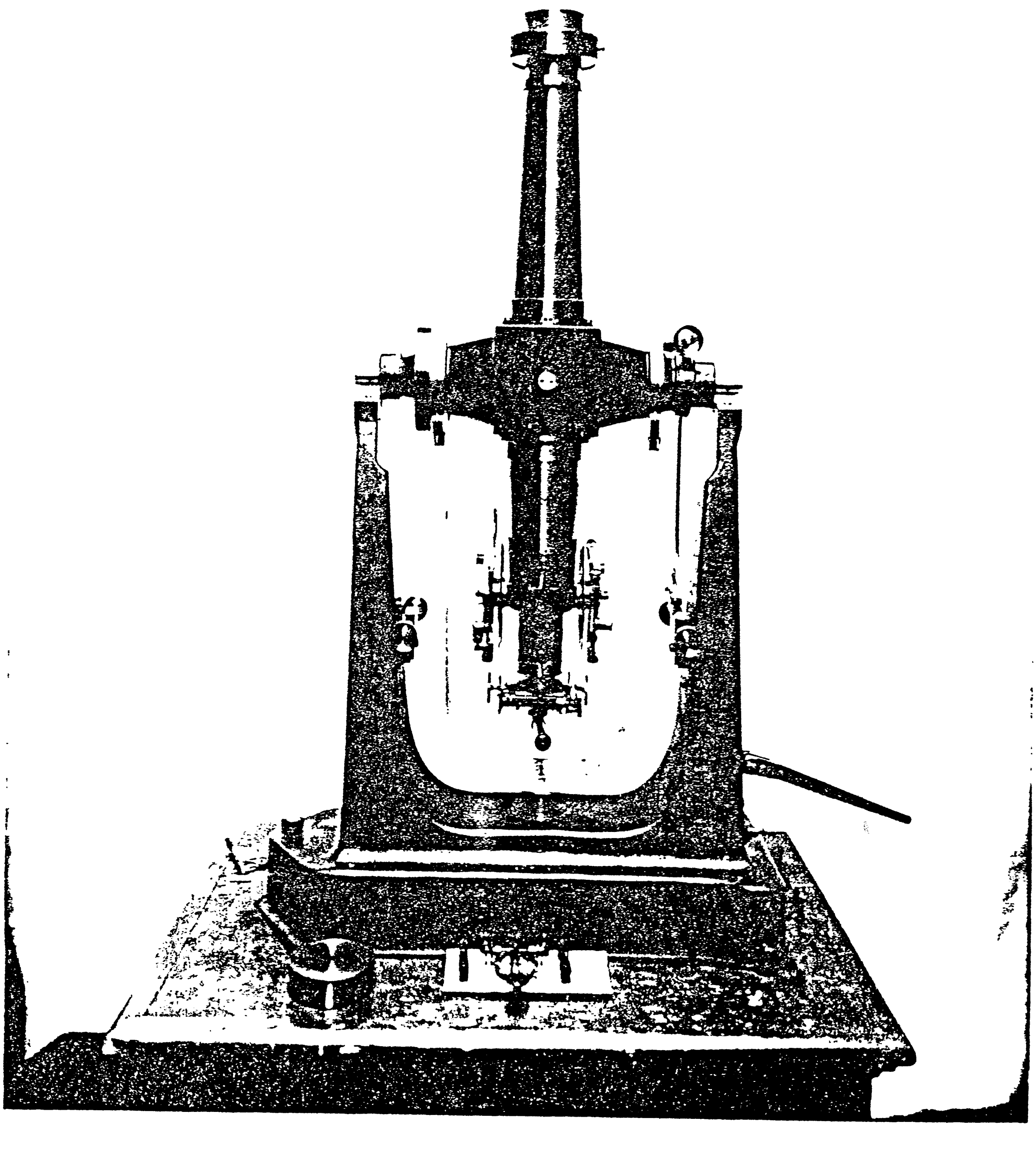
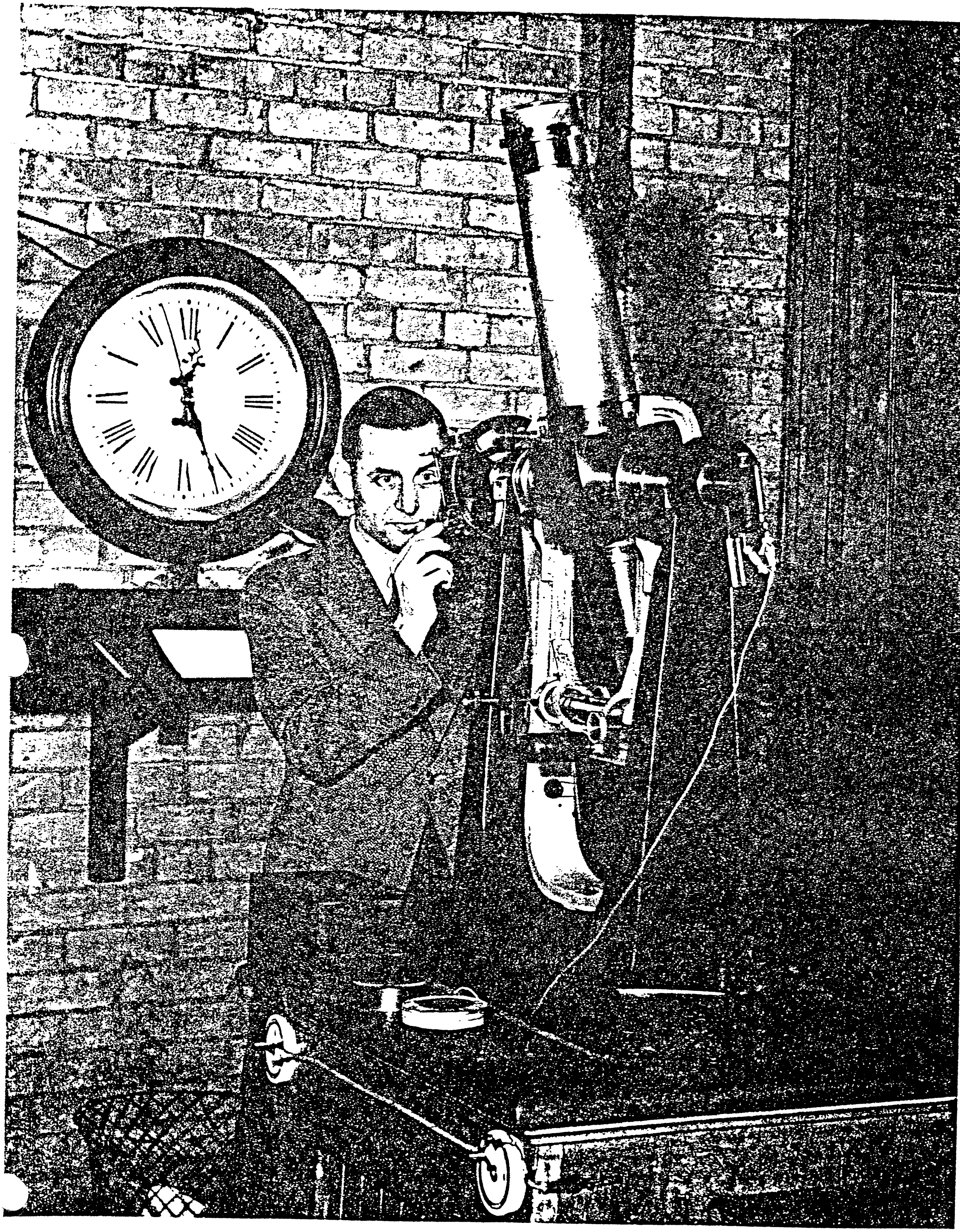


Fig. 60
Pg. 243 The original straight Cooke Transit. Courtesy Earth Physics Branch, E.M.R.



1 Fig. 61 Pg. 243 H.M. Thomson in an observing position at the broken type Cooke transit. Courtesy Earth Physics Branch, E.M.R.

Unfortunately the experiment was discontinued when it was realized that extensive funds would be required for a major redesign and relocation.

C.C. Smith recognized that the smaller Cooke transit was better than the meridian circle for night to night consistency of clock corrections. For several years during the late 1920's and early 1930's he accumulated evidence by using the smaller transit while someone else was observing with the meridian circle. It was also known that the broken type of instrument had certain advantages over the straight telescope. Smith wrote, "A straight tube transit has certain disadvantages that can be obviated by reflecting the light rectangularly by a prism in the cube [or centre of the little telescope], passing it through the axis and observing with the eyepiece on an extension of one of the pivots. The advantages of this so-called "broken type" transit are

Fig. 60

Fig. 6

(1) the observer's eye remains at the same convenient position regardless of the pointing of the telescope, and hence the errors that are due to the position of the observer north and south of the zenith are avoided;

(2) the level hangs directly under the rotation axis and is read on [the two settings for] every star;

(3) the instrument is very stable and easy to operate;

(4) zenith stars may be observed, thereby reducing the aximuth correction."

There was an additional straight Cooke transit of the required rugged design which under Smith's instruction was reconstructed in the Observatory machine shop. The result was an excellent transit at very little expense. It is described in the RASC Journal of October 1934. The reconstruction was done in time for the instrument to be used in

Vancouver by Smith in the 1933 World Longitude Campaign. In 1935 it came into regular use for the determination of the clock correction at Ottawa. Smith used it as long as he was with the Time Service, and on his retirement December 31, 1937, W.S. McClenahan took over the responsibility.

For nearly a decade the time service at Ottawa depended on the clock corrections provided by Bill McClenahan. The interval was not without historic impact. On August 28, 1941, by Order-in-Council, P.C. 6784, the Dominion Observatory time was designated as official time for Dominion official purposes. In the reorganization of government departments at the end of 1936 timekeeping responsibilities were discontinued by the meteorological Branch of the Department of Marine and Fisheries, and were not assumed by the newly formed Department of Transport, except that the Saint John, N.B. observatory was not closed till 1951. The Dominion Observatory was the only government agency equipped to become the custodian of official time, and now four and half years later was recognized as such.

In January of 1945 McClenahan was made Chief of the Time Service Division on the retirement of D.B. Nugent. A near tragedy occurred on the golf links on June 18 when he received an eye injury. It was his good observing eye, the other having suffered deterioration previously. Fortunately the injury proved to be superficial, and within a month he was able to resume both observing with the broken Cooke, and golfing.

The postwar years produced a quickening of activity at the Observatory. R.M. Stewart, who had agreed to remain at his post two years beyond normal age for retirement, and who for patriotic reasons

Fig. 62 Dr. C.S. Beals (1899 -). Courtesy Earth Physics Branch, E.M.R.

Pg. 245

had declined even to take time off for annual leave, retired in 1946. Fig. 62
Dr. C.S. Beals, (1899-) who had distinguished himself for his contribution to astronomy at the Dominion Astrophysical Observatory in Victoria, B.C., succeeded R.M. Stewart as Dominion Astronomer. He continued to maintain an active interest in astrophysics, and indeed made some significant contributions while at the same time keeping up with an increasing load of administrative duties. Then he effectively commenced a new career and won international recognition for his investigations of fossil meteor craters in Canada. Perhaps this helped to focus attention within the branch on the geophysical areas of research at the Observatory, namely gravity, seismology, and geomagnetism. Certainly under his direction, the geophysical effort expanded till it more than doubled in size the total astronomical manpower within the Observatories Branch. When government responsibility for astronomy was consolidated under the National Research Council in 1970, the geophysical remnant of the former Observatories Branch was of sufficient size and competence to form the Earth Physics Branch, Department of Energy, Mines and Resources.

A similar surge of encouragement and enthusiasm was injected into the astronomical effort at Ottawa, solar physics, meteor physics and positional astronomy all receiving encouragement to adopt modern methods, plan new and imaginative programs, and acquire the manpower to replace the shrinkage which had occurred during the 1930's and World War II.

When the author reported back late in 1945 after three years in the RCAF, he was assigned to a regular routine of observing with the broken Cooke transit. Memories come back of the cold winter nights when occasionally the smoke from the chimney of the Forage Division building, or of the Civic Hospital, both in the direction of the prevailing fair weather westerly air flow, would momentarily hide a star in transit. But one would maintain the steady motion of the micrometer wheels and feel gratified if on its reappearance the star was still at the bisection point between the moving wires. Upon occasion the seeing was decidedly bad, the star appearing to move erratically sometimes jumping beyond the micrometer wires. If the weather dropped to 15°F below zero, it was considered too cold, both the moving parts of the transit and the observer's fingers being too stiff for proper operation. This applied to both the meridian circle and the Cooke. Before that critical temperature arrived, one was troubled with frost from one's breath forming on the eyepiece and on the moving parts of the micrometer box. Wiping the eyepiece with alcohol cleared the frost. Then, to prevent more from forming during transit, it was common practice to hold one's breath while one's eye was fixed on the eyepiece, then to turn away with lungs fairly bursting to prepare for the second half of the transit. The cold always seemed to seep through to the marrow, in spite of frequent retreats to the warmth of the time room. There are memories of occasionally racing up and down the stairs from basement to dome to restore the circulation, and the brisk two mile walk home was just about right.

The physical discomforts of cold weather observing largely disappeared with the acquisition of heated flying suits in 1948. One can recall commencing an observing session with the heavy feeling of a cold. Then as the heat of the flying suit kept one comfortable in spite of zero degrees Fahrenheit the heaviness disappeared, the cold fresh air cleared the head and lungs, and next day one felt fine.

The flying suits were a potential hazard. One evening Tanner rushed into the time room from the meridian circle exclaiming "I'm on fire!". The author helped him hastily disrobe and found that the wiring of the flying suit had developed a hot spot and burned a hole through the underwear on the thigh. No other similar incident can be recalled.

Klotz, when recounting his experiences on the transpacific longitude campaign, conducted during 1903-04, wrote in part, "Summer prevailed throughout the campaign .... Contrary to expectation, there was less annoyance from beetles and insects while observing than is found in Canada. A light in the open at night with us attracts multitudes of moths and beetles, and one's patience is sometimes sorely tried to have an unexpected visitor stake out a homestead on the nose just at the critical moment of the transit of a star." On a balmy summer evening in Ottawa the novice observer quickly learns that bare legs are most attractive to the mosquitoes that readily find their way through the open shutters. Generally speaking, though, summer observing involved little in the way of physical discomfort.

The best seeing occurred when a light haze covered the sky, a condition that occasionally prevailed in the spring and summer. It was always a thrill to see a star move steadily across the field of the transit and keep it centrally between the micrometer wires. Then one looked forward to working up the time set next day, feeling sure that it must be a good one.

A good time set, generally speaking, was one in which the clock corrections (ΔT's) from the individual stars agreed to within one-tenth of a second of time. Sometimes, when the seeing was bad, the spread could be as much as three-tenths of a second. Bill McClenahan had one set with an internal agreement of seven hundredths of a second, which was a record.

A time set consisted of twelve stars, two of which were polars. The ten time stars were selected as close to the zenith as possible in order to reduce the azimuth correction to a minimum. Azimuth error was measured from the stars themselves, the polars combining with the southern stars to indicate how much the instrument might be pointing off from the meridian. At the mid point of each transit the instrument was reversed on its pivots, and the level was read in both positions.

The Cooke transit was a sturdy well built instrument, mounted on a heavy metal plate on a cement pier which extended down to a footing well below the frost line. It seemed to be unaffected by the weight of the observer's hands on the micrometer hand wheels, though it must be admitted that the operation was done with as light a touch as possible. On August 21, 1949, as J.P. Henderson was observing, he noticed that the bubble of the striding level moved full scale, and was starting back. He put his weight against the heavy uprights to see if he could detect some instability and arrest the motion, but to no avail. He then carefully observed the extent of the excursion, the interval of the swing, as well as the time. Next day W. Milne of the Seismology Division confirmed that the earth motions indicated by the excursions of the striding level of the Cooke corresponded exactly with the seismic recordings of an earthquake that had occurred off shore from Prince Rupert, B.C. It is not known whether an earthquake has ever been recorded before or since by a transit instrument!

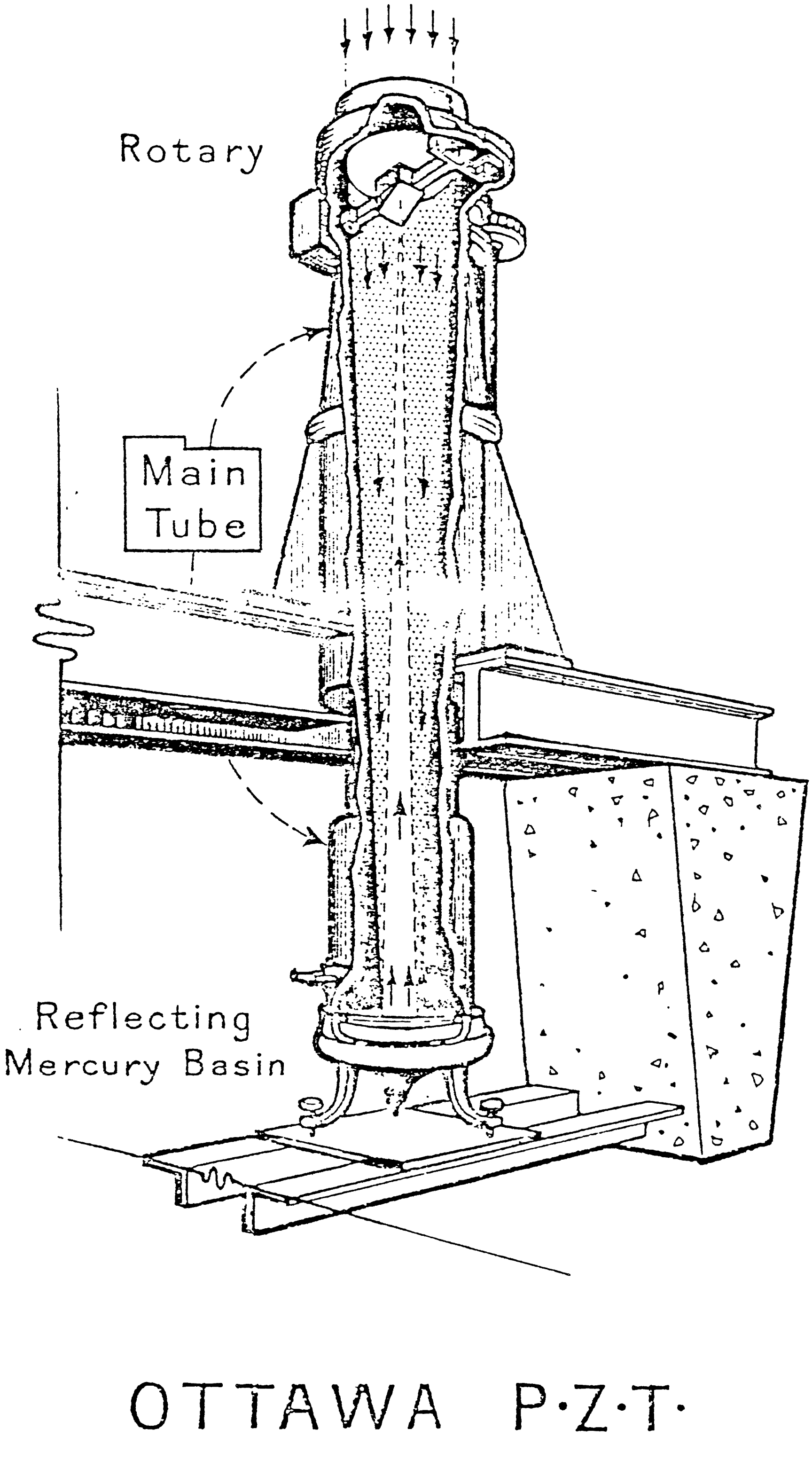


Fig. 63 Ottawa Photographic Zenith Tube (PZT) schematic. Courtesy
Pg. 249 Earth Physics Branch, E.M.R.

After World War II it became increasingly evident that the transit observations with the Cooke formed the weakest link in the determination and maintenance of fundamental time at Ottawa. Crystal clocks which supplemented the pendulum clock, S29, were exhibiting a day to day precision of a millisecond or two, whereas the results from a time set carried an uncertainty of about five hundredths of a second. Evidence from the U.S. Naval Observatory at Washington was that the photographic zenith tube (PZT) was ten times more precise.

Before the outbreak of the war, the PZT had received some attention at Ottawa, and indeed preliminary steps had been taken to compile a list of zenith stars suitable for the latitude of Ottawa. Soon after C.S. Beals became Director, in 1946, McClenahan was commissioned to visit Washington and to discuss with Paul Sollenberger, Director of the Time Service, the properties of the PZT. Plans at that time were well advanced for the construction of a new instrument, to be located at Richmond, Florida. The original one in Washington had been built by F.E. Ross in 1908 to detect latitude variation, and had been modified by F.B. Littell and J.E. Willis twenty years later so that both time and latitude could be determined simultaneously. Now, almost two decades later, the various modifications that had been made as technology had advanced from the pendulum to the quartz crystal frequency standard were being incorporated in the new design. Fig. 63

A PZT is mounted rigidly in a vertical position, and its range of operation is limited to those stars which culminate close to the zenith in their apparent daily motion from east to west. It is a reflex instrument. Light enters through an objective at the top to a mercury basin at the bottom, then is reflected back on itself and comes to a focus on a small photographic plate close to and just below the objective. As a consequence of the reflex characteristic, a PZT with a focal length of, say, 14 feet requires little more than 8 feet of head room.

It is composed of three parts, a rotary, a main tube, and a mercury basin. The rotary contains the object glass, the carriage for the photographic plate, the lead screw and the motor box. It takes its name from the fact that it rotates through precisely 180° after each exposure. In order to secure point images, the plate is moved at stellar speed by a precise lead screw. Control for the lead screw is a synchronous motor which, with its associated gearing permits the screw to be turned in either direction. No matter which way the rotary is oriented, head east or head west, the plate may always be driven from west to east. Further discussion of the plate and its reduction will follow later.

McClenahan was most favorably impressed with what he saw in Washington, and Paul Sollenberger, Superintendent of the U.S. Naval Observatory Time Service, was most generous in his cooperation. A full set of drawings was made available so that steps could be taken to have them modified to meet the Ottawa requirements. These were that the objective be 10 instead of 8 inches, and the focal length 14 feet. The increase in the size of the objective from 8 to 10 inches followed the design of the Greenwich PZT because it was felt that it might be necessary to go to fainter stars. The increase in focal length over the U.S. (12 feet, 6 inches) and Greenwich (11 feet, 3 inches) PZT's provided for a plate scale of close to 48 seconds of arc per millimeter.

Vickers Limited of Montreal formed all the castings, after first redrawing the Washington plans. The casting and figuring of the objective were assigned to Perkin-Elmer Company of Glenbrook, Connecticut. The other precision components associated with the control of the photographic plate, including the plate carriage, the lead screw, the 1000 cycle motor, and the sequence control gear box, were made with slight modifications directly from the U.S.N.O. drawings in the Dominion Observatory machine shop. J.P. Henderson suggested at the time that a Bodine 60 cycle motor, operating from controlled 60 cycle source, would do better than a custom designed 1000 cycle motor, and would be more readily replaced. It was in 1958, two years after he retired, that the design was modified to use his proposal.

In order to have the PZT readily available for test and development, it was mounted in the transit room using two of the three piers originally designed for the Cooke transit. The first test exposures were made in mid summer 1951, and by January 1952 it replaced the Cooke as the instrument for determining astronomical time at the Dominion Observatory.

Star positions for the PZT based on the FK3 catalogue were supplied by H.R. Morgan of the U.S. Naval Observatory. At the end of the first year of observing, the PZT results were used to smooth the positions in both right ascension and declination. Meridian circle observations, necessary to improve the attachment of the catalogue to the FK3 system were made during 1950 to 1953. As evidence accumulated through the years, R.W. Tanner was very careful to apply all the observational material to each star in subsequent catalogue revisions.

Initially the Ottawa PZT catalogue consisted of nearly 160 stars. These were divided into 12 groups of 2 hours each with an even distribution of stars north and south of the zenith in each group. Subsequently the catalogue was reduced to 80 stars which were divided into 8 groups of 3 hours each. This meant that during the summer solstice when a minimum of 7 hours of observing night time was available at Ottawa, two full groups could still be observed. The winter solstice at the latitude of Ottawa, by contrast, provided 14 hours of darkness. For the PZT, since observing was restricted to a half degree cone centred on the zenith, exposure could commence at the end of civil twilight.

The moon never rises high enough to shine directly into the PZT at Ottawa. A moon shade was designed initially, consisting of a sheet of plywood with a hole of about 14 inches diameter suspended horizontally about 3 feet above the objective, but was later abandoned. A stray cloud illuminated by the moon which happened to pass overhead during an exposure, or a light haze on a moonlit night was far more troublesome. Each exposure required 20 seconds, and each star four exposures, involving a total exposure time for the night of half an hour or more. City lights nearby caused no fogging. Up to 83 stars have been recorded on a single plate on long winter nights, involving nearly two hours of exposure time, without undue fogging or difficulty in identification.

A fast plate, Eastman 103-0, was used initially to be sure of recording the faintest star of the catalogue, which was between 9th and 10th magnitude. It is a blue sensitive emulsion which is readily handled in the light of a red filter Wratten Series 2. Subsequently the catalogue

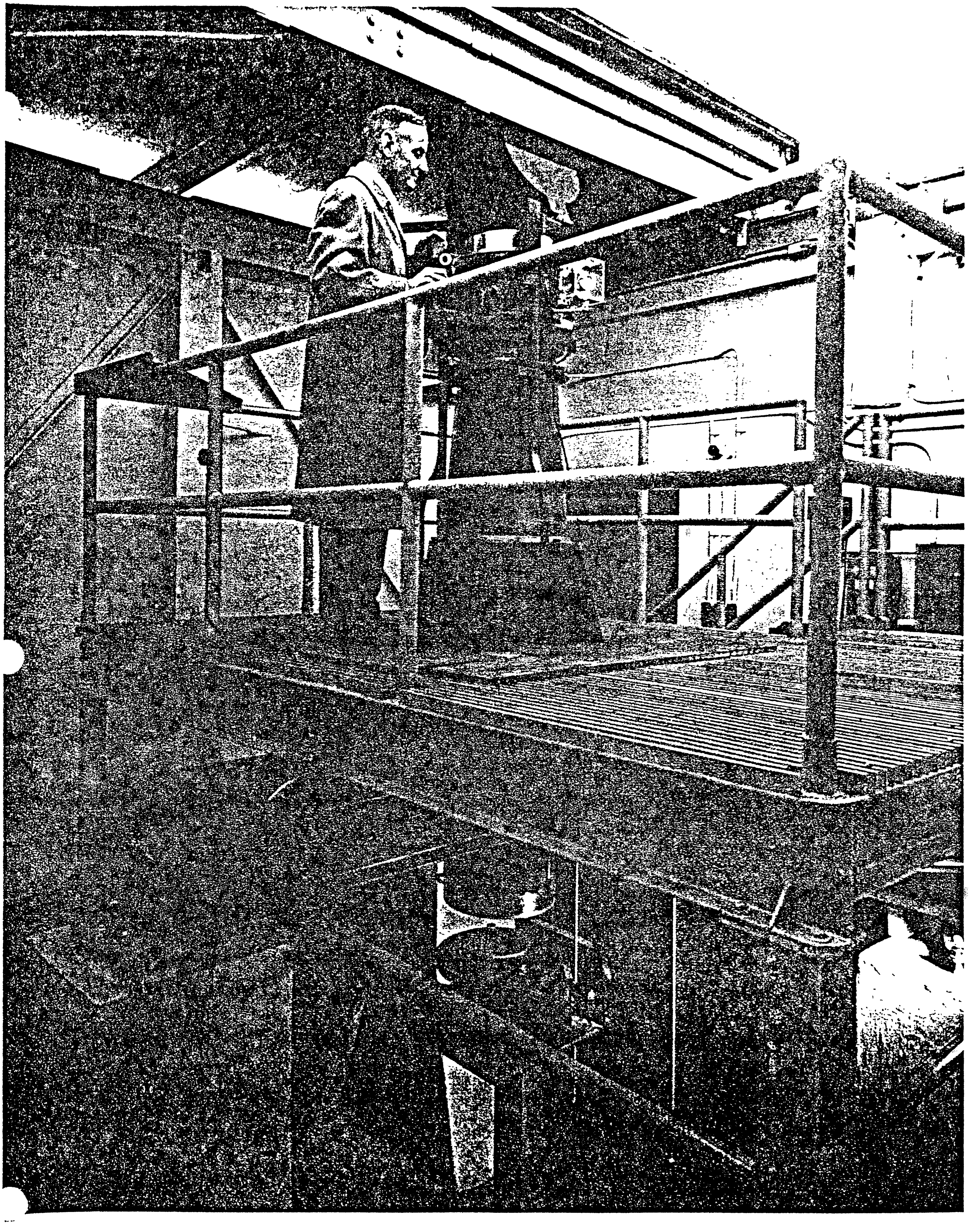


Fig. 64 The Ottawa PZT in its hut with the roof partially open. The
Pg. 253 shutter is open exposing the instrument to the sky. The hood at the bottom is raised showing the mercury basin. Courtesy Earth Physics Branch, E.M.R.

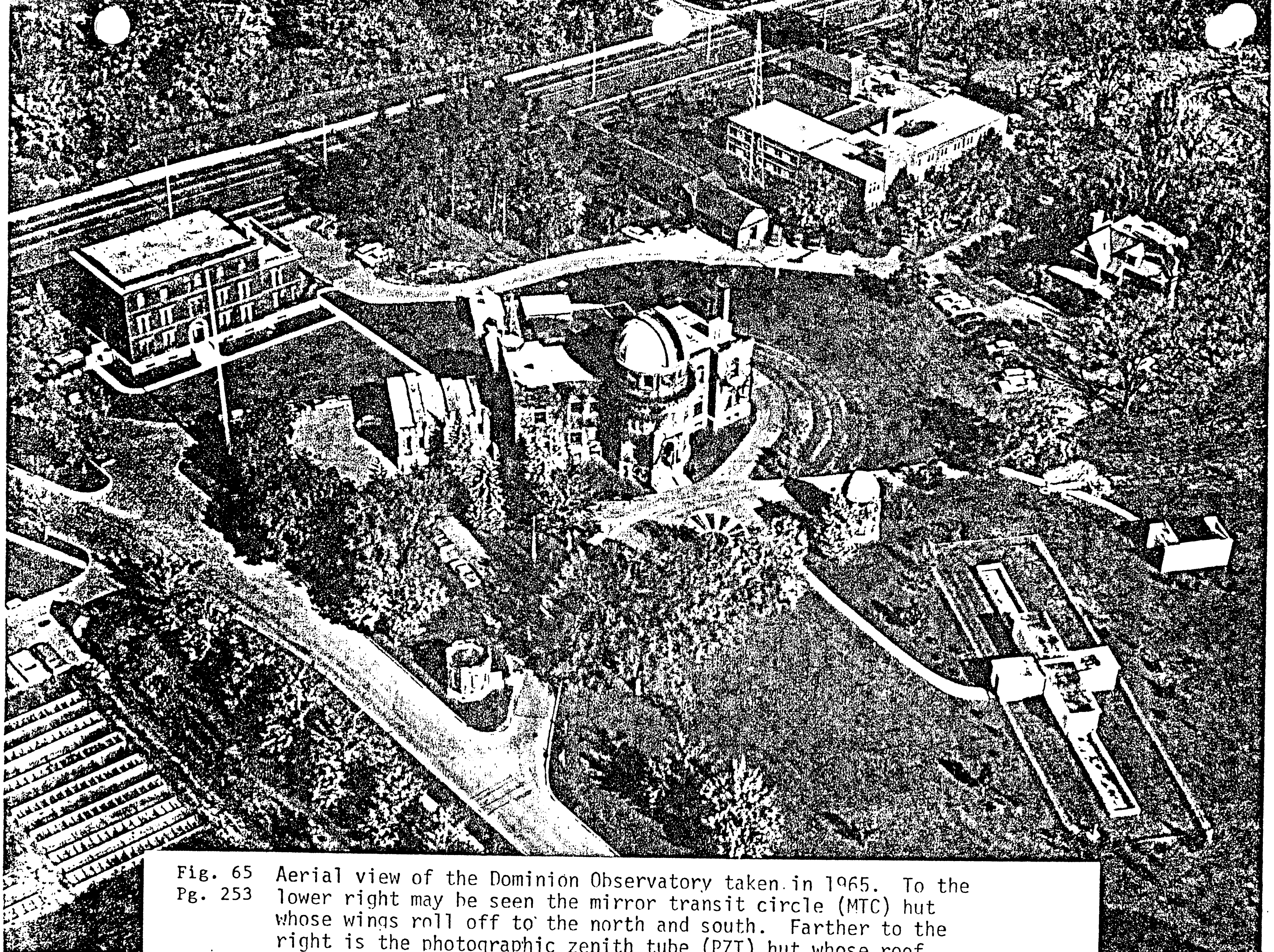


Fig. 65
Pg. 253

Aerial view of the Dominion Observatory taken in 1965. To the lower right may be seen the mirror transit circle (MTC) hut whose wings roll off to the north and south. Farther to the right is the photographic zenith tube (PZT) hut whose roof rolls off to the east and west. The transit room at the west (left) end of the observatory building was the home of the meridian circle and Cooke transit telescopes, and the temporary home of the PZT. Courtesy Earth Physics Branch, E.M.R.

was restricted to stars whose magnitudes ranged from 5 to 9. Later tests showed that the slower emulsion Eastman II-O produced smaller, sharper images with less fogging and graininess, so it replaced the 103-0 plate.

An analysis of the various errors attendant on the PZT performance led to the expectation that the night to night scatter should be of the order of $\pm 0\overset{s}{.}006 = \pm 0\overset{''}{.}06$. Instead it was nearly three times this value. Principal blame for this circumstance was credited to the fact that the transit room was constructed of the same solid stone and masonry as the rest of the Observatory building, and in spite of fans to encourage good air circulation, a temperature differential between inside and out of less than two degrees centigrade was seldom attained.

The big improvement occurred in 1960 with the removal of the PZT from the transit room to a properly designed observing hut made of Fig. 6 asbestos siding attached to a metal framework. It had very low heat capacity. Furthermore the whole roof was designed to roll back so that the instrument was essentially exposed to the outside air. In the annual report which appeared in Monthly Notices 1961, Vol. 2, No. 4, the following was stated. "In 1960 May, the PZT was moved from its temporary location in the transit room to a properly designed hut with a consequent drop in night error in α and δ (dispersion of the nightly values from the adopted smooth curve) from 16 milliseconds to 7 milliseconds, and from $0\overset{''}{.}09$ to $0\overset{''}{.}04$ respectively." The precision originally expected had been achieved.

The location of the observing hut on the grassy slope in front Fig. 65 of the Observatory had to be considered a temporary site, made available on a short term basis by the Department of Agriculture during the period that the mirror transit circle (MTC) was being developed. Five years later when definite plans were initiated for its removal, Wm. Markowitz of the U.S. Naval Observatory was in the midst of plans for the construction of a new PZT to be located in Pinto Indio, Argentina, on the same latitude as the PZT at Mount Stromlo, Australia. Considering the small additional cost of constructing two instead of one, arrangements were made for a second Canadian PZT to be made at Washington, incorporating improvements that had been developed both in Washington and in Ottawa. The new instrument, when finally completed had an 8-inch instead of a 10-inch objective, but with all surfaces coated, it proved to be entirely adequate for the Ottawa PZT catalogue. So the older instrument, whose larger objective matched the Herstmonceux PZT, was established on the same latitude as Herstmonceux just south of Calgary, Alberta, to form the first northern hemisphere pair of PZT's to use an entirely common star catalogue. Washington and Tokyo are close enough in latitude that they share a few stars in common. Subsequently a new instrument of 8-inch objective has replaced the older one at Calgary, and again the coating on each of the optical surfaces has made it capable of recording all the stars of the Herstmonceux catalogue. Also the focal length of the new PZT is the same as the Herstmonceux one so that the plate scales are identical.

Attached to the lead screw which drives the photographic plate of the Ottawa PZT is a small cylinder with a slit which permits photoelectric timing pulses to be recorded for each exposure to the tenth of a millisecond. The lead screw of the original Ottawa PZT turned once in two seconds. The new PZT's at Ottawa and Calgary have a period of 3 seconds for their lead screws.

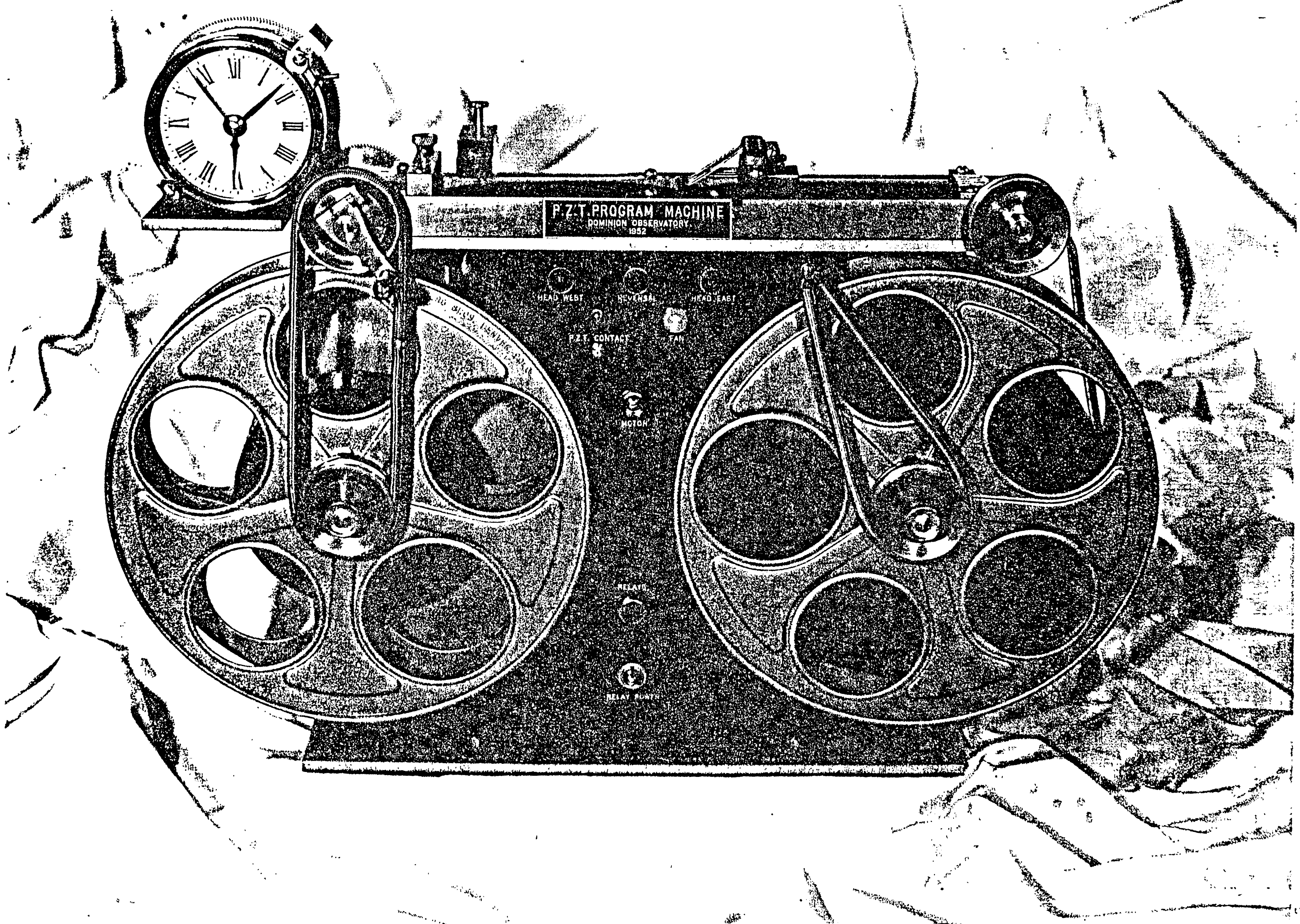


Fig. 66 Front view of the PZT program machine. The punched tape is made
Pg. 255 of 35 mm movie film. Sprock - and gear connection to the clock
provides positive timing. P..ot lights indicate the various

SIZE

The shutter, when closed, is in the form of a loose fitting cap which fits down over the objective but without coming in contact with it. The cap is divided into two halves with a small overlap, and each half is hinged outboard from the objective on an arm which is mounted on the platform and is quite independent of the PZT. The starting and stopping of the plate drive, and the opening and closing of the shutter are carefully synchronized. Besides excluding unwanted light, the shutter, when closed, is an effective dew cap and dust cap. Occasionally when a sudden shower has overtaken the site, the shutter has also kept the rain from the object glass.

Automatic control of the PZT is provided by a 24-hour timer which is set to open the roof at the end of civil twilight at dusk and Fig. 66
close it again at the beginning of civil twilight at dawn. A sensor mounted above the roof line will detect precipitation, in the form of either rain or snow. In either event the sensor flap will close and the roof also will close. Twenty minutes later the flap will open, and if precipitation has ceased the roof will open and observing will resume. Otherwise the roof will remain closed for another twenty minutes or multiple thereof.

The other piece of automation is the program machine, designed by V.E. Hollinsworth in 1952, which controls the start and stop of each exposure. It consists of a 1000 feet of 35 mm film which is drawn from one reel by a synchronous Bodine motor and wound up on a second reel. On the way the film passes under four fingers, and perforations in the film allow the fingers to drop into holes in the bed plate, thus providing sufficient motion to close the appropriate contacts. Two contacts control the start and stop of the PZT observing sequence and the other two control the fan which draws air down through the tube at all times except during an observation. The air within the tube is thus prevented from becoming striated.

An essential part of the program machine is the clock. Its sweep second hand is geared to the sprocket which draws the film so that any point on the film is represented by a time indication on the clock. With the motor declutched the film may be cranked forward or backward and the clock hands will follow exactly. The motor is driven synchronously by a 60 cycle sidereal frequency synthesized from the same crystal clock which controls the PZT plate drive.

Thirty-six hours of operation are contained within 1000 feet of film. As a result the whole catalogue can be punched onto the tape with a generous overlap. Due to proper motion and precession the star positions change sufficiently that a new tape is prepared each year.

The generous overlap also means that the PZT plate may be loaded during normal working hours, and the program machine set in operation. Twenty-four hours later the exposed plate can be removed and a new plate loaded, the program machine turned back to the correct sidereal time and set in motion for the following night. The exposed plate is developed and measured.

The mercury basin of the PZT is important because of two functions which it performs, reflection and focus. As a reflecting Fig. 67
surface it defines the vertical as determined by the force of gravity at the spot, and because it can be adjusted up or down, it is used to focus the stellar images on the photographic plate.

Fig. 67 Schematic showing how the out-of-focus image of the photographic
Pg. 256 Zenith tube image will be displaced as a result of half the shutter remaining closed. a. west half closed; b. both halves

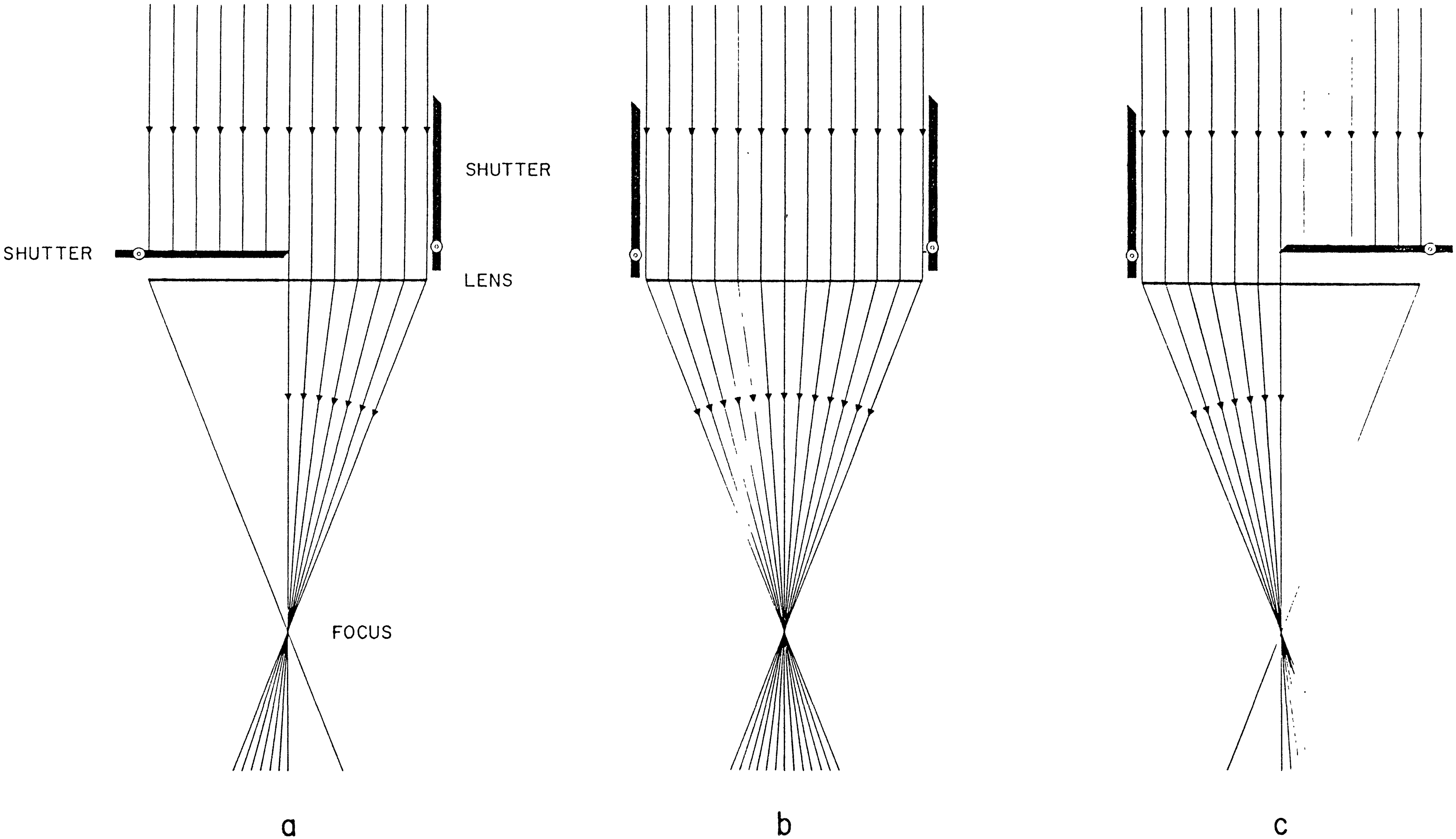


Fig.2

In order to make the mercury surface most effective, it is contained within a shallow dish with a sloping edge so that any wave on it will be shallow and readily damped by the sloping beach at the edge. Also the dish is lined with copper which readily forms an amalgam so that the mercury tends to climb up the sloping edge rather than form a convex meniscus as it does in a glass tube. Finally, to minimize the effect of vibrations, the mercury dish is floated in a larger basin of mercury.

The scum which forms continuously as a consequence of the copper amalgam, dulls the mercury surface, and must be removed. A glass rod drawn across the surface is most effective. A test dish lined with gold made a surface that remained bright and clear for many nights, entirely free from scum, and subject only to dust accumulation. Gold and mercury have such an affinity for each other that before long the thin lining had been absorbed, leaving the iron dish on which the mercury would not flow.

The late D.F. Stedman, who made many notable contributions in applied chemistry at NRC, took a personal interest in the problems of the mercury reflector of the PZT. It was under his direction that the copper lined dish was "wetted", using hydrochloric acid as a cleanser and adding to it a drop of mercury which spread as a thin film over the copper. He prepared the gold lined dish, knowing that it was fragile, but from a desire to learn how much of an improvement a scum free surface might be. This was followed by an unsuccessful attempt to obtain by electrolysis a thin film of another noble metal amalgam, palladium. Nothing has really been found to replace the copper lined dish.

The focus of the PZT was determined initially by the use of a tape measure, followed by test exposures to find the sharpest image. An invar rod with a sharp point was then adjusted to preserve the distance. The lower portion of the rod could be lowered for the measurement, then pushed up into a retaining clip.

By accident one night one half of the shutter failed to operate, leaving only the west half of the object glass exposed. The fault was noted when the plate was removed. A decided offset in the ΔT for the night was blamed on the fault, but to be sure a special test was made the next night, a few stars being recorded with the west half of the shutter inactive, followed by a few more with the east half inactive. The difference in ΔT showed conclusively that the images were all being recorded beyond the true focal point. This is shown schematically in Figure 68. Since then periodic tests have been made, using this method as a sensitive indicator, and the elevation of the mercury surface adjusted to the nearest millimeter.

Originally the PZT plates were measured using a Toepfer measuring engine. It had a horizontal screw of half millimeter pitch and a vertical screw of one millimeter pitch. The principal drawback to the Toepfer machine was that the main eyepiece and the magnifiers associated with the divided heads of the two screws provided in effect three optical systems of different accommodation. Fig. 68

In the design of a new measuring engine, certain definite objectives were sought. As much as possible, visual microscopes would give way to projections, thus minimizing eye strain. Measurements in both coordinates must be made accurately and easily. A seven times Fig. 69

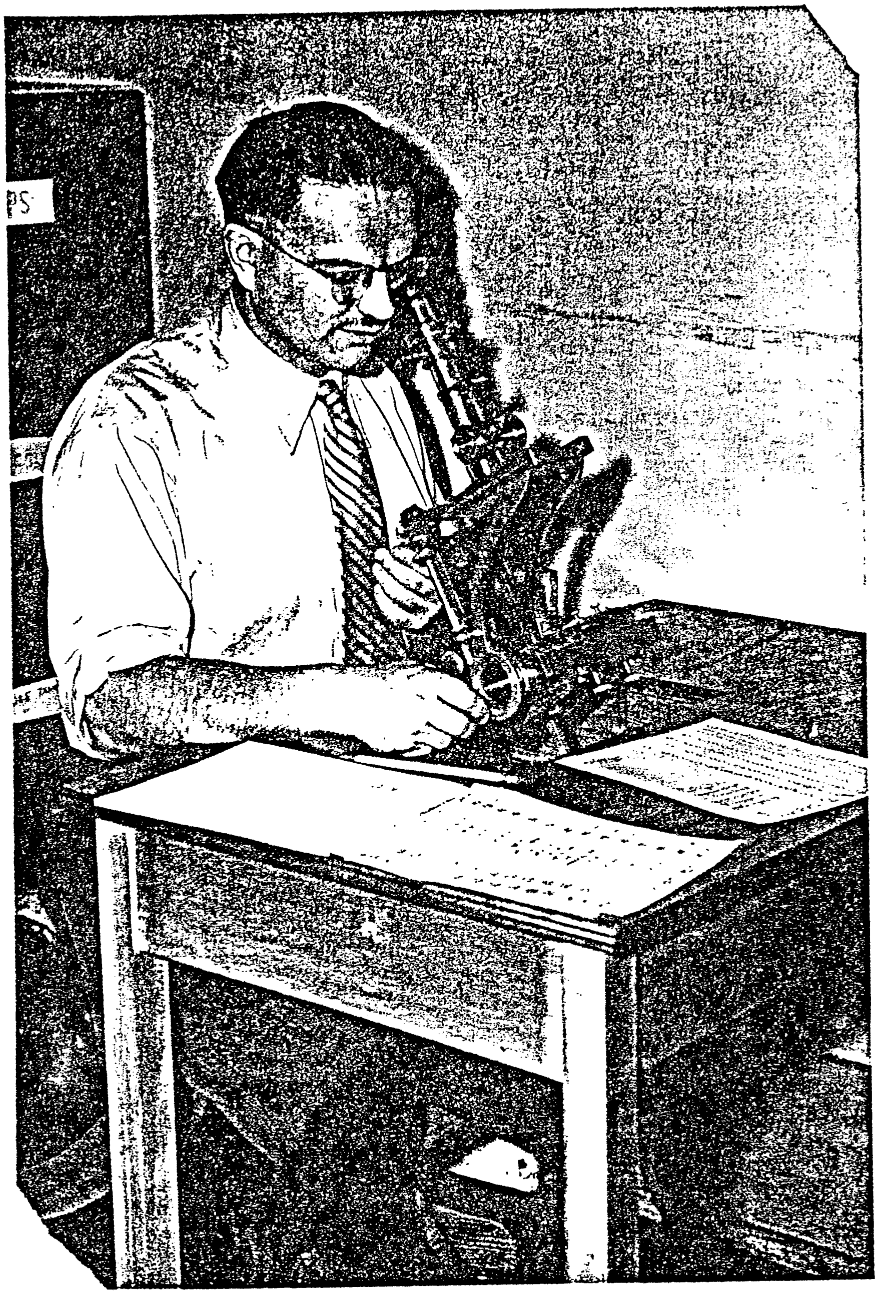


Fig. 68 D.L.G. Miller at the controls of the Toepfer measuring
Pg.258 engine, used initially to measure the PZT plates.
Courtesy Earth Physics Branch, EMR.

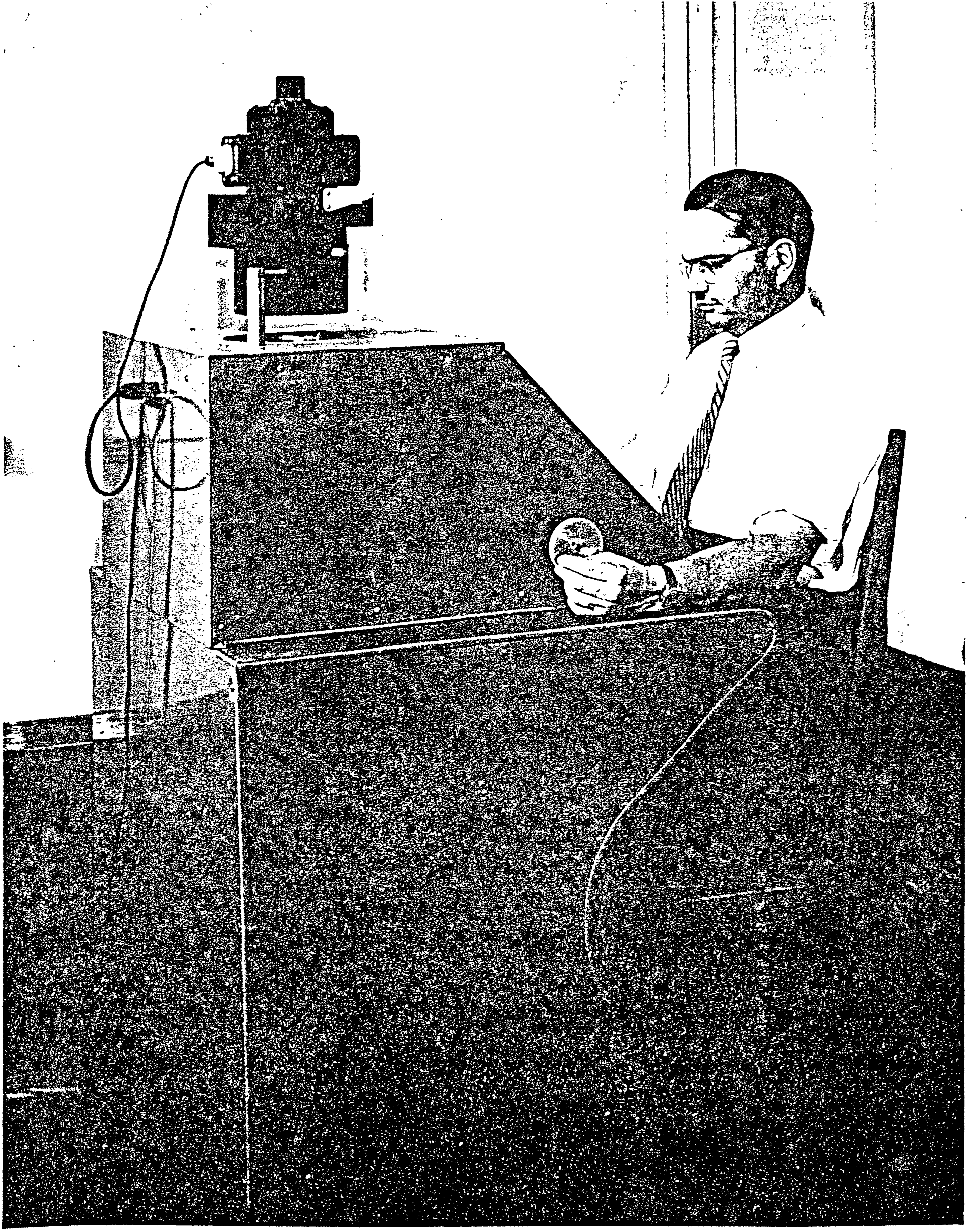
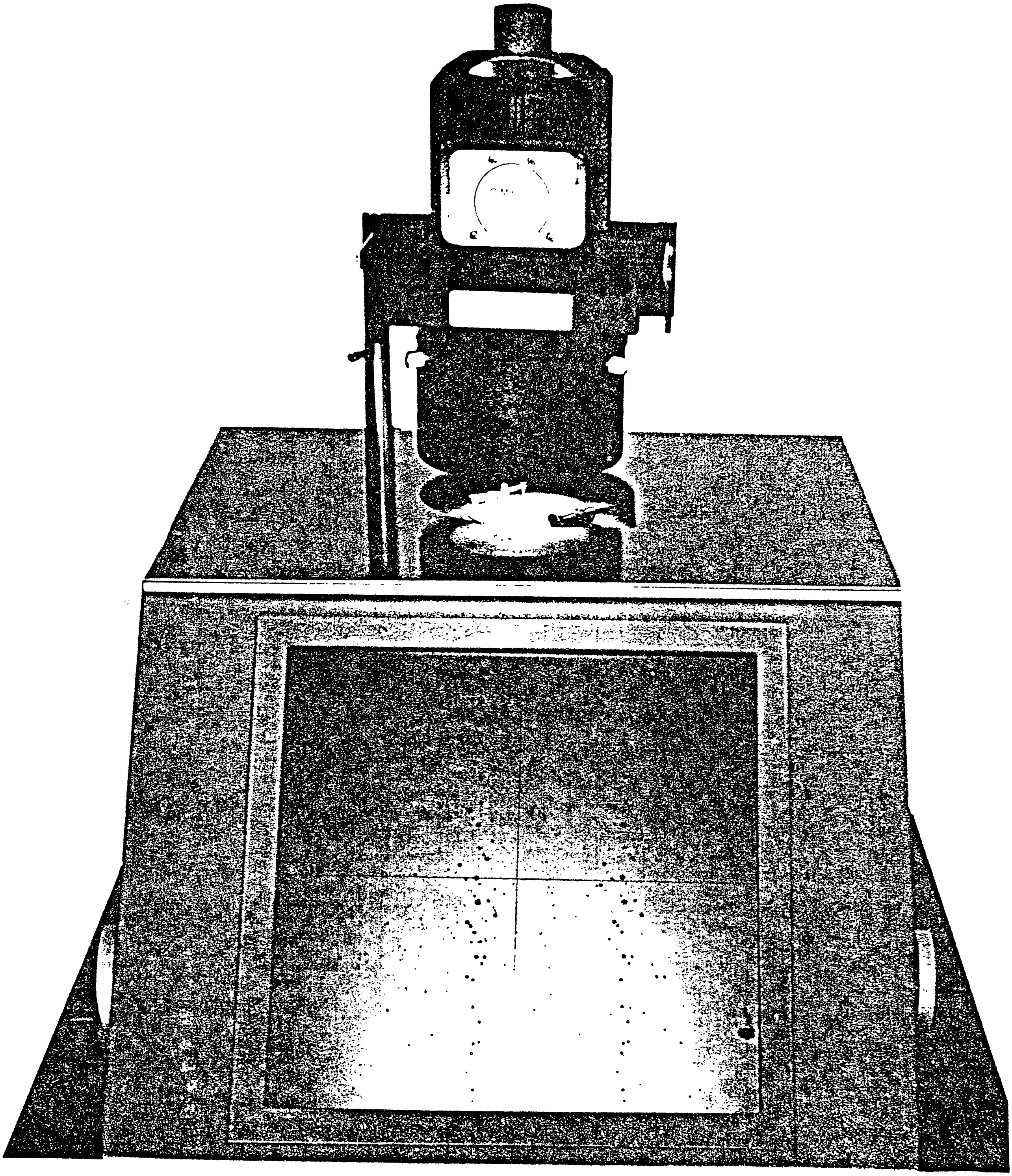


Fig. 69 The PZT measuring engine designed and built at the Dominion
Pg. 258 Observatory in 1954, with D.L.G. Miller at the controls. It has since been adapted to an on-line card punch, and a duplicate has been made for use at the Calgary PZT observatory. Courtesy Earth Physics Branch, E.M.R.

SIZE 60%



SIZE 65%

Fig. 70 PZT measuring engine with star images projected onto the
Pg. 259 viewing screen. Courtesy Earth Physics Branch, E.M.R.

enlargement of stellar images was considered adequate, though this was later increased to about 18 times. The decision to use projection, eliminating the use of visual microscopes, arose from the success of previous developments using this principle at both Victoria and Ottawa (J. RASC 42, 226, (1948) and J. RASC 45, 199, (1951)).

The final machine, as designed by the author, with considerable input by C.S. Beals, is still in use in Ottawa, and a copy has been made Fig. 70 for use in Calgary. Plate illumination is provided by a 100 watt mercury vapour lamp (G.E. type H100-A4) mounted in an Omega enlarger head. This is projected by an enlarging lens to a mirror tilted at 22½ degrees and brought to a focus on a ground glass viewing screen tilted at 45 degrees. The fiducial lines are drawn with India ink directly onto the ground glass, thus avoiding parallax. The two ways are moved by precision millimeter screws belt driven from two conveniently located hand wheels, one on each side of the machine. Originally veeder counters were attached to the end of the two screws and their readings also projected. They were subsequently replaced by digitizers whose outputs were fed directly into an on-line card punch. The computations involved in the reduction of the PZT observations at Ottawa and Calgary have been adapted to data processing, and are available week by week for the international offices, namely the Bureau International de l'Heure in France and the International Polar Motion Service in Japan.

In 1970 the Ottawa PZT was removed from its position on the lawn in front of the Dominion Observatory, and relocated about 10 miles due west at the Quiet Site of the Department of National Defence. Its new position was measured by the Geodetic Survey as $49\overset{s}{.}323$ west of its former position. However the difference as determined by PZT observations is $49^{s}.199$, an apparent discrepancy of $0^{s}.124$ (3.8 m or 12.5 ft.), which must be credited to change in the vertical. The force of gravity suffers deflections, so that the distance between two adjacent locations measured by astronomical methods can differ from the distance measured by the surveyor's tape along the ground. W.F. King, more than 60 years earlier had pointed this out as the limitation to the astronomical determination of control points in map making (pg. 185). In this case, however, it was the astronomical value that was required in order to avoid a step in the Ottawa PZT results.

In order to make use of the information recorded on the plate, accurate measurements must be made by some arbitrary scale in the two coordinates which are parallel to the meridian and the prime vertical. Neither of these appear directly on the plate, nor are they necessary. The star images themselves provide the clues both for plate orientation in the measuring engine and for the scale of the plate.

Four images are taken of each star at 30 second intervals. If one were to consider four instantaneous exposures uniformly disposed Fig. 71
with respect to the meridian, they would appear as in Figure 71a, in a line just slightly curved with respect to the prime vertical at Ottawa (concave to the north pole). Two things occur to modify this picture. The plate is driven during each exposure, and the plate is reversed 180 degrees between each exposure. The result of the first is that the stars record as point images, and the second causes the formation of a parallelogram, images 1 and 3 being on one side of the prime vertical, while 2 and 4 are an equal distance on the other side, as in Figure 71b.

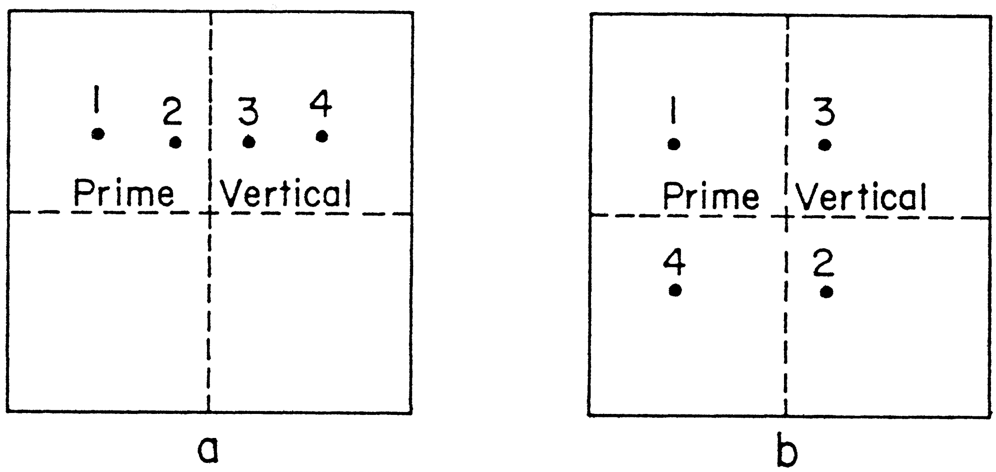


Fig. 71 a. Schematic of four instantaneous exposures of the same
Pg. 261 star taken 30 seconds apart.

b. The same four images recorded with a 180° reversal of the rotary between each exposure.

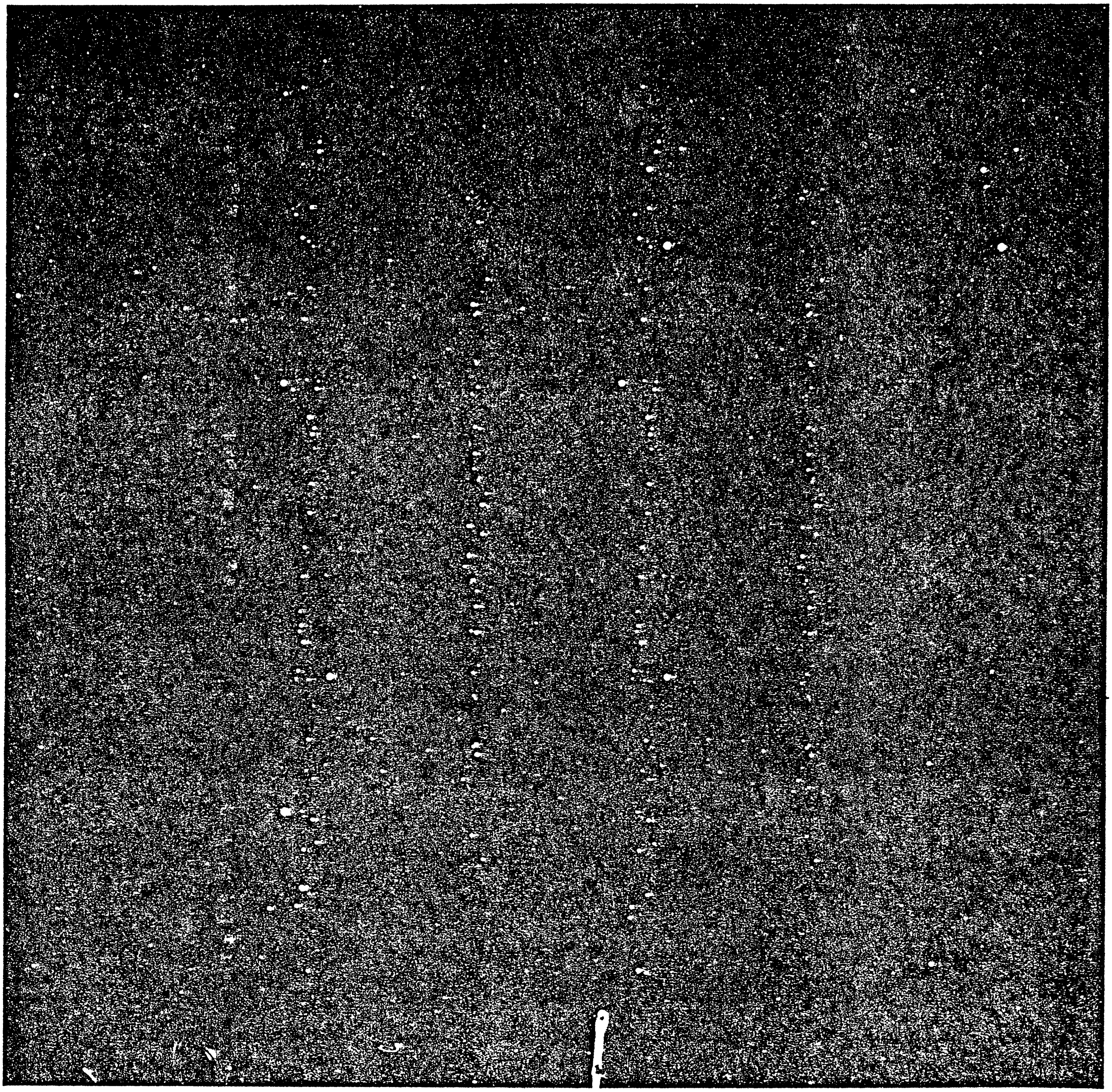


Fig. 72
Pg. 261

A typical star plate No. 3114 obtained Dec. 5/6, 1967 with the Ottawa photographic zenith tube (PZT). 40 stars are recorded, each one 4 times, 20 "head east" and 20 "head west" giving rise to four columns of stars. In addition to the program stars there are numerous "volunteers" which happened to be in the field of view during exposures. The magnitude of the stars varies from 5 to 10 photographic. Courtesy Earth Physics Branch, E.M.R.

The distances on the plate from 1 to 3 and from 2 to 4 are exactly one minute of atomic time, which establishes the plate scale. Confirmation of the scale is obtained by measuring from 1 to 4 and from 2 to 3, both of which distances are equal to twice the zenith distance of the star. (A small correction, called reduction to the meridian, must be introduced to make this statement true.)

When the plate is inserted in the measuring engine it is oriented so that the one axis of the engine is parallel to the average of the two directions, 1 to 3 and 4 to 2. Then the other axis of the engine will be parallel to the meridian. The x and y position of each of the four images of each program star is measured to the nearest micron (thousandth of a millimeter). The plate is then rotated 90 degrees and the measurement repeated in order to disclose and hence eliminate small errors inherent in the measuring engine.

Figure 72, is an example of a plate obtained with the Ottawa PZT. Forty stars were recorded, half "head east" and half "head west". The prime vertical is horizontally through the mid position of the plate, and one can readily see that each column is symmetrical about this central line. As each exposure is made, other stars in the field will also record. To the skilled operator these volunteers are readily recognized and present no problem as the plate is being scaled. Fig. 72

Both the Ottawa and the Calgary PZT's are able to secure observations on about 60% of the nights throughout the year. The average night to night scatter of the Ottawa observations is 3.5 milliseconds in ΔT, and $0\overset{\prime\prime}{.}04$ in latitude, a uniformity which places it to the forefront internationally. The Calgary record, perhaps due to the Chinook winds, is not quite so good, the night to night scatter being 6.5 milliseconds in ΔT, and 0$''$.04 in latitude. Both instruments are making a valuable contribution to the geodynamics of earth rotation and polar wander.

During the 18 months of the International Geophysical year 1957.0 to 1958.5, in response to a request by N. Stoyko of the Bureau International de l'Heure (BIH), the broken Cooke transit was reestablished on what had been the north collimator pier. The PZT at that time was still in the transit room supported between the main pier and the south collimator pier of the original Cooke position. The purpose was to secure a set of observations that would be comparable to those taken before the introduction of the PZT.

Also during July 1957, Dr. Wm. Markowitz provided a dual rate moon camera which was designed to operate with the 15-inch equatorial. In preparation for the camera, G.A. Brealey redesigned the eye end of the 15-inch so that a wider breech (9 inches from a former 4 inches) was available. Also a more sensitive method of focusing was incorporated. A few of the plates were measured on the Mann measuring engine at Ottawa in order to determine the ΔT between mean solar time and ephemeris time. All of the plates were sent to the United States Naval Observatory for measurement and reduction after the star field had been identified. Fig. 73 Fig. 74

The moon moves relatively rapidly through the stars, 0$''$.55 per second as opposed to the more leisurely motion of the sun which is 0$''$.04 per second. In order to secure a picture of the moon and the stars simultaneously, a tilting filter was located close to the plate surface. Its tilting motion was computed to cause a displacement of the lunar image exactly equal to the apparent motion of the moon. Also the density of the

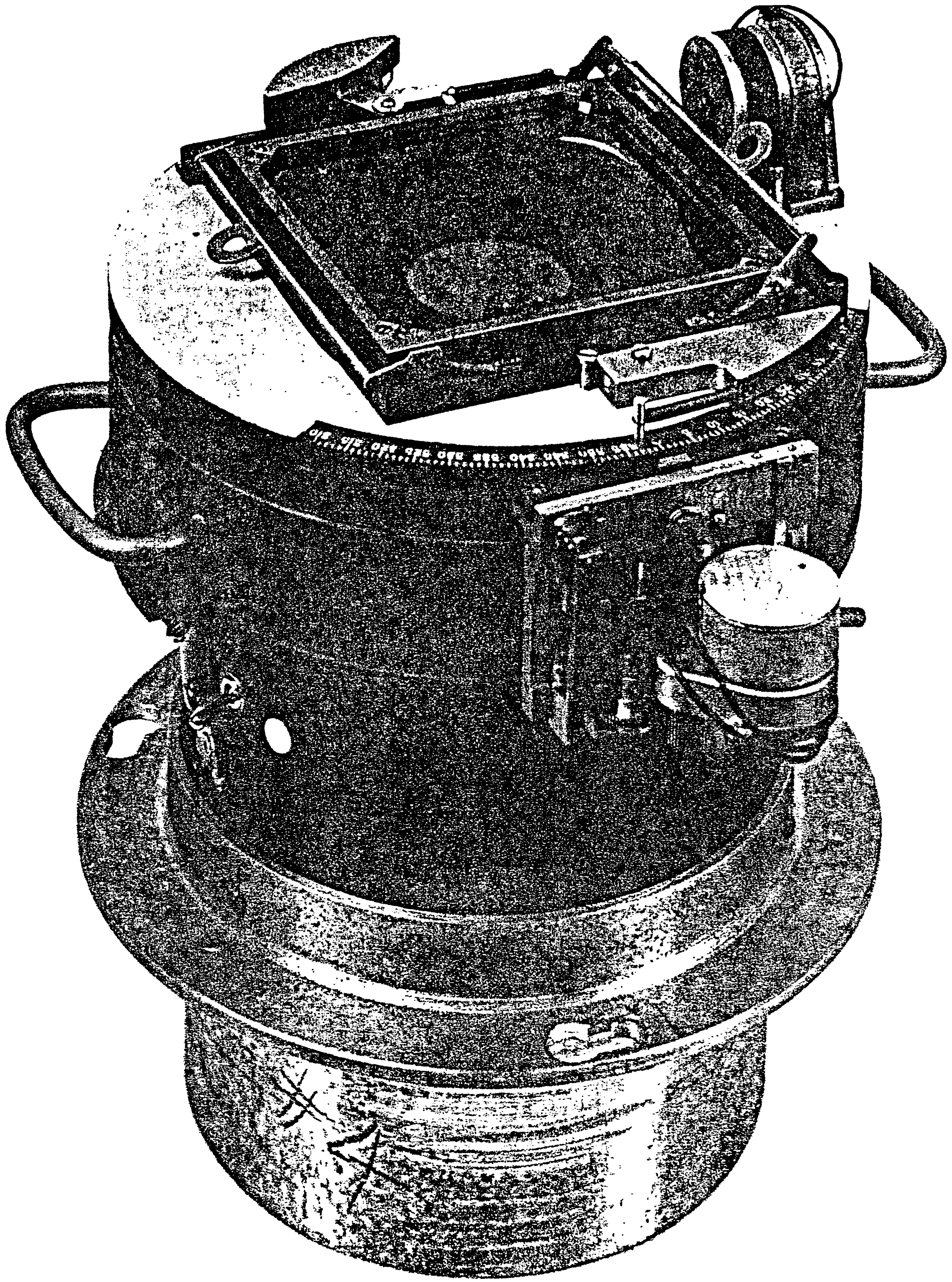


Fig. 73 Markowitz dual rate moon camera. The round disc is the tilting
Pg. 262 filter which compensates for the motion of the moon and reduces its brightness to that of a star. The plate holder can also be driven at stellar speed if the telescope remains fixed. Courtesy Earth Physics Branch, EMR.

S = 53%

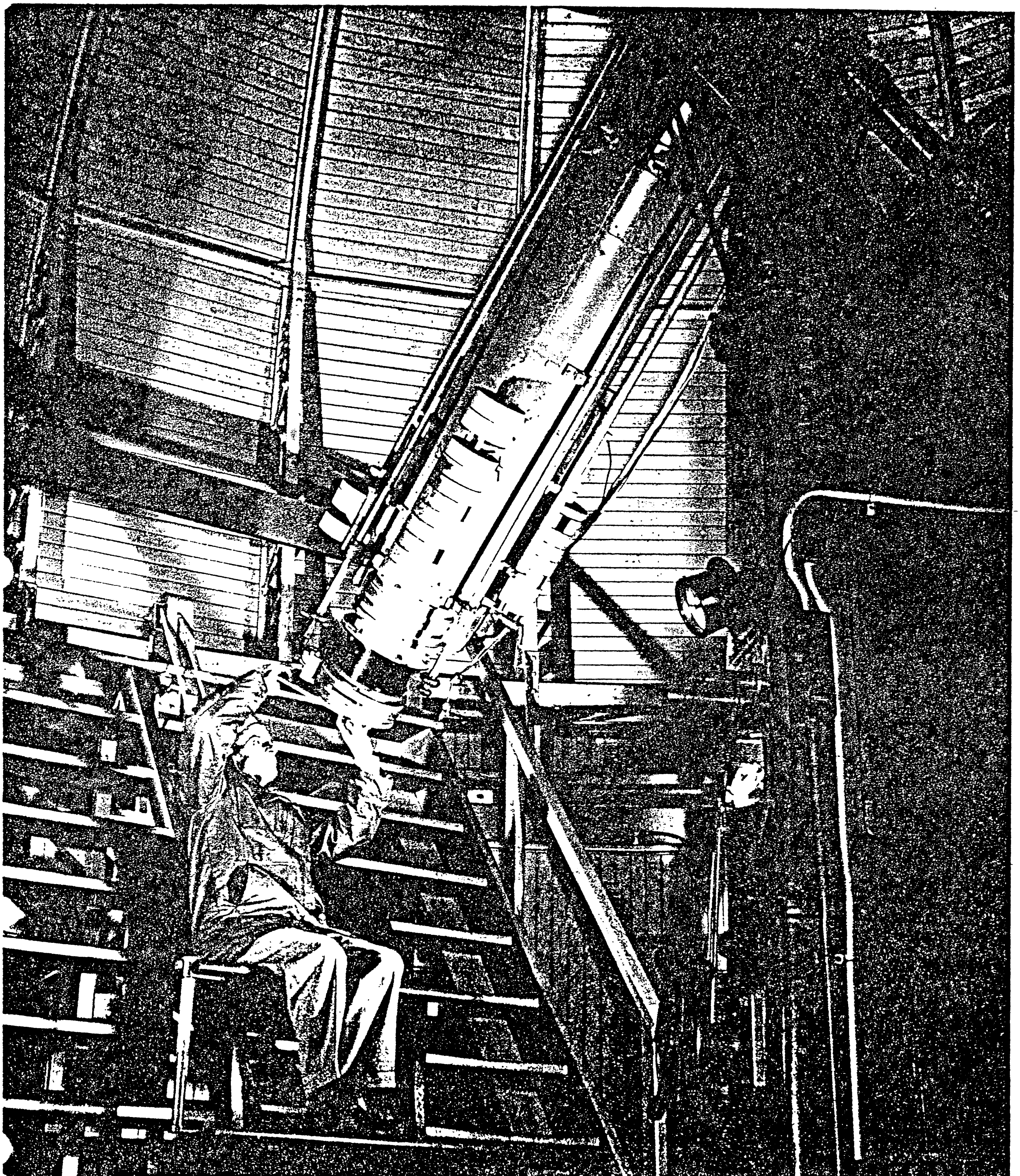


Fig. 74 Pg. 262 Markowitz dual rate moon camera adapted to the 15-inch refractor of the Dominion Observatory. The telescope is driven at stellar speed, and the plate holder of the camera remains fixed. M.M.Thomson at the controls. Courtesy Ear h

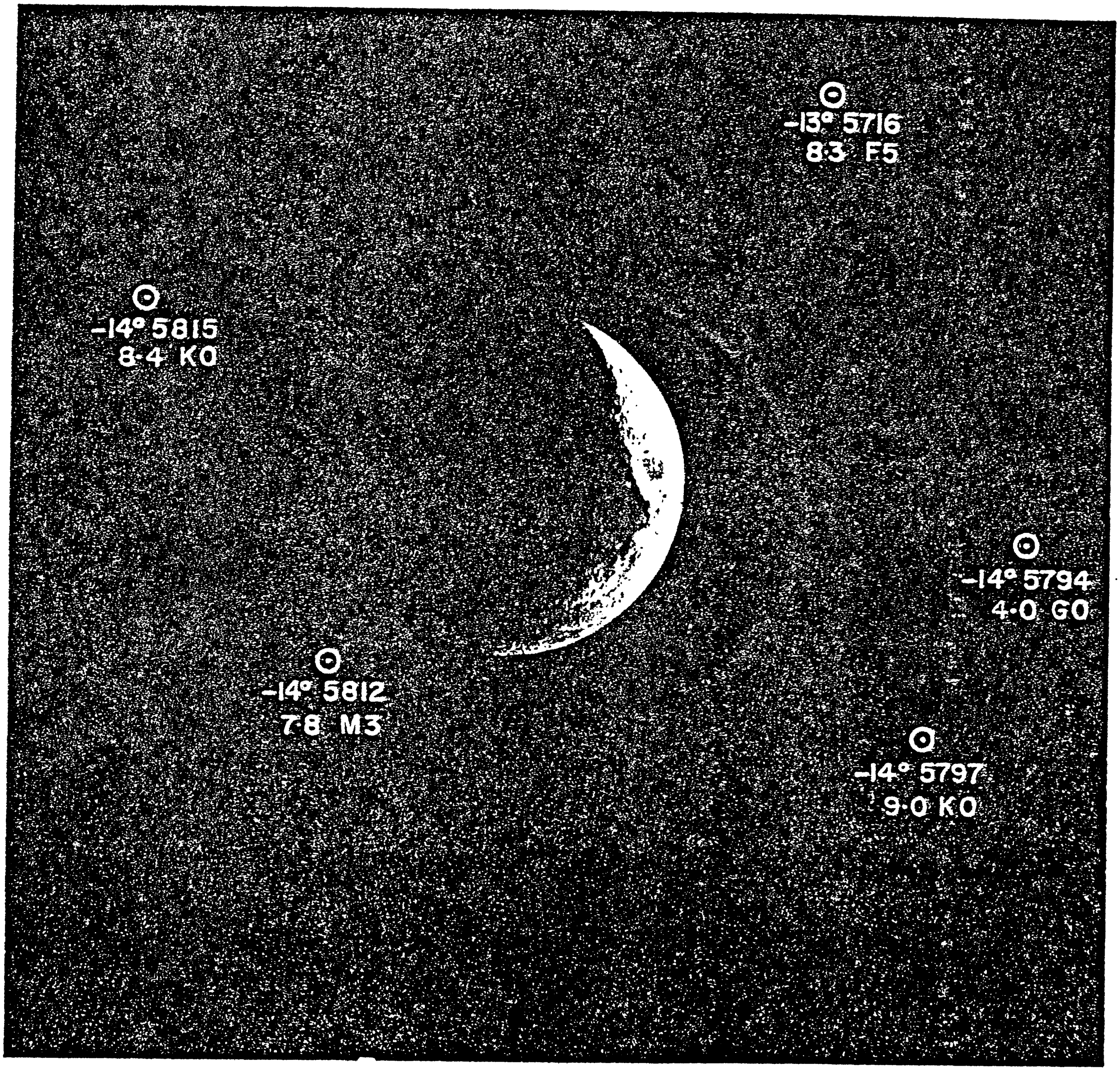


Fig. 75 A picture of the new moon secured with a 20-second exposure on
Pg. 263 type 103-G Eastman Kodak emulsion. North is to the top. Stars have been accentuated for reproduction. Each star is identified with its B.D. Catalogue number, its magnitude and spectral type as listed in the Yale Zone Catalogue. Light from the moon has been intercepted by the tilting filter. Courtesy Earth Physics Branch, EMR.

filter was adequate to reduce the light from the moon to the equivalent of an average star. Another motor within the camera, (hence the name dual rate), caused the plate to move at stellar speed so that both the moon and the stars moved at stellar speed. Since the Ottawa 15-inch was synchronously driven using a crystal controlled 60 cycle frequency, the plate motor of the moon camera was disconnected. The moon camera program continued at Ottawa for a few years after the 1GY, but was finally suspended in 1963.

The use of the moon as an hour hand against the background of stars was made possible because of two programs, the one relating to the lunar theory and the other to the lunar profile. Electronic computation replaced desk computers, so that a new set of moon tables were made possible in strict accord with the intricate gravitational theory of the moon. Dirk Brouwer of Yale, G.M. Clemence of the U.S. Nautical Almanac office, and W.J. Eckert of the Watson Computing Laboratory cooperated in this monumental task. The lunar profile is both rugged and changeable, the former due to the mountains and craters which cover much of the surface, the latter due to libration. C.B. Watts of the U.S. Naval Observatory made an extensive survey of lunar profiles, the published result of which enabled the profile on any particular date to be related to the same centre of gravity as the profile for any other date. Fig. 75

A drawback to the moon camera method is due to the inability to compensate for a slight shift of the lunar image during exposure. A stellar image, enlarged due to poor seeing, can still be centred upon. The corresponding circumstance would be the ability to see the full orb of the moon. In ordinary light this is possible only during the brief interval of full moon, nearly half of the lunar profile being obscured at all other times. So in every exposure of either ten or twenty seconds there is some uncertainty as to the exact position of the limb and hence of the centre of gravity of the moon.

The advantage of the moon camera is that photographs are not limited to the meridian, but may be taken in any part of the sky. They are taken in pairs, the camera being reversed through exactly 180°. The time of an exposure is the instant that the tilting filter is exactly parallel to the photographic plate, and is determined from a set of contacts made by the filter during its rotation. Universal time is used to record the event. The position of the moon in its orbit is tabulated in ephemeris time, and hence appears to be in the wrong position both in right ascension and declination according to the time by the observing clock. It is this error, translated into a time interval, which is the difference between universal and ephemeris time.

Transit observations of the moon, using the transit circle with micrometer setting for both right ascension and declination, are obtained routinely by several observatories. The large number of lunar occultations observed by amateurs, with improved technique and accurate timing, is processed annually at the Nautical Almanac office of Great Britain, and affords further evidence of the reading of the ephemeris clock.

The Quartz Crystal Frequency Standard

THE QUARTZ CRYSTAL FREQUENCY STANDARD

The first discussion of an electronic or electromechanical frequency standard recorded in J.P. Henderson's diary occurred in 1929, when J.W. Bain of the Radio Branch, Department of Marine and Fisheries, mentioned that they were intending to purchase an absolute frequency standard from Teddington, England, with the output in the form of a wheel turning 1 rps. The question from Bain was, would the observatory have a chronograph and clock to determine accurately the interval of the output? J.P. Henderson's reply was, yes, if a telephone line and proper terminal equipment were available.

The Minister of Marine and Fisheries, by virtue of the Radiotelegraph Act, 1913, was authorized to make regulations and prescribe conditions and restrictions to which a licensee was subject. The regulations conformed to international conventions, such as the 1912 London Convention. Article 4, Section 2 of the 1927 International Radiotelegraph Convention of Washington states, "Waves emitted by a station must be maintained upon the authorized frequency, as exactly as the state of the art permits, and the radiation must also be as free as practicable from all emissions not essential to the type of communication carried on."

Mr. Ed Davey, a wireless operator who was associated with the radio monitoring operation of the Marine and Fisheries Dept. from its inception, recorded in 1967 his reminiscences of these early days.

"The first frequency standard operated by the old Radio Branch of the Marine and Fisheries Department that I have recollections of seeing in approximately 1932 was a Sullivan Fork, operating at 1000 cps.

The temperature control system for the fork chamber depended on the expansion of toluol confined in a fairly large glass tubular helix. After several "flare-ups", the system was condemned as being rather crude and a decided fire hazard .... This project was the responsibility of the late J.W. Bain, who had a short time before, entered the Radio Branch from a lecturing professorship at Queen's, I believe. He worked under A.N. Fraser, Chief Engineer, and C.P. Edwards, Director. The purpose of the Sullivan Fork was not for the measurement of remote signals, but rather for the calibration of wave meters which were in field offices for the adjustment of transmitters ashore and afloat, a number of which were of the "spark" variety. Some time later, perhaps a year or so, Mr. Bain was able to purchase the first General Radio Primary Standard of Frequency developed by J.K. Clapp of General Radio."

Initially the new standard together with three Canadian Marconi T.R.F. (tuned radio frequency) receivers were installed in the test room on Wellington Street. Due to interference caused by the 4 KVA transmitter (VAA) on the floor above, and to street cars nearby, the monitoring equipment was moved to the Booth Farmhouse on the Experimental Farm.

The year was 1934. A discussion involving J.W. Bain and A.N. Fraser of Marine and Fisheries, and R.M. Stewart, C.C. Smith, and J.P. Henderson of the Dominion Observatory, resulted in a telephone line connection from the Booth Farmhouse to the observatory. A frequency of 1000 Hertz from the frequency standard operated a synchronometer which Mr. Bain made available for the time room. The synchronometer contained a vertically mounted phonic motor with a shaft from the armature which had to be spun by hand to get it started. It turned at 10 rps, and controlled both a clock dial and a 1 rps contact arm. The contact arm tripped a contact on a graduated drum whose position could be read to a tenth of a division (a thousandth of a second). It was used to indicate the performance of the crystal frequency standard of the monitoring station with respect to the observatory primary clock. Hence it became known as "Cm" meaning crystal clock monitoring station.

Ed Davey continued his reminiscences, "It wasn't long before the Time Room observed that the rate of our crystal clock was as good as, and sometimes better than their own time standards. This in turn led to the Time Room forsaking the Riefler and Shortt pendulums in favor of a crystal controlled time base."

In 1932 a second body was established by Parliament with regulatory powers in the radio frequency field, namely the Canadian Radio Broadcasting Commission. As the name indicates , the activities of the CRBC were restricted to the broadcast band, 500 to 1500 kilohertz. The regulations required that each broadcast station shall be so operated that the frequency is maintained between the limits of 50 hertz above to 50 hertz below the assigned frequency.

A three component General Radio crystal frequency standard was purchased by the CRBC, and space was provided for it by the National Research Council on Sussex Drive, Ottawa. The principal crystal was a quartz bar designed to operate at 50 kHz, while the other two quartz bars were cut to oscillate at frequencies of few hertz above and below. Uniform beats between the principal and the two offset frequencies resulted in an elegant method of internal monitoring. But the inherent characteristic of quartz oscillators to drift in frequency required an absolute or fundamental frequency reference. At that time the astronomical pendulum, which was accurately monitored against earth rotation, was the only such reference. Accordingly, Keith A. MacKinnon, engineer at the CRBC monitoring room, installed a telephone line to the Dominion Observatory with which he was able to introduce the half minute pulses of the free pendulum of S29 to his monitoring chart. It was necessary to allow for the rate of the pendulum as revealed by star observations and, in addition, to allow for the difference between sidereal and mean time. MacKinnon also monitored the U.S. Naval Observatory time signals and the WWV standard frequency transmissions of 5, 10, and 15 megahertz from the National Bureau of Standards, Washington, making a total of five independent checks on his primary crystal.

Canadians were made aware of the CRBC frequency standard by the "Oh Canada" time signal that was heard nightly over the CRBC network. The last note of the bar marked zero of the hour. Ed Davey claims that Alphonse Ouimet, then an engineer at Sussex Drive, later to become head of the CBC, was responsible for this contribution.

The feedback to the observatory from both these monitoring sources proved to be very helpful in observing the performance of the observatory clocks.

In 1926 Henderson built an oscillator to resonate at 10 hertz and in order to use this frequency as a scale on the chronograph, he adapted a Baldwin earphone with a syphon pen as a high speed recorder. Ten years later he was working with a 1000 hertz fork from which he counted down to 200 hertz and to 50 hertz by multivibrators. A small amount of power at 50 hertz was used to hold a special d.c. motor in synchronism, and hence to drive a drum chronograph at 1 rps, and by gear reduction at 1 rpm. The greatly improved stability of Cm over the fork encouraged him to add a 10 hertz multivibrator stage. The Baldwin phone and syphon pen responded readily to both the 10 and 50 hertz frequencies. It was therefore a useful tool in examining the short period variations of the Riefler and S29 pendulums, and in measuring the lags of relays associated with the clocks and with the transit instruments. The contacts within the clocks, and the commutator contact associated with the micrometer of the transit instrument, were capable of light duty only. The heavy duty operation of external circuits, such as the printing hammer of the printing chronograph or the impulse to the downtown time service, had to be handled by a relay.

Relay lag, which really means the length of time required for the armature of the relay to respond to the impulse given to the coils, was readily measured by recording a series of clock beats, some with the relay in the circuit, and some with the relay bypassed. One such measurement made in 1931 showed that the relay lag of the meridian circle transit micrometer was 0.025 second. When out of adjustment due to pitted points, excessive gap, improper spring tension, etc., the lag generally increased, and has been observed to have three or four times its normal value. In spite of preventive maintenance, relays continued to go out of adjustment.

Once when C.C. Smith was measuring the relay lag from the transit instrument he asked Henderson if he could devise a relay with no lag. Henderson experimented with electronic devices in which higher voltages and sharper rise times could be used. In 1933 a 1200 ohm relay on the output of an old peanut tube recorder had a lag of 0.013 second. The same relay on the output of a more modern recorder using 227 tubes had a lag of about 0.008 second. A more sensitive relay of only 300 ohms resistance had a lag of only about a millisecond. Experiments were conducted with neon and argon gas tubes which could be fired with an input contact, and which would then discharge a condenser storage through an output circuit such as the coils of a relay. More use was actually made of the flash from the gas tube to illuminate a sectored disc on the end of the 10 rps shaft of the synchronometer whereby Henderson was able to examine photographically the behaviour of clock beats. The contact of the synchronometer drum was shown to have an eccentricity of several milliseconds.

The thyratron, a three element gas filled tube of conventional design, was sensitive enough that it could be tripped directly from a telescope or clock contact and instantly exhibit the arc type of voltage drop through the plate circuit so that it offered very little impedance to the external circuit. It was well adapted to the heavy surge required by the hammer of the printing chronograph, since its input could be either a make or a break circuit. It became known as a "speeder upper".

Another electronic relay of less conventional design was contrived by Henderson using the ordinary type 45 power tube. Having the grid held in bias through a high impedance network, enabled him to provide control of the output by a high impedance low current contact to the grid such as with finger tips. He applied this to the pendulum of one of the time signal machines, the contact with the pendulum being a fine wire (number 40) against which it brushed when it swung back and forth through dead centre. The mechanical energy exacted from the pendulum was far less than was involved in the usual type of contact. The extremely small amount of current drawn by the grid of the tube caused little or no pitting or burning or sparking at the point of contact with the pendulum.

In 1938 Henderson also developed the inductive impulse method for the instantaneous operation of relays. The method used the break of a contact to release the stored up energy of an 8 to 10 henry inductance which had been charged by a dc of about 8 volts. An ordinary 110 volt neon bulb, with its base resistor removed, effectively blocked the low voltage from the external circuit, but presented no barrier to the inductive surge when the contact was opened. Several relays on the output of the time signal machines were operated in this manner.

The CRBC, as a regulatory authority, ceased when Parliament revised certain statutes in December 1936. Radio monitoring was then consolidated under the authority of the newly formed Department of Transport. A year and a half later the frequency standard established by MacKinnon was transferred to Bain and Davey at the monitoring station, augmenting their equipment which now included a Marconi as well as a General Radio standard. Part of the delay in the transfer was due to the continuing need for standard frequencies within the laboratories of NRC, and it took a while for the priorities between NRC and DOT to be settled.

When D.W.R. McKinley, a recent Ph.D. graduate of the University of Toronto, arrived at NRC late in 1938, one of his first chores was to provide a standard frequency throughout the labs, as had been done by

MacKinnon. Initially he arranged for the transmission by telephone line of 1000 hertz frequency from the monitoring station via the observatory. Later he assembled the material for his own generator. By the end of 1938 he was able to synchronize his standard with WWV to one beat in 10 seconds on the 5 megahertz transmission, which meant about 2 parts in 10^8. Since Bain also took regular readings of NAA time transmissions, it would appear that the assessments of the observatory clocks from both the monitoring station and NRC were somewhat biased by USA sources of calibration.

The impact of the quartz crystal frequency standard upon the astronomers was definite. A year after his report that the fourth room in the clock vault was being prepared for a second Synchronome, C.C. Smith was turning a friendly ear to the suggestion by Henderson that they assemble the necessary parts for their own crystal clock. Smith retired in December 1937 before any steps could be taken. In fact it was not till the depression years were over and priorities for the war effort were being claimed that a General Radio frequency standard was obtained for the time service. It arrived at the observatory on April 17, 1942, and became known as Co to distinguish it from Cm of the monitoring station and Cr of NRC.

General Radio had several alternatives to offer. The deluxe model, involving three oscillators, was similar to the one acquired by MacKinnon. An economy unit had only one crystal. The crystal frequency was doubled from 50 kHz to 100 kHz, then divided down in two multivibrator steps from 100 kHz to 10 kHz to 1 kHz. From Henderson's diary one learns that the original unit purchased by Bain had 3 tubes of type 112A, plus one for output amplifier and external feed, i.e. a total of 4 tubes per stage, all of filament type. Power was derived from floating batteries. "Bias voltages were from "C" batteries which always seemed to be going dead. Filament type tubes were very critical to filament voltage, a drop of two-tenths of a volt often causing one or other of the multivibrators to drop out. Consequently an uninterrupted run of more than a week was a real achievement" (Ed Davey's reminiscences). By the time the order was being considered for the observatory, a model which could be plugged directly into the ac line was available. Since there was no room for another large bank of batteries, it was decided to take advantage of the modern design of tube rectifier for the plate and grid bias voltages. Also from the standpoint of economy a single crystal unit was ordered. Its synchronometer provided the seconds pulses by which it was compared with the other clocks of the observatory.

An interruption in the ac line was a real, though not very frequent hazard. As a precaution, Henderson installed his own Esco 32-110 volt dynamotor, which generated 110 volts ac from 32 volts dc. The observatory battery bank was tapped at 38 volts and #12 copper leads were used from the battery room to the time room a total distance of perhaps 30 feet. High speed (1 rps) chronograph records showed that the build up time of the generator was about 0.6 second. The heaters of the tubes (probably type 227) seemed to bridge the build up time satisfactorily. In order that the high voltage and bias supply should also be unaffected, a large capacity of 560 microfarads was placed across the rectifier output with 1000 ohm resistor on the ac return to protect the rectifier tube.

In 1952 the motor generator gave way to a Cornel Dubilier vibrator converter of 375 watts capacity, similar to the type used on railway coaches. Within the next two years a total of five such units were installed, affording individual protection to each of the principal crystal clocks and their associated circuits.

Early in 1948, Toronto Hydro began pulling switches in various parts of the city to conserve power. Ottawa received similar treatment later in the year. The observatory, being on the same circuit as the Civic Hospital, was not subjected to deliberate cuts, though adjacent buildings on the Experimental Farm were. However it was disturbing to experience drops in voltage of 10% which seriously affected the output of amplifiers, mainly due to reduced cathode emission.

The threat of power cuts, whether deliberate or accidental, was sufficiently real that an emergency gasoline powered generator was requisitioned. A survey revealed that the minimum power requirements within the time service, including all the clocks, amplifiers, telescope illumination lamps, receivers, relays, and lights for the time room, amounted to 11.55 kilowatts. In November 1948, a Hercules gasoline powered generator of 20 kilowatts capacity was installed in the basement of the machine shop, and the necessary wiring to the time service was completed early in 1949. About 15 seconds were required for build-up time, and this was readily bridged by the battery operated vibrators.

With this improvement, Co became the primary timekeeper of the observatory, with Cm (Monitoring Station) and Cr (NRC) serving as reference standards. S29 was relegated to the lesser duty of providing sidereal time for transit observations. Even in this role S29 was limited and within a few years was to be replaced by sidereal seconds pulses derived electromechanically from a crystal source.

Traditionally the time service had relied on battery supply for the operation of clocks, relays, telescope illumination, micrometer contacts, and so on. The battery room, with its banks of large capacity lead acid cells was a source of dc supply of any value up to about 100 volts. Every 10 years or so the cells had to be replaced. Originally, a motor generator operating off the mains supply was used to restore the charge once a week. In the early 1930's the generator, now worn out, was replaced by a two tube tungar rectifier. About this time small copper oxide dry disc rectifiers were introduced, either to maintain a floating charge to compensate for the drain on a portion of the battery bank, or to provide an independent source of dc.

As the wiring of the observatory became aged, and the insulation deteriorated, leakages to ground tended to develop at different points across the battery. At one time it was a wire to the dome for telescope illumination. At another time it was a wire to the transit annex for the operation of a relay. A third case was a wire which provided field illumination for the transit telescope, and there were more. The requirements for 6 volts here, 8 volts there throughout the observatory were distributed uniformly across the battery bank, and a short to ground could occur with disturbing effects almost anywhere. Another hazard almost brought S29 to a standstill when the impulse from the Slave failed to arrive due to a blown fuse on one of the several outputs of the battery bank.

Soon after World War II the old wiring, consisting of bundles of twisted pair lamp cord which spilled out of overcrowded wooden troughs and festooned the hallways, was replaced by metal clad multi-wire cables. Terminal blocks, properly identified, greatly simplified the task of coordinating and monitoring all the services from the time room throughout the observatory and the city.

Returning to the General Radio frequency standard, there were other problems besides voltage supply requiring attention. The crystal oscillator would not hold its frequency in spite of attempts to adjust the inductance and capacity of the associated tuned circuit. The crystal had to be replaced, and in December 1944 a new 50 kHz bar was installed. One instance will suffice to show how several troublesome factors will converge. In 1948 a power failure of 1½ minutes was not bridged because, apparently, the battery bank had been allowed to run down. But quite independently several tubes had run their normal course and had to be replaced before Co was operational again. The philosophical outlook on these various mishaps was that experience was gained on how to avoid a subsequent occurrence. More important, though, was the fact that a single frequency standard was quite insufficient for the effective operation of a time service. The other two standards, Cm at the Monitoring Station and Cr at NRC, were very useful in assessing the performance of Co, but neither of them could be readily switched into service in place of Co. More crystal standards were required at the observatory.

It was just a year after this episode with Co that S29 came almost to a standstill. The slave pendulum was easily restored, but the free pendulum was more difficult. All but one of the mounting bolts were removed in order to tilt the case and in the process the vacuum seal developed a leak. A week elapsed before the seal was restored. Meanwhile Time Machine #1 was switched to Co control, and it would have remained that way indefinitely were it not for the faulty relay which two months later caused the output to slip several seconds. TM1 was thereupon restored to S29 control.

In 1947, Hollinsworth completed the construction of a multivibrator chain which counted down from 1000 hertz to 100 hertz, and from 100 hertz to 10 hertz, and then with a multiplication of six, generated 60 hertz. Much of the pioneer work had been accomplished by Henderson a decade earlier, but had never been engineered into a convenient and compact rack and panel assembly. Hollinsworth had some difficulty with the 10 hertz unit because of the bulky components and because of division by ten at the low frequency. McKinley achieved a crystal control of 60 hertz by using a six sector disc of mumetal as an inductor on the 10 rps shaft of the synchronometer. Due to occasional stoppages, the synchronometer was not as consistent as the multivibrator chain. Either source could be fed into the 60 hertz amplifier which produced 150 watts at 110 volts, "sufficient to operate quite a number of small motors drawing from 2 to 10 watts" (Hollinsworth, Can. Journal of Research, 27(F) 470 (1949)).

Hollinsworth then designed a sidereal converter employing two gear ratios, 119:114, and 317:333. The input was a 1 rps crystal controlled 60 hertz motor. The 1 rps sidereal output differed from ideal by about one second in 8 years. There was both a phasable and a fixed phase output contact, so that the converter could be used as a comparator and also as a sidereal clock. An attempt was made to derive a 60 hertz sidereal by using a 60 sector mumetal disc on the 1 rps shaft, following the example of McKinley. But the frequency modulation resulting from the residual eccentricity of the gear wheels made the result impractical.

Henderson used the principle of a rotary transformer to derive 60 hertz sidereal. The 60 hertz mean time was split into 3 phases, using a condenser advance, an inductive retard, and a resistance for zero phase, and the three wires were fed into the field windings of a selsyn motor. The output from the rotor winding could then be advanced or retarded according to the direction of rotation. With a simple gear ratio of 23:140 on the output of a one rps mean time shaft, the selsyn shaft was advanced 0.16428 ... of a revolution each second. The resulting 60 hertz had a gaining rate of 0.016 second per day on sidereal time. Not only was it a small rate but it was far more uniform than could be expected from the best pendulum. As a result, frequency dials replaced the old seconds dials that had been used as observing monitors in the transit rooms and the domes, and frequency drive replaced gravity drive for chronographs and equatorial telescopes. In reporting the 1950-53 observing program with the Meridian Circle transit telescope, R.W. Tanner and E.G. Woolsey stated, "The printing chronograph has been converted to synchronous motor drive on crystal controlled frequency, and served as observing clock with small nearly constant rate. Hourly comparisons of the chronograph were made, at first with the slave of Shortt 29, later with a mechanical converter controlled by a second mean time crystal." (Pub. Dom. Obs. 15 381 (1957))

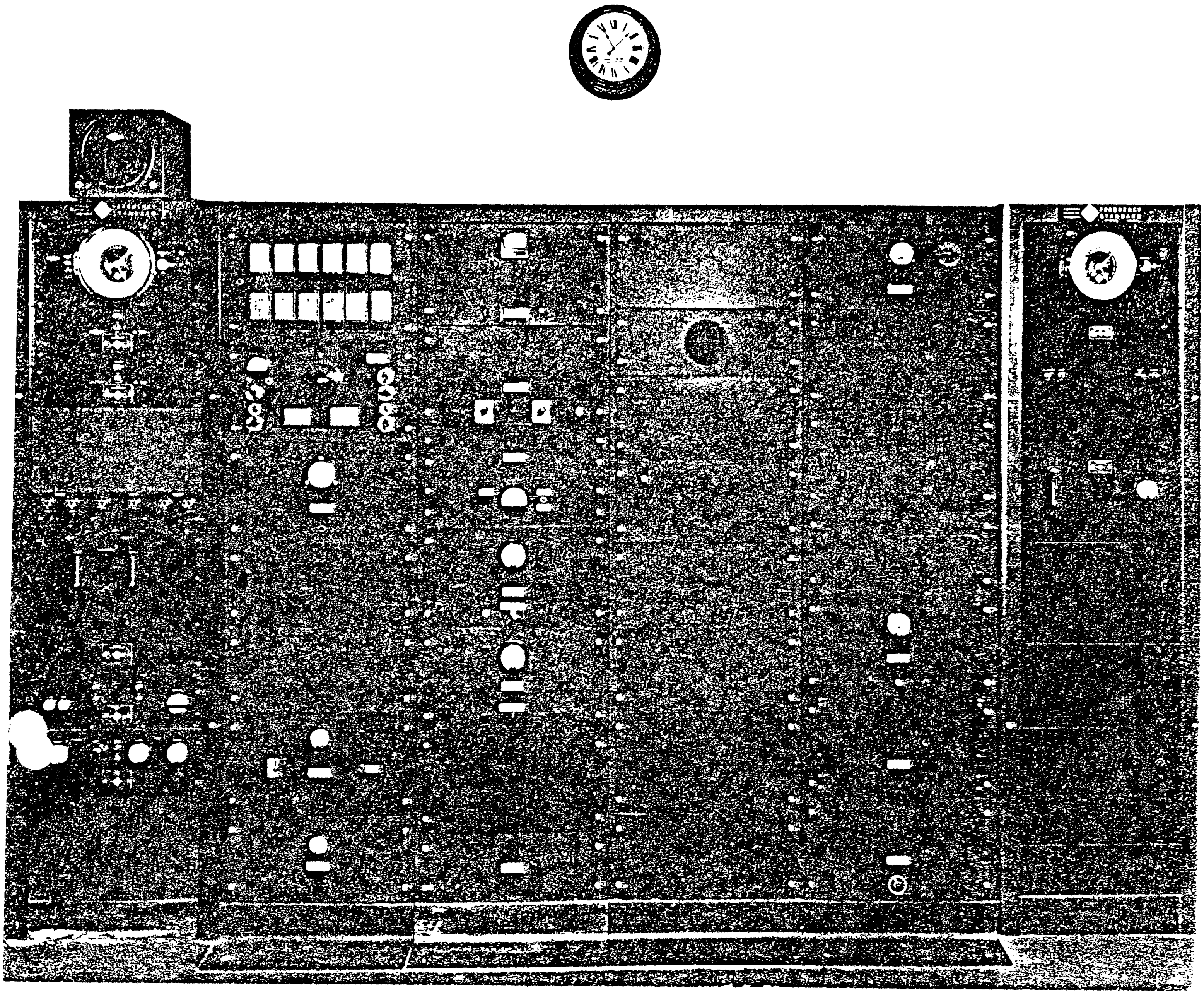


Fig. 76 Pg. 279 Electronic equipment in the time room in 1951 where formerly the marble switch board stood. Two General Radio frequency standards, surmounted by synchronometers, stand at either end. An HRO receiver, and various amplifiers, electronic relays and distribution panels fill the intermediate racks. Courtesy Earth Physics Branch, EMR.

Fig. 77 M. M. Thomson at the Western Electric type D0175730 primary
Pg. 279 frequency standard in the clock vault where formerly an astronomical pendulum had been mounted. The vault provided both thermal control and freedom from vibration caused by traffic. Courtesy Earth Physics Branch, EMR.

Haines Scientific Instruments of Englewood, N.J., produced a frequency dial with an internal gear ratio from mean time to sidereal. Several of these were installed as monitors in locations where sidereal time was required with precision to the minute only.

Dr. C.S. Beals, who succeeded R.M. Stewart as Dominion Astronomer in 1946, was careful to consult with W.S. McClenahan and members of the time service staff in planning the future. In spite of moves at Washington and Greenwich observatories to rely upon crystal frequency standards, McClenahan felt some reluctance at abandoning the pendulum. It had the advantages of long periods of trouble free operation, low power consumption, and precision adequate for most time-keeping requirements. Younger staff members, however, carried the day, and within the first four years of the 1950's four crystal primary Fig. 76
frequency standards were acquired.

The first was a General Radio, type 1100-AP which arrived in April 1950. As an updated model of the one bought in 1942, it had a 100 kHz crystal, and improved thermal control of the oven. A synchronometer provided an output at the seconds level. The next two were Western Electric frequency standards, type D0175730, which arrived in 1951 and Fig. 77
1953. McKinley of NRC already had one and was impressed by the calibration of the oscillator circuit which permitted an adjustment to a part in ten to the ninth, equivalent to about a tenth of a millisecond a day. The W.E. frequency standards were complemented by Ernst Norrman multivibrators which counted down from the 100 kHz frequency of the oscillator and provided outputs at 1000 hertz, 100 hertz, and 60 hertz. A General Radio synchronometer for each standard provided day by day comparisons at the

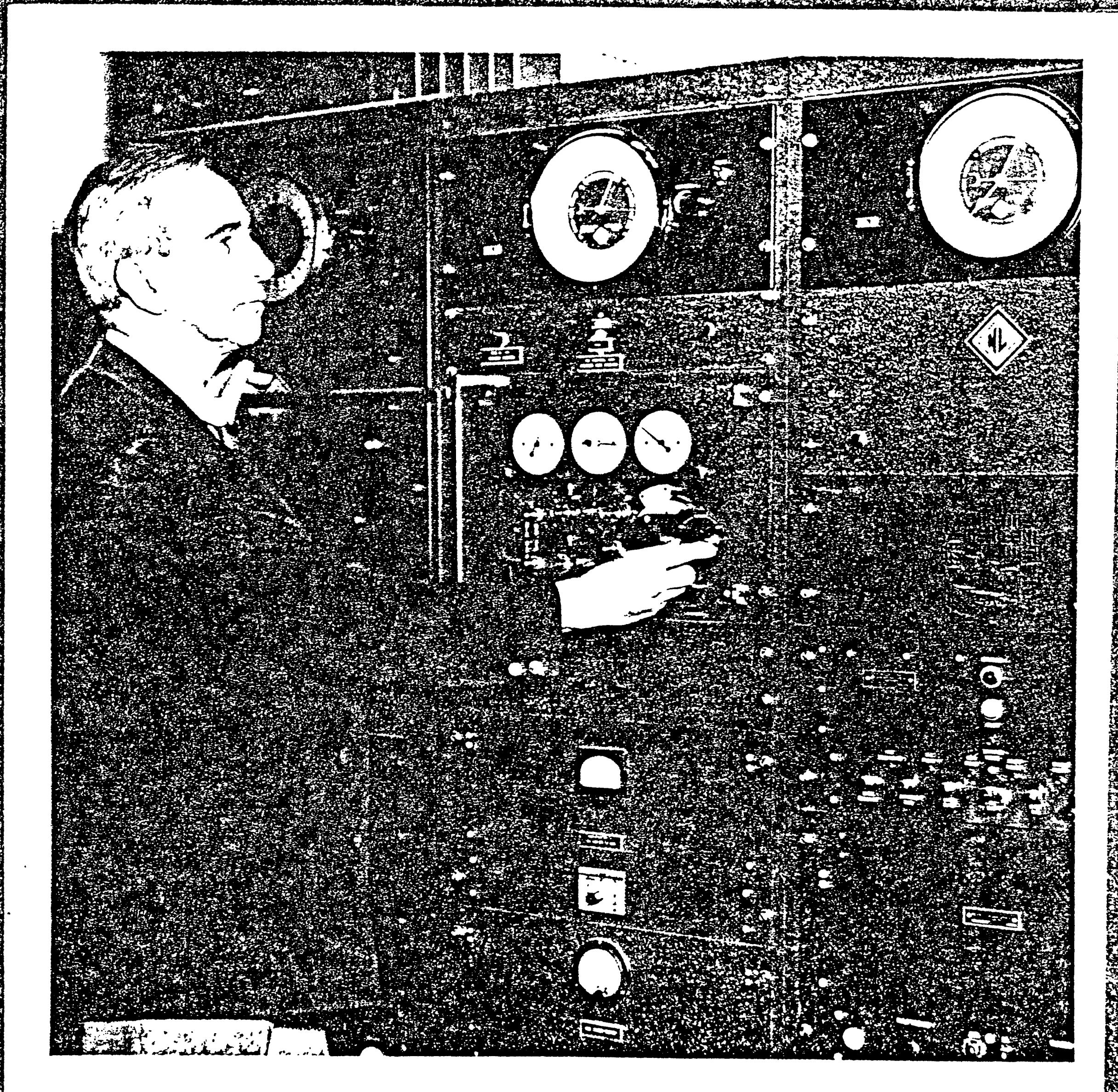
seconds level. Ernst Norrman arrived at 60 hertz by counting down to 100 hertz, then multiplying to 300, and dividing down to 60, thereby avoiding the problems Hollinsworth encountered at 10 hertz. Because of the relative ease of adjustment, the W.E. frequency standards became work standards, and were removed to the clock vault for better control. Subsequently the thermostats on the W.E. ovens became defective and in 1954 were replaced by mercury units.

With four crystals, the old name Co ceased to exist. Instead, the crystals became known as X1, X2, X3 and X4, the first two referring to the two G.R.'s and the others being the W.E.'s.

Various techniques were employed to compare the performance of the crystal clocks. Henderson devised a scheme in which the minute pulse operated a light metal pointer like a hammer onto a drum chronograph. The worm which advanced the carriage was reduced in speed so that the record could be accumulated for four days. At first a carbon paper was wrapped around the drum on top of the chronograph paper. But it was just about the time that ball point pens were introduced, and a ball point cartridge was used to mark directly on to the chronograph paper. The resulting chart showed the short period as well as the long period variations of each of the crystals. The method was not continued after Henderson reached retirement age in March 1956. Continuous strip chart recorders, designed to give similar information, were coming into service, and in the next few years several were acquired.

In October, 1951, two time signal machines, built by Muirhead of England, arrived and were immediately named M24 and M25. They were each controlled by 1000 hertz synchronous motors which were manually brought up to speed by a removable hand crank. It might be noted here Fig. 78

Fig 50



SIZE 65%

Fig. 78 J.P. Henderson adjusting the phase of one of the two Muirhead
Pg. 280 timing devices. Courtesy Earth Physics Branch, EMR.

that the later models of General Radio synchronometer came equipped with small electric motor starters. The Muirhead motors were continuously phasable so that the output contacts could be adjusted to the nearest millisecond. In addition to the normal signals required for the time service with an omission on the 29th second and 56th to 59th seconds of each minute, there was provision in the Muirhead machines for a lengthening of the minute dash from one-third to one-half of a second, and the dash on the hour to one second. "CHU-CANADA-CHU" was sent in Morse code twice during the first minute of each hour in place of "CHU-CHU" which appeared but once on TM1 and TM2. Provision was also made for the transmission of 61 beats to the minute, following the method employed on some of the European transmissions. It was never used.

The next acquisition was an Essen ring crystal frequency standard developed by L. Essen and W. D. Dye in the Research Laboratories of the British Post Office (IEE Proceedings, 1951, Pt 2 pg 154). Attention had been drawn to them by J.T. Henderson of the Applied Physics Division of NRC. S.N. Kalra of the electricity section of Applied Physics Division had placed an order for two. C.F. Pattenson, who had inherited the frequency standards work from McKinley in the Radio and Electrical Engineering Division had also ordered two. McClenahan, Beals, and J.P. Henderson were sufficiently impressed that an order for one was placed. It was to operate like an astronomical pendulum with no adjustment in rate once it was factory tested, and the frequency trimmer was accordingly left out. All the components except crystals arrived early in 1954, and in July of that year Mr. Jack McClements of the British Post Office brought the crystals by hand and assisted in their installation. The observatory ring became known as R5 or 5DO.

McClements and Lloyd Miller were carefully observing the beats between the new ring crystal and the General Radio crystal, X2, which was located in the time room. They were seated quietly in the wireless room next door. All at once one of the summer students bounded across the time room floor because her boyfriend had arrived unexpectedly, and with each step the frequency of X2 took a noticeable shift. So the calibration of the Essen ring was held up until X3 (a Western Electric in the vault) was substituted. The humorous event actually demonstrated that the General Radio crystal was not sufficiently well shielded from vibration. Kalra came to the rescue by designing a shock mount, and both X1 and X2 were removed to the vault. The Essen ring was also placed in the clock vault, the very room which C.C. Smith some 20 years earlier had designated as the home of a second Shortt clock. Coaxial cables from the clock vault to the time room connected the various oscillators to the appropriate multivibrators, amplifiers and other gear.

The Essen ring multivibrator counted down to 50 hertz from which a small 50 hertz motor was driven. A single tooth on the 1 rps shaft advanced the second hand of the clock in one second jumps, resulting in an audible click. Because of the noise it created, the clock was not used. Furthermore the rather high negative rate of the oscillator really made it of little value as a clock. The rate continued to increase negatively, and never approached zero, as had been forecast.

McClements gave Hollinsworth and Miller the circuit details for a multivibrator using cold cathode tubes to count down from 50 hertz to one pulse per second. Several units were made up and adapted to the Ernst Norrman and General Radio low frequency outputs. The resulting pulse was more uniform than the synchronometer contact and provided an effective way of measuring the accumulated daily gain or loss of each crystal with respect to the others to a tenth of a millisecond a day. This was a hundred-fold increase in precision over the pendulum clock.

The British Post Office had developed a circuit which used the ordinary watt meter to count the beats between two oscillators. They were made up in units of three to display the continuous performance of three crystals at the 100 kHz level. Two of these units were installed in the time room in 1956 and two groups of three crystals were made up by using the ring crystal, R5, twice. A polaroid camera was mounted across the room to record photographically the readings of the dials at 10:00 a.m. each day. The relative performance of each crystal could then be read to a very high precision, but the short term variations did not warrant using a value beyond $1{:}10^{10}$.

More of the ring crystals were acquired by the Ottawa group within the next year or two bringing the total to 9. There were 4 at the Applied Physics Division of NRC, 3 at the Radio and Electrical Engineering Division of NRC, and 2 at the Observatory. More than ever it became evident that this resource could be pooled to provide a Canadian standard of time and frequency.

W.B. Smith, who had in the postwar years become engineer in charge of the Department of Transport radio monitoring facilities, supported the move to increase the range of the CHU time transmissions, and advocated as early as 1948 that the frequencies be derived from a quartz crystal frequency standard. The Ottawa monitoring station as well as other monitoring stations within the range of CHU could then base all frequency measurements on a Canadian standard. Smith collaborated in every way possible by providing space and technician services at the Greenbank Road transmitter site.

Kalra, undertook to establish a Canadian standard of frequency based on the evidence of the frequency standards located at the three centers. J.P. Henderson had demonstrated that 100 kHz frequency could be transmitted short distances of a few miles by ordinary telephone line providing there were no loading coils or repeater amplifiers in series. Kalra was able to receive a 100 kHz signal from 5DO, and a similar signal from one of the Essen rings at Pattenson's lab which had been moved in 1954 to the Montreal Road site. Both signals were weak on arrival, requiring a radio receiver to detect and amplify each.

5DO, which at the observatory was referred to as R5, was assessed with respect to UT2 from observations with the photographic zenith tube, and the results communicated to Kalra. "The accuracy of the absolute frequency determination is limited by the errors of astronomical observations and the uncertainty of the corrections to be applied. In most cases it is possible to achieve an accuracy of $5{:}10^9$ if it is assumed that all the corrections needed for the determination of a second of UT2 are known exactly. Recent work of Essen and Markowitz (Essen et al. 1958) has shown that there are secular changes in UT2. For a further study of these effects and for the investigation of the possibility of redefinition of a time interval in terms of atomic phenomena, a cesium beam frequency resonator has been developed by Kalra, Bailey and Daams (1958) ... International intercomparisons of frequency standards are carried out by measurements of time signals and by phase measurements of low frequency carriers. Results show agreement with the United Kingdom and U.S.A. standards to well within $1:10^8$ frequency." (Kalra, S.N., Pattenson, C.F., and Thomson, M.M., Can. J. Physics 37 10 (1959).)

A 10 kHz signal was sent to Pattenson from the Observatory. The distance was too great for the 100 kHz signal from R5 with any usable strength. Also it was impossible to attempt to detect a very weak signal and at the same time radiate on the same frequency. The results of the astronomical observations were also communicated regularly. Pattenson and J.C. Swail undertook to engineer a system in which the carrier frequencies of CHU would be "maintained at an accuracy and precision consistent with standard frequency transmissions" and the actual seconds pulses would bear "a known and constant phase relationship to the carrier frequencies" (Swail, J.C., and Pattenson, C.F., J. Sc. Instr., 40, 321, (1963)). The system was installed in January 1961.

A contribution to the crystal oscillator era of timekeeping came from an unexpected quarter. H.D. Valliant of the Dominion Observatory Gravity Division had spend a frustrating field season because the portable crystal oscillator and associated multivibrator states which he was using had been difficult to maintain. In preparation for future field work he acquired in 1959 a James Knights 1 MHz crystal frequency standard, fully transistorized and complete with a standby floating battery supply. This he took to Kalra for an assessment, where it measured up to all its advertized specifications. From Kalra it came back to the Observatory and was used for several months as part of the time service. So impressed were Hollinsworth and Miller that one was immediately requisitioned, and became the controlling oscillator for CHU. Subsequently the older crystals at the observatory were retired as more efficient and more precise oscillators of the James Knights-Sulzer design were acquired.

Reception of Radio Time Signals

RECEPTION OF RADIO TIME SIGNALS

"The Dominion Observatory was among the first institutions to make a successful effort to determine longitude by using wireless signals", wrote C.C. Smith in an unpublished historical document written in 1930.

In April 1914, Dr. W.F. King, the Chief Astronomer wrote to C.P. Edwards of the Naval Service, Department of Marine and Fisheries, as follows:

"In pursuance of the preliminary experiments being carried on with a view to the determination of longitudes by wireless telegraphy, it seems desirable to erect a temporary receiving station in the vicinity of Haileybury, as nearly as possible under field conditions; in connection with this I should be glad of the benefit of your advice.

"As you are aware, a chronometer has been installed in the wireless station at Kingston, which can be used for sending out signals whenever required; it is proposed in the preliminary experiments to determine whether these signals (or, failing them the Arlington longitude and time signals) can be successfully received with the required accuracy at as great a distance as Haileybury.

"Our present proposal is to erect a temporary aerial of say 500 feet to 750 feet length, composed of two aluminum wires supported by portable 30 feet masts lashed to trees as high as possible. I should be very glad of any suggestions you might be able to offer in regard to this; also in regard to earth net, guy wires, etc., which would be required, and on any other points which may occur to you. It is desirable to limit the equipment as far as possible to such as could without undue difficulty be transported by canoe, as some of the stations ultimately required can, I believe, be reached only in this way."

An entry in Otto Klotz's diary dated April 23, 1914 reads: "In evening at Observatory when Mr. C.P. Edwards, Dept. of Radio Telegraphy, gives a splendid address on that subject illustrated by many experiments. A feature was the wireless greetings from the Kingston station, and the receiving of the check on time signals at 10:00 p.m. from the Washington Observatory through the Arlington radio station there." Doubtless the lecture was answer in part to the request for information.

The site selected for the first test was Quinze Dam in the head waters of the Ottawa River. In order to avoid the roar of the rapids, the wireless set was placed in a settler's root cellar. It was a crystal set, built before the days when radio tubes were a common commodity. A similar set was installed at the observatory. Unfortunately the signals from the Barriefield station at Kingston could not be heard at Quinze Dam in spite of all these precautions, and it was necessary to use the stronger signals from Arlington. The result of the successful experiment that summer demonstrated that wireless time signals could yield results comparable to the telegraph method. The surveyor was no longer restricted to the telegraph line. His instruments could be carried into the vast Canadian northland, anywhere, just so long as he was within range of a radio time signal.

W.A. (Wally) Dier, a skilled telegrapher who could tap a key with either hand, and who knew both Morse and land line code, had been hired by Dr. King to operate the radio, receive the time signals, and assist R.M. Stewart in the work of the time service. Dave Robertson, another person trained in telegraphy, had charge of the telegraph lines in the time room, by means of which time signals were exchanged with field personnel. Each evening in the field, Wally Dier copied the news from Sayville, keeping the camp informed of the details leading up to the outbreak of war, then of the progress of the conflict. Some items which he copied were messages in English sent to Germany and to German ships at sea warning them of circumstances of the war. When the words came out in German language, he kept on copying though he didn't understand a word of it. When the copy was relayed through R.M. Stewart to the Defence Dept., these special messages ceased, and Wally was officially thanked for his contribution to the war effort.

Four stations in the upper basin of the Ottawa River were occupied during the summer of 1914. The following season seven in Quebec and two in Ontario, near Georgian Bay were similarly occupied. Only one position was determined by radio time signals in 1916, following which the exigencies of war drew all such activities to a temporary halt.

The cessation of hostilities on November 11, 1918 brought a renewal of scientific activity. The Dominion Astrophysical Observatory in Victoria, B.C., with Dr. J.S. Plaskett as Director, was officially opened. The Geodetic Survey, which had been a part of the observatory until King's death in 1916, now functioned as an independent unit with Noel Ogilvy as Director. Several men who had formerly been attached to the radial velocity program of the 15-inch telescope were now assigned other duties. J.S. Plaskett and W.E. Harper had gone to Victoria, C.R. Westland, T.H. Parker and J.B. Cannon had moved over to the Geodetic Survey. A new appointment made in 1919 to carry on the work of the 15-inch equatorial was Dr. F. Henroteau.

In July of 1919 J.P. Henderson, M.A., arrived at the Observatory having been appointed as assistant astronomer. A note of his appointment in the RASC Journal of 1919 (pg. 298) indicated that he had been acting as assistant in astronomy at the University of Toronto for the last four years. His interests were in fact quite broad. At the time Wally Dier was struggling with a crystal receiver at Quinze Dam in 1914, Henderson, a graduate student at the University of Toronto, was spending the summer as a wireless operator on a ship on the Great Lakes, mainly to become proficient in the use of Morse code. He was an experimenter, having acquired some of the early radio tubes in the days when the crystal detector was the principal element of a receiver. Some years previously his father had pioneered in the purchase of a car, and Henderson, then but a lad, was entrusted with its care. Motor mechanics appealed to him. Then, as if to round out his interests, he studied the pipe organ, and for a while came under the influence of Sir Ernest MacMillan.

Henderson soon realized that the 15-inch telescope had just about reached the end of its usefulness as an instrument for determining radial velocities. The brighter stars to which it was restricted had all been observed, and fainter stars required very long exposures with such a small aperture. The work was done much more effectively by the new and larger 72-inch telescope in Victoria. The chances are that he might have had more heart for the program had it not been for two things, the imcompatibility of his ~~supervisor~~ colleague, F. Henroteau, and the much more attractive program of wireless time signals upon which R.M. Stewart had recently embarked.

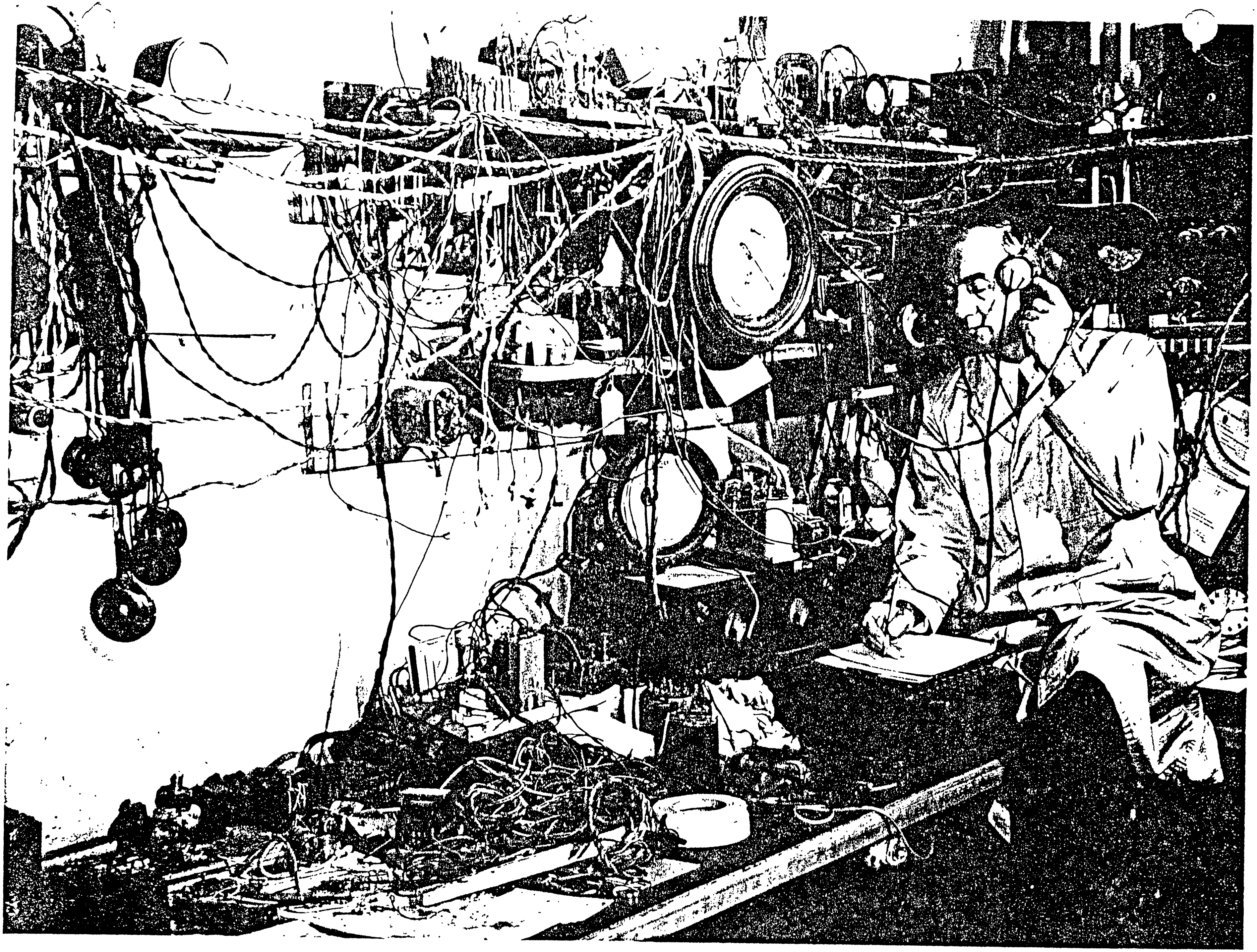


Fig. 79 J.P. Henderson in the Wireless Room, Dominion Observatory, 1949.
Pg 291 Photo by Malak

< ZE 65

Without neglecting his obligation to the astronomical program, Henderson found himself drawn into the wireless program. Stewart, who had great skill as a mathematician, and some as a mechanic, was quick to recognize the interest and ability that Henderson possessed in the new science of radio engineering. Within five months he entrusted him with a key to the wireless room, and in return was delighted to see his old tube set augmented by a much more efficient tube set which brought signals in from Washington (NSS) Canal Zone (NBA) and San Francisco (NPG). From then on there was no turning back. Henroteau complained in vain about Henderson leaving the dome for short periods to make a wireless time comparison. Really he had little grounds for complaint because in spite of the interest he displayed in electronics, Henderson was faithful to his obligations as astronomical assistant, and contributed to the publication of two papers on A Spectroscopic Study of Early Class B Stars (Pub. Dom. Obs. Vol. 5, 1920-22).

In his spare time during 1920, Henderson spent many hours in the wireless room improving the receiving apparatus, and devising a method for recording the signals on a drum chronograph. Also he became associated in a volunteer capacity with C.P. Edwards, Colonel A.W. Steele, and others conducting research at the Test Room of the Naval Service, Department of Marine and Fisheries, at 279 Wellington Street. Fig. 79

The following year the observatory was called on to play an important role in the survey of North Western Canada. Oil had been discovered about 60 miles north of Norman on the Mackenzie River, and the necessity arose for an immediate survey to locate the numerous claims that were subsequently staked.

"It would have been too great and too expensive an undertaking to extend so far north in such a short time the meridians and base lines which in Western Canada form the control for subdivision surveys and traverses. On the other hand it was most desirable that the surveys in the far north should be linked up with the existing surveys in Western Canada. Consequently it was decided to run a stadia traverse from the most convenient northerly point in the existing surveys right down to the oil fields. The part of the Dominion Lands survey that was chosen from which to begin the traverse was the point where the 30th base line crosses Slave River. This is about 65 miles up the river from Fitzgerald at the head of Smith rapids and the approximate latitude of the point is 59° 08'. From here to the oil well below Norman the distance is nearly one thousand miles. In running such a long traverse it is only to be expected, in spite of the most careful work, that small errors will creep in and that their effect may accumulate as the survey progresses. In order to correct these errors and to prevent their accumulation certain suitable points in the course of the traverse were selected at which the latitude and longitude were to be determined. The traverse was "tied in" to these points as it proceeded and the position of all points along the survey are therefore referred to the geographical positions of the selected points.

"It was the task of the observatory to determine the latitude and longitude of each of these control points. During the season of 1921 the survey was carried down the river as far as the Sans Sault rapids, about one hundred miles below Norman. The control points selected were Resolution on the south shore of Great Slave Lake near the mouth of Slave River, and Providence, Simpson and Norman on the Mackenzie River. The positions of these points were established in the summer of 1921 and points as far down as Arctic Red River were established the following season to provide for the required extension of the survey to the Delta of the Mackenzie.

"Owing to the fact that most of these places are several hundred miles from the nearest telegraph station, the usual method of determining the longitude by exchanging signals over the wire could not of course be employed. Instead of this, time signals that are sent out by wireless from several stations were made use of. The time signals which were used in the work were those from Annapolis, San Francisco, San Diego and Panama." (A.H. Miller, J. RASC, 17, 197, (1923).)

The observatory party was made up of three persons, A.H.S. Swinburn, who took the star observations that are required for obtaining the latitude and longitude, J.P. Henderson, who secured the wireless time comparisons, and A.H. Miller, who made measurements of the force of gravity at each of the stations.

Swinburn was supplied with a two inch astronomical transit of the broken type fitted with a transit micrometer and also a sidereal chronometer, and a drum chronograph. His work was hampered somewhat due to the short period of darkness in the arctic summer nights, and to the mists that frequently rose from the land of lakes and muskegs. As a result it required from ten days to three weeks to complete the observations at each station after the cement piers had been constructed. For his gravity measurements, Miller used a half seconds (invariable) pendulum apparatus which had been in the possession of the observatory since 1902.

"The receiving of the wireless signals was attended to by Mr. J.P. Henderson. He also had difficulties to contend with. Owing to the great distances from the sending stations and the almost continuous daylight, static disturbances gave a considerable amount of trouble. It was therefore necessary to set up the wireless apparatus to the very best advantage. Although at points farther down the river it was not possible to get very much of the press news sent out by wireless, Mr. Henderson was very successful in getting the time signals from the various stations, which were absolutely necessary for the successful completion of the work. At the times the signals were received they were compared by the method of coincidences by extinction with a chronometer which was set to gain about one second in every hundred seconds on the mean time signals. As the signals last for five minutes there are ordinarily at least three times during the five minute interval when the second beats of the signals coincide with the beats of the gaining chronometer. It is possible by this coincidence method to make a time comparison to within a hundredth of a second. This chronometer was compared on the chronograph, each time just before and just after the receipt of the signals, with the sidereal chronometer used by Mr. Swinburn in his star observations. In this way the sidereal chronometer time of arrival of the signals at any particular station was determined to within perhaps a few hundredths of a second. As the sidereal chronometer was in turn compared (also on the chronograph when the star observations were made) with the time of transit of the stars, it was finally possible to determine the arrival of the wireless signal in terms of the sidereal or local star time at the place of observation.

The same signals that were received at the field stations were also received at the observatory at Ottawa and their time of arrival was compared with the standard Riefler clocks of the observatory. The variations of these clocks from the local sidereal time at Ottawa are determined very accurately from the regular observations that are taken with the meridian circle. The local sidereal times of the same time signals were therefore determined both at Ottawa and at the field station. After allowing for the time of transmission of the wireless signal (about one hundredth of a second for 2000 miles) the difference between these local times for the arrival of the same signal gives the difference in the longitude between Ottawa and the field station." (A.H. Miller)

It was a heavy daily schedule that Henderson set for himself:

1 a.m. NPG (San Francisco)	1 p.m. NBA (Darien, Canal Zone)
5 a.m. NBA (Darien, Canal Zone)	3 p.m. NPL (San Diego)
12 noon NSS (Washington)	10 p.m. NSS (Washington)

The times are eastern standard, for the convenience of comparison with results of signals observed at Ottawa. In addition to the routine of wireless time signals there was the maintenance of the radio equipment, batteries, receivers, antennas. The news, so vital to avoid isolation, was copied whenever possible, sometimes competing against static which more often than not determined the end of reception.

In 1921 five stations were occupied, Peace River, Providence, Simpson, Norman and Resolution, and the following season four more, namely Liard, Good Hope, Arctic Red River, and Chipewyan. The operation was a success from every standpoint, a fulfilment of the forecast made in 1914 that radio would free the surveyor from the limitations imposed by the telegraphic method of time exchange. In addition, by copying the news broadcasts at every opportunity, Henderson demonstrated that radio was the vehicle with which to bridge the gap and break down the isolation of the communities of the north. An attempt had been made to extend the telegraph. Only a relatively short distance had been covered by 1922, and the cost of servicing the poles, which could not be held upright for long in the muskeg terrain, was high. The 1921 and 1922 field excursions by the Observatory survey team demonstrated the effectiveness and efficiency of radio communication, and shortly thereafter Col. A.W. Steele authorized the establishment of a radio communication network for this northern frontier.

Two notes of interest appear in Henderson's diary in 1922. On Saturday, August 26, while in Arctic Red River, he gave a demonstration of radio telephony, using his two receivers, speaking into the ear phones, and communicating between two adjacent buildings. Radio of any description was a novelty, and the transmission of voice was clearly a wonder of the modern age. The other note had to do with their homeward journey up the MacKenzie River on the Lady Mackworth. Henderson set up a receiver and delighted all on board by copying for them the news of the world as it came over in Morse Code. Captain Gardiner proudly proclaimed that his ship was the "first Canadian steamer equipped with wireless in the Arctic Circle!".

One day in 1921, just before the signals became unreadable due to onset of heavy static, Henderson recorded the results of the boxing match in which Dempsey overcame Carpentier. Otto Klotz reported the incident (J. RASC, 15, 306, (1921)) in the following humorous but pointed note

"At Fort Providence, in the wilds of the Mackenzie Basin, were three Dominion Observatory astronomers recently observing for geographic positions in connection with oil discoveries. The longitude work is necessarily by wireless, receiving signals from Annapolis, San Diego and San Francisco, the same signals being recorded also at the Dominion Observatory, Ottawa. By comparisons later the longitude of the Mackenzie station is found.

"The wireless expert and astronomer, J.P. Henderson, caught the wireless message announcing the result of the encounter between Dempsey and Carpentier, showing the latter to be an eclipsing variable, radial velocity in line of sight 120 km a second, period 12 minutes for 4 revolutions.

"The news was had at Fort Providence as soon as elsewhere, and spread up and down the Mackenzie to the consternation of natives and others, as this is the only wireless outfit in these boreal regions."

At a few of the stations occupied by the observatory party, a reminder of their visit was left in the form of a sundial, designed by Henderson, and mounted on the cement pier built for A.H.Swinburn's transit instrument. In each case it was the only indication of the time of day, and it remained as a useful curio in the community.

The success of these two seasons in the north established Henderson as an authority on the time signals that might be useful and also the radio equipment that would be best suited for field work. He built several long wave receivers for use by observatory and by topographic survey personnel. Also a miniaturized form of the long wave receiver was built which would fit into a vest pocket.

"Some years ago we put out the first of a type of combination set for operation on two specified wave bands, a double-throw double-pole switch changing from one band to the other. Separate regenerative coils are used, but the same tubes and two variable condensers, one in series with the aerial and the other in parallel with the tuned coil. Most of these sets have been made to cover bands 200-750^{m}, and 7,000-20,000 m, the shorter waves being used for concerts and also ships and weather, and the longer for time signals and long wave press reports. Any two bands could have been selected and built into the set. They were not made with plug-in coils for changing because of the difficulty we have always experienced in assuring that the contacts will remain good when used in outside work; also a lot of separate coils are troublesome to carry." (J.P. Henderson, J. RASC, 22, 77, (1928).)

The above quotation indicates that a future trend in radio manufacturing had been anticipated, namely band switching. It was suggested to Henderson that he apply for a patent, but he declined.

The time service at Ottawa had a three fold objective, the determination of fundamental time from star observations, the wireless reception of time signals in order to compare the results of timekeeping at different observatories, and the dissemination of time locally and nationally for the benefit of all sections of the community. Only a few modern observatories were equipped to maintain a time service, a growing number pressing on with other avenues of astronomical research and relying for their time on radio time signals emanating from other laboratories.

Prior to the advent of radio the local observatory had some degree of confidence that the results of its own transit observations gave a time that was entirely adequate and accurate. Radio dispelled the myth. Lack of a standard star catalogue, or of a uniform method of reducing to mean solar time, led to discrepancies of several hundredths of a second. It was to study these differences that in 1918 the Dominion Observatory commenced the daily reception of wireless time signals. At that time Annapolis or Arlington (USA) was received; in April 1921 the Bordeaux (France) signals of 300 beats were added to the program of reception; in August, 1924, the Nauen (Germany) signals; and in January, 1928 the signals from Rugby (England) were included.

Originally the comparison was made merely by observing the coincidence of audible beats between the incoming signal and the local chronometer. Some degree of precision could be obtained, but there was liable to be a personal equation with different observers. "Since 1920 the method of wireless reception employed has been that of the coincidence of signals by extinction, using an auxiliary clock. This method, first suggested by W.E. and F.B. Cooke in Monthly Notices, 77, 469, (1917) is described in detail [by Henderson] in the J. RASC, 19, 48, 1925" (C.C. Smith, Pub. Dom. Obs., 1, 1 (1930)).

The auxiliary clock or chronometer was equipped with a contact which was open half a second and closed half a second. The radio output was thereby obliterated for the first half of each second. If the auxiliary clock had a gaining rate, its beats would gradually overtake the radio signal, and the moment of coincidence was judged to be just after the last little pip of signal was heard. In the case of a vernier time signal which beat 61 times to the minute, a sidereal chronometer replaced the gaining chronometer. The radio time signal then overtook the chronometer beats, became obliterated, and then a few seconds later reappeared at the leading edge of the break. The moment of coincidence in this case was just before the first reappearing pip of the radio time signal. The coincidence in each case was estimated to the nearest half second.

The favorite location for the chronometer, or for the relay operated by the chronometer, was at the ground side of the antenna circuit. It was reasonably effective in removing the incoming signal from the receiver during the half second "opens". A new idea was conceived in 1925 when Henderson placed two matching step-down transformers back to back on the output of a receiver, the low voltage winding of one feeding the low voltage winding output of the other, and the earphones or loud speaker on the high voltage output winding. The chronometer contact was then placed either in series or in parallel with the low windings, providing makes and breaks which were electrically clean and noise free, and were no strain on the delicate contact points in the chronometer. From then on all radio sets both for field or for laboratory time signal duty were fitted with the back to back transformers for coincidence comparisons. Actually the output of the receiver was not disrupted, and in fact was only partly used. In the event of good clear reception it was then possible to record the signal on the drum chronograph as well as compare it by the coincidence technique.

The U.S. Naval system of signal transmission seems always to have been based on 60 beats to the mean time minute, except for omissions of the 29th and the 55th to 59th each minute. The last minute of the five minute transmission omitted the last ten beats, 50th to 59th. For mariners, the ship's chronometer could be set to the nearest second by visual monitoring while listening to the radio time signals. A more exact comparison for scientific purposes required a gaining chronometer, which at first was set to gain about 15 minutes a day, thus assuring a coincidence once in about 90 seconds or three during the five minute interval. A difference of a second in the determination of the coincidence meant a difference of 0.01 second in the final clock correction. The drawback to this method was that one coincidence could occur during the five second silent period, and a surge of static could make one or both of the others uncertain. An increase in the gaining rate to about 30 minutes a day resulted in a coincidence every 50 beats, or five during the 5 minute interval. By estimating the moment of coincidence to the half second, there was but small drop in accuracy, compensated for by the increased number of estimations.

The European stations made extensive use of a transmission involving 61 beats to the mean time minute, in which the minute markers were lengthened for identification. A coincidence with a mean time chronometer was assured once each minute, by means of which the mariner could readily check his chronometer to within a few sixtieths of a second. Reception of this type of signal at Ottawa was readily accomplished using a sidereal chronometer, the coincidences occurring about 70 seconds apart for a total of four or five during the five minute transmission period.

In both cases the comparison chronometer was carefully compared with the primary clock before and after the signal reception so that the time of the signal was ultimately known in terms of the astronomically determined time of the observatory.

Longitude was one of the quantities that would be improved by extending measurements over long arcs covered by the radio time signals. In 1885 and subsequently, the longitudes of Western Canada had been carried by telegraph from Seattle (the longitude of which had been fairly well established) to Kamloops and from here to the west coast and also easterly. Meanwhile the longitude of Montreal, besides being established by observations with Greenwich, had been tied in with the longitude of the United States at Albany and Harvard College. Afterwards the longitudes of Western Canada were connected directly through Winnipeg and Ottawa to Montreal. By 1919 there had been 174 longitude stations established in Canada, 14 of them by wireless, and R.M. Stewart, at that time head of the time service, proceeded to adjust the net of Canadian longitudes. The solution showed a disagreement of 0.128 second between the difference of longitude of Montreal and Seattle depending on whether it was carried through the Canadian or the American net. Due chiefly to the consideration that the longitude between Seattle and Kamloops was of very small weight, it was decided to use only the tie to Harvard College and disregard the Seattle Kamloops arc. The solution gave Ottawa and Vancouver the longitudes $5^h\ 02^m\ 51^s.940$ and $8^h\ 12^m\ 28^s.348$ respectively. The adopted longitude of Ottawa formerly had been $5^h\ 02^m\ 51^s.983$.

After much preliminary discussion, carried on over several years, it was decided at a meeting of the International Astronomical Union at Cambridge, Mass., in July, 1925, to carry out an extensive scheme of longitude determinations in October and November, 1926. Almost a quarter of a century had elapsed since the transpacific longitudes had been measured. During this interval advances had been made in technology.

Emission and reception of wireless time signals had replaced the telegraph wire and the submarine cable with its repeaters, and measurements were being made with increasing accuracy. Now it was appropriate to measure long arcs extending from continent to continent and encircling the globe. "The test of the Wegener theory of continental drift was admittedly the most active stimulant to the desire for such measurements" (C.C. Smith, (1930) unpublished).

"Forty-two different observatories and observing stations covering almost all of the inhabited parts of the globe took part in the measurements. Canada occupied two stations, one at the Dominion Observatory and one at Brockton Point, near Vancouver, this being the point from which the transpacific longitudes were started." Fig. 80

"As finally adopted, Algiers, Zikawei and San Diego were accepted as one main figure, and Greenwich, Tokyo, Vancouver and Ottawa as a second principal figure. The longitude of the other points were deduced differentially from these points." (C.C. Smith, (1930) unpublished)

At Vancouver the observatory at Brockton Point was enlarged, and an insulated clock room was added to house the Howard sidereal clock and a half second gravity pendulum. C.C. Smith and A.H.S. Swinburn operated a straight transit (Cooke) and a broken transit (Heyde) respectively, the Cooke being 12 feet 6 inches to the east of the Heyde. Fig. 81
J.P. Henderson set up the aerials and receiving equipment, and connected a double line to the home of J.H. Walsh, keeper of the Brockton Point gun, to provide him with time signals, concert music, and intercom with the observatory. The radio equipment included a double wave receiver, a short wave receiver, batteries, charger, and spare parts. A.H. Miller,

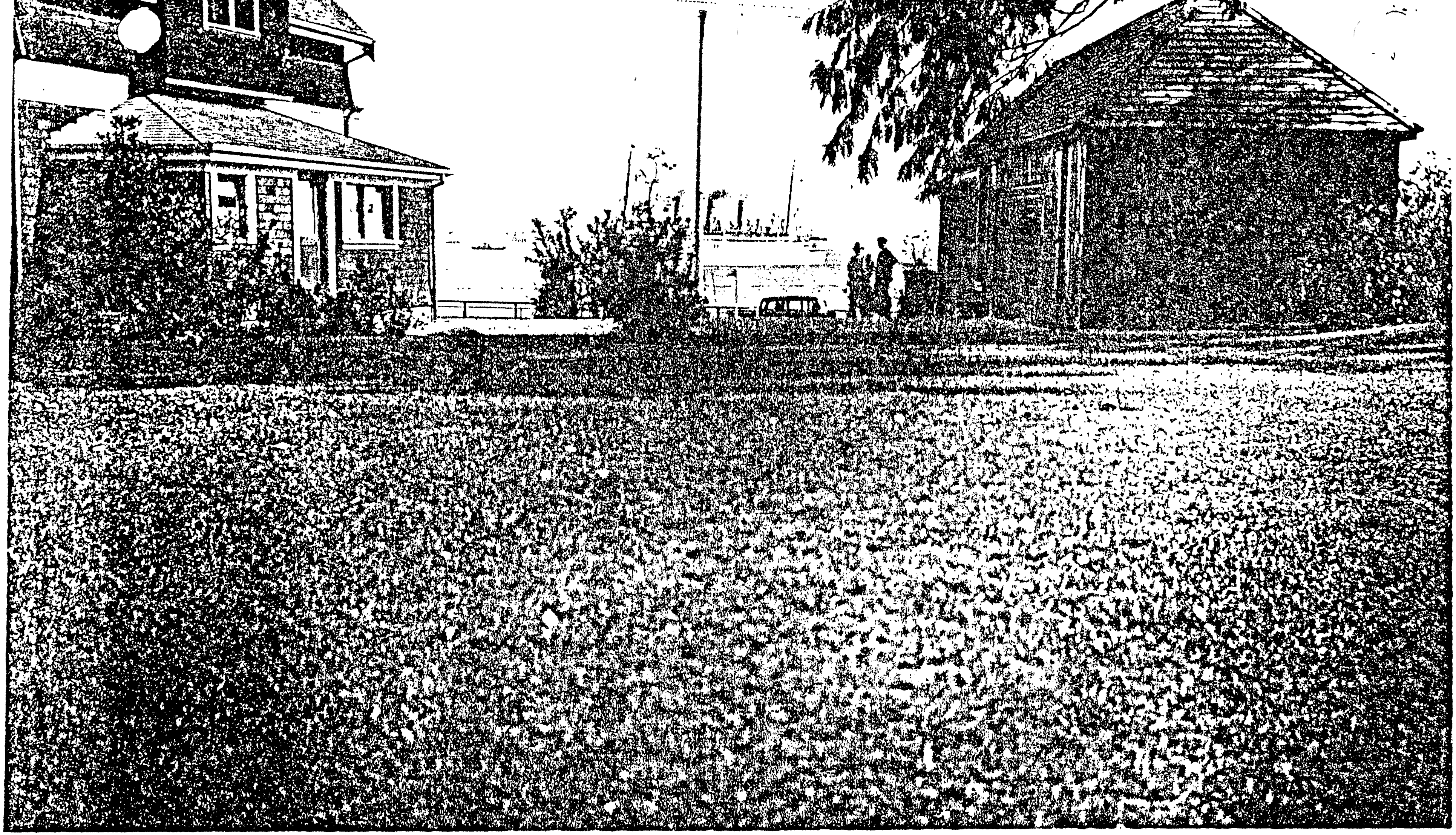


Fig. 80
Pg. 303

The observing site at Brocton Point, Vancouver, B.C., was occupied by O.J. Klotz at the turn of the century. It was used during the World Longitude Campaigns of 1926 and 1933. J.P. Henderson is on the right. Courtesy Earth Physics Branch, EMR.

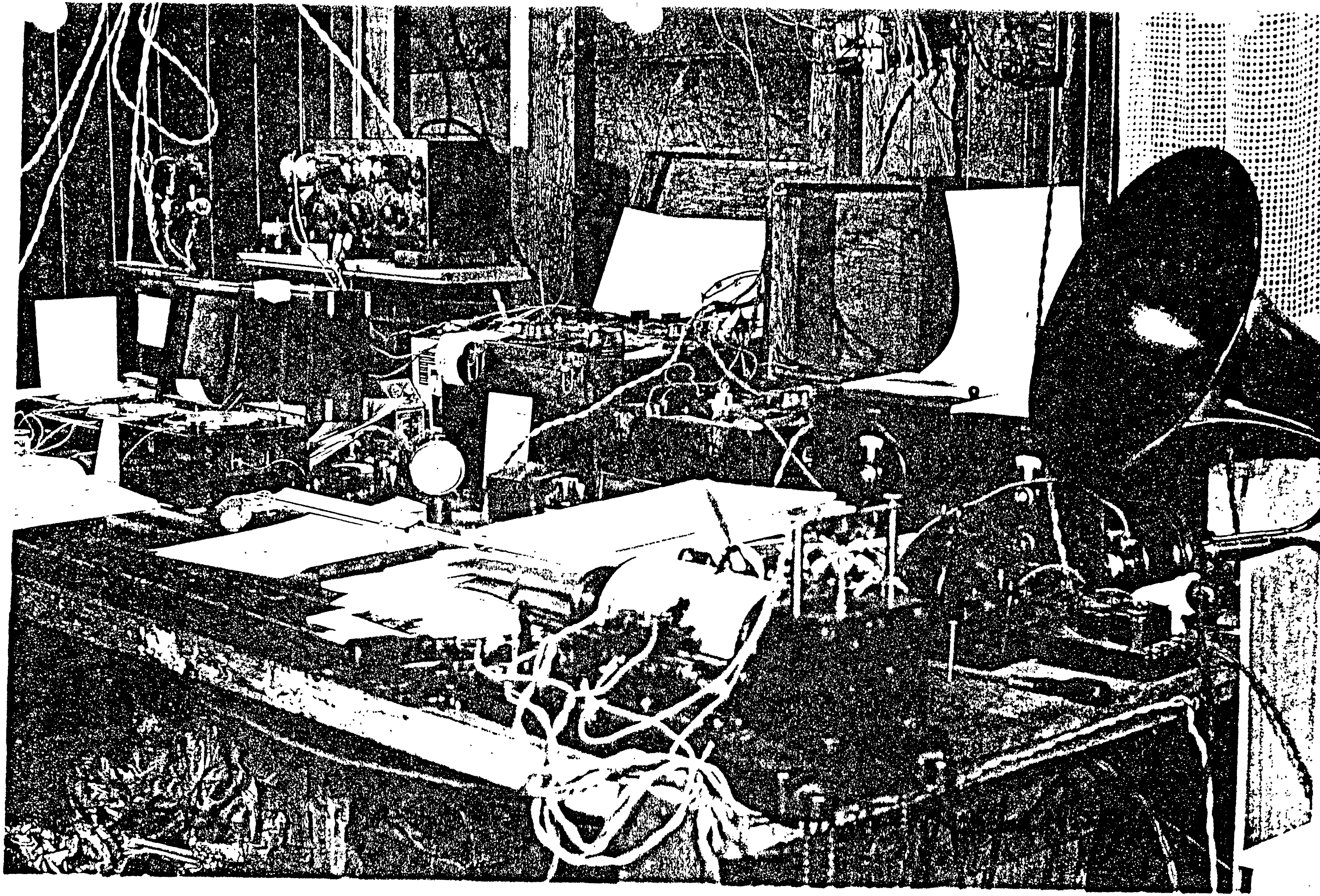


Fig. 81
Pg. 303

The wireless receiving equipment at Brocton Point observing site, Vancouver, 1933. Several chronometers, receivers, and a drum chronograph may be recognized. Courtesy Earth Physics Branch, EMR.

who had gone down the Mackenzie River with Swinburn and Henderson in 1921 and 1922, took advantage of the timing facilities provided by the observatory at Brockton Point and installed his gravity pendulum. It was a precise half second pendulum which, according to Henderson, served not only as a means of measuring gravity, but additionally as a check on the Howard clock.

A near tragedy almost overtook the Vancouver group. C.C. Smith, who had spent several years as a surveyor at the west coast, went on an inspection flight on October 25. 1926 The glassy calm of the water on the return of the flight proved deceptive, causing the plane to crash, and the occupants to be spilled into the water. Smith surfaced within the radius of the still rotating propellor, fortunately escaping with only a scalping. After two weeks of hospitalization he was back on the job, staying with Mr. Walsh, and making daily visits to the doctor for dressing. Five or six years were to elapse before the wound finally closed over, but it did not detract from Smith's ability and drive as Chief of Canada's time service.

Computations conducted at Ottawa and reported to the American Astronomical Society at Amherst, Mass., Sept. 1928, gave the adjusted results for the primary figure which included Greenwich, Tokyo, and Vancouver. The longitude of Ottawa was $5^h\ 02^m\ 51\overset{s}{.}928$, 0.012 second smaller than the value reported above for the 1920 adjusted results. For Vancouver the value was $8^h\ 12^m\ 28\overset{s}{.}343$, 0.005 second smaller. The weight attached to these new results was too small for any changes to be made.

In 1933 the whole program was repeated, with improved instrumentation. Smith had converted his Cooke transit to a broken type, so that he and Swinburn each observed with broken type transits, Swinburn using a Heyde. At Ottawa, also, W.S. McClenahan used a Heyde, while R.J. McDiarmid used the meridian circle. All four observers were thus able to use zenith stars for time purposes, thus minimizing the error due to azimuth. In 1933 a group of stations located at Cape of Good Hope, Adelaide, Wellington, and Buenos Aires formed a southern figure. Then to connect all observing locations, both north and south of the equator, a group of equatorial stars was prepared which were to be observed by everyone. The same time of year, October to November, was selected, with the suggestion that principal stations such as Ottawa and Vancouver might start Sept. 15 and continue till December 15, which was done. In the 1926 campaign, observations were to be conducted in the first half of the night and a second set in the second half of the night in order to coordinate efforts with those observing to the east and those observing to the west. Also an independent check could thereby be made of the systematic difference in the results of a.m. versus p.m. observations which some people had reported. Fig

Some changes were made in the 1933 campaign. Transit observations for time were to be taken before midnight local time, and a common star catalogue (Eichelberger) would be used. Radio time signals would be restricted to those in the long wave band, because short wave transmissions had certain anomalies of radiation not well understood.

The schedule of time signals followed at Ottawa was NSS-noon, GBR-1 p.m., FYL-3 p.m., NSS-4 p.m., NSS-10 p.m., NSS-12 midnight NSS-3 a.m.,

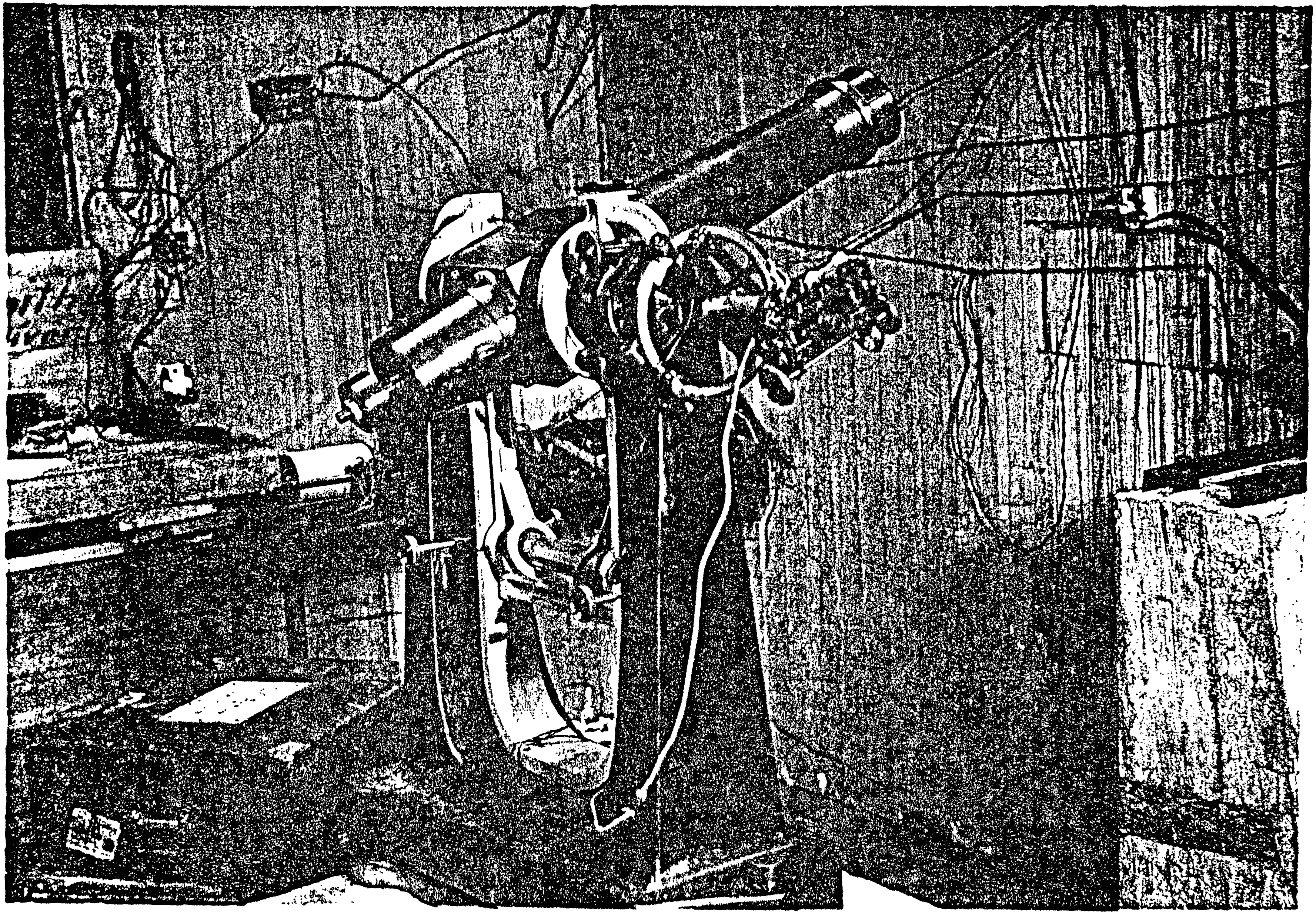


Fig. 82 The broken Cooke transit instrument at the Brocton Point site,
Pg. 305 Vancouver, 1933, with drum chtonograph in the corner. Courtesy Earth Physics Branch, E.M.R.

FYL-3 a.m., GBR-5 a.m., DFY-7 a.m. NSS = Washington, FYL = Bordeaux, DFY = Nauen, and GBR = Rugby. Times are eastern standard. Washington signals terminated on the hour, while the European signals (rhythmic) commenced one minute after the hour, both having a duration of five minutes. They were observed by the method of coincidences by extinction, and when strong and free from static, were recorded. The Ottawa program of radio time signals was handled by the author, while J.P. Henderson followed a similar program at Vancouver.

Every effort was made to measure and account for errors. A personal equation machine was employed by the observers at both Ottawa and Vancouver, and careful note was made of instrumental constants and relay lag. At the conclusion of the campaign, a record of all the radio observations in terms of the local sidereal time was forwarded to the Bureau International de l'Heure, Paris.

The number of permanent observatories or astronomical stations participating in the second campaign was about 87, almost double the number in the first campaign. The interval of 7 years was actually too short to give any evidence for or against the Wegener theory of continental drift mainly because the instruments available were not sufficiently precise. C.C. Smith, in reporting to the Royal Society of Canada in May of 1935, stated that though the evidence was inconclusive, the exercise was an outstanding demonstration of international cooperation. A valuable by-product was the more accurate determination of the longitude of participating stations, a comparison of the right ascensions of the stars used, and some indication of improvements in radio instrumentation.

At the close of the longitude campaign in 1933, wireless reception of time signals was extended into the short wave band, the following program being observed on a seven day a week schedule at the Dominion Observatory.

Station	GMT h	GMT m	kHz	
DFW (Germany)	16	06	16.55	
NAA (Washington)	17	00	8410.	(Jan 1938 NAA 113 kHz)
GBR (England)	18	00	16.0	
FYL (France)	20	06	15.7	
LSD (Rio de Janeiro)	23	50	8830.	
PPE (Monte Grande)	00	00	8721.	
NAA (Washington)	03	00	9050.	(Jan 1938 NAA 113 kHz)

LSD observations were started April, 1933; PPE March, 1934; NAA short wave July 1934, when the long wave was discontinued; DFW March 14, 1935 when DFY was discontinued. The comparisons were by coincidences, and when the signals were strong enough they were also recorded on the drum chronograph.

During 1933 and 1934 nearly 1500 wireless comparisons were made by the two methods, coincidences and recording, yielding an average difference Tc - Tr of + .014 second, which was ascribed to a lag in the recording circuit. The signals were, for the most part, from the relatively close U.S. Naval Observatory, the European signals being recorded only a few times.

Henderson's long wave receivers continued in general use in the wireless room and by government field parties during the 1930's, the field sets coming back regularly for maintenance and repair. Thomson assembled a tuned r.f. short wave receiver which was useful because of the increasing emphasis on short wave time signals. Generally, though, the research in receiver design subsided with the availability of commercially designed receivers.

The retirement of C.C. Smith on the first of January 1938, left a vacancy which was not filled due to the depression. The outbreak of war in 1939, with subsequent gas rationing, and the further reduction of staff due to war service (Thomson was away for three years from October 1942), made it necessary to curtail activities. Hostilities caused the wireless time signals from Germany and France to be suspended. The South American signals were not monitored after 1942. Henderson, who had experimented with 5 metre transmission and reception for several years, arranged to monitor two of the time service functions using a 1000 hertz and a 400 hertz tone modulating two 5 metre transmitters at the Observatory, and these were received at his home at 50 Perth Street, about two miles distant. The one provided an alarm in case of a failure of seconds pulses to the Observatory transmitters CHU, the other monitored the circuit to the broadcast station CBO. Hollinsworth also provided himself with a 5 metre receiver in order to collaborate in the monitoring program.

The Observatory had become increasingly noisy electrically with the increase in clock circuits, and the development of CHU transmitters. They had commenced as 5 watt units, except for one or two intervals each day when a more powerful tube was turned on to radiate on the 40.8 metre channel. By the outbreak of war the three frequencies were operating continuously with inputs ranging up to 50 watts. On June 7, 1944, a private telephone line was installed between Henderson's home and the Observatory, and the receivers were moved to the quiet location. A stepping switch at 50 Perth Street, which could be controlled from the Observatory, selected in succession NSS on 113 kHz, WWV on 5000 kHz, VAA on 8330 kHz, CBO on 910 kHz and CFH Halifax on 105 kHz.

The main source of electrical interference at the Observatory ceased in 1947 when three RCA type AT3 300-watt transmitters were installed at the Department of Transport Short Wave Station on the Greenbank Road, and CHU transmissions from the Observatory ceased. Other noise reducing steps had also been taken. Frequency dials, some operated by crystal generated 60 cycle, others from the mains, replaced second and minute jumpers. Mechanical relays were replaced by grid operated tube relays and pendulum clocks were finally replaced by crystal frequ. standards. Relay clicks became a thing of the past.

By 1951 the attic room, as it was called, was free from all transmitting electronics. With a little rearrangement it became the home of a group of receivers, any one of which could be selected from the wireless room. The telephone line to Henderson's home was continued for another year or two for experimental purposes, then discontinued. GBR was restored to the list of 60 beats to the minute as well as the rhythmic signal of 61 beats to the minute. From a comparison of the two it was evident that they were derived from the same source, and monitoring of the rhythmic signal was discontinued.

Technology advanced rapidly in the postwar years. The method of reception using coincidence by extinction gave way to the method in which the radio signals were compared with microdial readings on a General

Radio synchronometer. Several settings with the microdial were made to the point where the leading edge of the incoming signal was just obliterated by the microdial contact. Reading to a tenth of a division meant that the comparison was made to a nominal accuracy of a millisecond.

The oscilloscope made possible a visual display of the incoming signal, and the delay counter, which controlled the start of the sweep to the tenth of a millisecond, afforded a means of comparing the signal and the observatory reference clock with this precision. The method was particularly useful for monitoring the output of CHU, and frequently the more distant signals, especially WWV, were capable of reception with the same precision.

For a while the attempt was made to monitor the long wave (very low frequency) seconds pulses of NBA. On the oscilloscope the slow build up time which characterized these signals was clearly displayed. Also the static often made it difficult to determine where the signal started. By registering several seconds pulses on a polaroid picture, it was possible to distinguish the actual signal shape because a repetition of at least part of the pulse each second made it the dominant feature, and the start of it could be determined. Low frequency signals proved to be more useful as a vehicle for comparing time at the frequency level. Special tracking receivers, designed to accept both the incoming radio frequency and a frequency from the local standard, would register the difference, either in beats or in parts in 10^{10}. One part in 10^{10} corresponds to 8.64 microseconds in 24 hours.

Transmitters, such as CHU, were improved initially by good crystal oscillators. Then by 1960 a quartz crystal frequency standard was used to generate each of the three frequencies as well as the seconds pulses. A rubidium standard replaced the crystal, and a cesium standard replaced the rubidium during the 1960's. Time transmissions at other national laboratories followed a similar pattern of improvement.

In 1941, for the first time, a fundamental catalogue of stars, FK3, was accepted internationally. From this date forward transit observations for time were based on a unified system of star positions. Following the war, astronomical determinations for time improved by an order of accuracy with the use of the photographic zenith tube, the Danjon astrolabe, and other advanced techniques. It became meaningful to compare clocks with earth rotation to a few milliseconds each clear night instead of a few hundredths of a second, as formerly. Furthermore the introduction of small corrections to compensate for polar wander and annual fluctuation resulted in a time which had reasonably good short term stability, but which suffered from small random fluctuations in earth rotation.

Because of improvements in the astronomical determination of time, and also in the broadcast and reception of time signals, the BIH was able to prepare a better international clock from all the current data. The contributions from the individual laboratories were then examined to see if there might by chance be a systematic difference. Any such difference was then interpreted as a small error in the adopted longitude. It was a global adjustment such as was hoped for in the world longitude campaigns of 1926 and 1933, but for which the technology of the day was not sufficiently advanced. Now, with much improved data, several small adjustments were suggested. The US Naval Observatory at Washington acknowledged a small adjustment at the beginning of 1961 and 1962. In a communication about this date from Dr. N. Stoyko, Chief of the BIH in Paris, the Dominion Observatory was informed that its adopted longitude appeared to require no change. Mr. R.M. Stewart, always a man of precision, would have been delighted to learn that the adjustment he made in 1920 had stood the test of time. Recently a 10 millisecond change has been made by the BIH to the reference meridian of Ottawa, making it $5^h\ 02^m\ 51^s.950$.

By the time the second was defined in terms of the cesium atom (1967), commercially designed atomic clocks were available. One had been installed at the transmitter site to control the carrier frequencies and seconds pulses of CHU. The value of the transmissions were thus considerably enhanced. The same was true of the transmissions from other observatories.

For the intercomparison of the time maintained by the various laboratories around the world, the most important link has become the chain of Loran-C stations. Designed originally as an aid to marine navigation the carefully coded emissions from each station are precisely controlled by cesium atomic clocks. The performance of each clock is checked by regular visits with a portable cesium standard. Special receivers designed to lock onto the code of the transmission provide a means of comparing both the time and frequency of the signal with the working standard of the laboratory. The time comparison remains relative until a visit to the laboratory by a portable cesium clock team establishes the travel time to the tenth of a microsecond from the Loran-C station.

One can readily recognize the change that has occurred with the introduction of the cesium standard. Originally the uniform marker against which time was checked was the mean solar day, and from it was derived the hour, minute and second. Now the marker is the very short interval of time required for a transition to occur between two hyperfine levels in the ground state of the cesium atom. It corresponds to a frequency of 9 192 631 770 cycles per second, and the main effort is to establish this frequency with increasing exactitude. Present day (1973) technology yields a precision of a few parts in 10^{12}, which means that if two standards could be kept in operation for one hundred years they would drift apart by only a few milliseconds. At the present rate of advance this precision should soon be improved by another few orders of accuracy, to say a part in 10^{14}.

Time Distribution in Canada

TIME DISTRIBUTION IN CANADA

Twenty-one years after the sod was turned in 1902, the first radio time signal was broadcast from the Dominion Observatory. It came about as a natural consequence of J.P. Henderson's enthusiasm as a radio experimenter, and must have had the full support of Klotz and Stewart.

The short wave end of the radio spectrum below 200 metres was essentially wide open to experimenters in the early 1920's. It was the practice to take out a license for each transmitter. Henderson acquired the license 3AF in 1922 which had particular significance in that it was the sixth (F being the sixth letter in the alphabet) call sign issued for amateur experimental work in Ontario. In January 1923 he acquired 9CC for experimental work on 275 metres, and 3VO for amateur communication. Later that year he and a few others of the Ottawa Amateur Radio association acquired the experimental broadcast license, 10AP, which was operated from the wireless room of the Observatory. The ultimate objective of this station was to radiate time signals, but it was necessary first to have an acceptable program of music to which people would listen in order to introduce a short interval of seconds pulses.

Commander Edwards and Col. Steele established a broadcast transmitter at the test room on Wellington Street with the call sign AP. Their chief interest was to test various wavelengths to discover which was the most effective in the spectrum below 500 metres. For a while there was a broadcast station in 1923-24 operating with the call sign CHXC, and the test of a good receiver was its ability to tune out the local signals and pick up the more distant ones such as KDKA. Neither the receivers nor the transmitters were capable of sharp and accurate

JPH diary – 1924 March 15 P.M. failure of GNW telegraph with time signals to CKCH

June 4 Music on water from CKCO

July 20 receiving CNRO in car uptown

Oct 20 lecture

memo re CKCH → CNRO. Mr Swift, Radio Eng of CNR Montreal; this is first stn purely CN, others routed Mtl, Calgary

1925 Sept 16 at CNRO – also listened for CNRA Moncton NB n.g.

1928 May 4 – field strength of CNRO

1931-32 annual report, time signals transmitted over CNRO

1934-35 CRCO 880 kc/s

1935-36 CNRO changed to CRCO

1927-28 signals at 3 PM over CNRO daily except Sunday

1946
1948 CBC 1 pm

1948 "Canada's Time Service" by MMT (RASC)

At present the CBC network of over 50 broadcast stations transmits time signals at 1300 hours eastern time. Eastern time refers to standard or daylight saving, whichever prevails at Ottawa. Second beats with a musical pitch of 800 cycles per second commence at about 12h 59m 20s carry through to the hour, omitting the 29th and also the 51st to 59th seconds.

CKCH / CO

Time signals via CNRO - CRBC - CBO

1924 : 9 PM = CKCH in Feb

1927
3m at 3pm except Sunday — 1928 : 3 PM = CNRO 435 metres

1929 Sept 7 CNRO changed from 435 to 500 m

1937 3 PM = CRCO

~~Nov — 1939 — BBC — "Cn Canada"~~

1939 Jan - CRBC equipment set up at monitoring stn by Ed Leavey

July - noted "Cn Canada" missing

Nov. 5 13h00 first day of 30s broadcast

CFH / April 9 1943 - Navy requests time signals.

C.O.'y has a line to CN Tel. (+ to CBO) suggest Navy

1944 June 14, CFH (105 kc/s) monitored

started time signals Sept 24/43 — discontinued 1954 (spring)

CB moved

1934-35, time sent by telephone beats CNR & CPR,
Obs'y lines, short wave, and CRCO 880 kc.

1935-36, CNRO Changed to CRCO

1936, Tues Mar 17 noon, relay at Obs'y not working for about 5 mins. failure to get time to CRCO.

1937, CRCO at 3 pm

1938, Tues Feb 22, Dr. E. A. Hodgson at University of Vermont, Burlington, Vt., receiving CBO noon for seismographs, and wish time also on Sundays. Suggest 7335 kc or 3330 kc, but they have no s.w. receiver.

1938, Mon April 25, confused with change of time (DST) Plugged in CNR line to recording chronograph, and so cut off our MT snglans from 11.57 am DST transmission to CBO.

1941, Obs'y time designated as official time for Canada.

1946, Oct 30, negotiations between Mines & Resources and Transport re CHU via DOT transmitters fouled due to tone of M&R letter. JPH tried to correct via Mr. Bain, but no headway.

1948, five day week in Gov't service.

1950, Mar 18, Max Gilbert says CBC serviced by CN to Winnipeg, C.P. Teleg west of Winnipeg. Lag, Ottawa-Winnipeg, $^{s}.034$ CNT.

1953, Jan 16, Mrs "Bunny" Crawford replaced K Nevins.

1954, Diana Middleton bouncing across Time Room floor detected by Lloyd Miller & Jack McClements of England, testing rate of Ring Xtal oscillator in Wireless Room.

From J. P. Henderson diaries (July 1985)

Before 1919, Reception NAA time sigs by Mr. W.A.Dier.

1922, Aug 26, demonstation radio telephony 1st in Arctic at Arctic Red River

1922, Nov 23. Time sent occasionally with 10AP on 250 m broadcasts.

1923, Mar 9, time sent occasionally on 9CC mostly 275 m

" July 19 regular interchange MT & Sid time sigs with Mr. Doxsee at Shirley Bay, mostly 225 m & 275 m.

1924, 9 pm = CKCH in Feb

" Mar 15, pm, failure of GNW telegraph with time sig to CKCH.

" July 12 CKCH received in Ford.

" July 20 Receiving CNRO in car uptown.

" Memo CKCH → CNRO. Mr. Swift, Radio Engineer of CNR in Montreal: this is the first station purely CN. Others rented in Montreal, Calgary.

1925, Feb 8, transmitter modifications. Time sent frequently on 52 m

" Sept 16, at CNRO listened unsuccessfully for CNRA, Moncton, NB.

1927, Sat April 23, 3 pm, start sending time signals at 3 pm daily through CNRO. Start of their broadcast from 3 to 4.30 daily. This in place of evenings.

1928, Feb 24, transmitter ¼kw used regularly for time signals on 52.5 m, 3 pm & 10 pm.

" Mar 1, 9CC on 52.5 m, complete AC operation. Sent time signals 3 pm.

1929, Jan 15, transmitter ¼kw changed to 40.8 m, VE90B on regularly as before.

1927-28, Signals at 3 pm over CNRO daily except Sunday.

1928, 3 min at 3 pm - CNRO 435 m.

1929, CNRO changed from 435 m to 500 m.

1929-30, time sigs sent out daily over CNRO and twice daily over 90B on 40.8 m

1931-32, time sigs sent over CNRO, and 40.8, 20.4, & 90 metres from Obs'y.

1932, Aug 17, 20.4, 40.8, & 90, all continuously.

See pg 150-151 in book

tuning. For this reason Henderson and his group suspended operation of 10PA in February 1924 when the CNR station CKCH was inaugurated with George Wright as manager. Within a few weeks CKCH became CNRO and subsequently CRCO, then CBO. A loop was extended from the CNR telegraph office to the studio of CNRO in the Jackson Building at Bank and Slater Streets in order that every evening at 9 p.m. the Dominion Observatory time signal could be broadcast. Through the years the time signal broadcast was changed to 3 p.m. and then to its present location of 1 p.m. At first the pulses were formed by a buzzer. Within a matter of weeks an audio oscillator, tuned to 512 hertz, was installed in the studio. It proved to be so acceptable that a second oscillator was built for the broadcast of time signals from CNRA in Moncton, N.B., whose signals originated in the Saint John, N.B., weather office.

1935-36

During the summer of 1923 a seismological field station was established at Shirley Bay, about 10 miles west of the Observatory. Transmitting and receiving facilities were established at the site so that W.W. Doxsee a seismologist would be able to receive the time pulses from the Observatory clock, and also communicate directly with J.P. Henderson in the wireless room, the wavelengths used being mainly 225 and 275 metres. During the summer's operation both mean time and sidereal seconds pulses were transmitted to Shirley Bay, using the 9CC transmitter. Communication between Doxsee and Henderson was maintained with the call signs 3AF and 3VO, which were regular amateur calls. 9OB was acquired sometime later for use in broadcasting time signals. The prefix VE, which today characterizes all Canadian Amateur licenses, i.e. VE9CC, VE3AF, etc., did not become mandatory till 1928 when the large number of operators made it desirable to have a distinctly Canadian identification.

Many hours were spent by Henderson investigating the properties of short waves, down to the 5 metre range. His results formed the basis of some very popular demonstration lectures to the Ottawa Radio Association during the 1920s.

Time signals were emitted frequently, but on no fixed schedule. An attempt was made to determine how well they were received in different parts of the country, for which purpose Henderson maintained active contact with amateur operators, particularly in the Toronto-Hamilton area. Also portable equipment was assembled which he carried in his car and canoe in order to test the effectiveness of the time signals and the field pattern of various transmissions in the Ottawa area.

In March 1923, WWV of the National Bureau of Standards, Washington, D.C. (later Fort Collins, Colorado), commenced the valuable service of transmitting on various wavelengths and announcing the value of each to the exact metre. The first of these transmissions monitored by Henderson at the wireless room of the Observatory occurred Tuesday, May 29, 1923. A note in his diary indicates that WWV was monitored as the wavelength was shifted in 10 metre steps from 210 metres down to 150 metres, and the setting for each carefully checked on the General Radio wavemeter. The voice announcements were not distinguishable, but they were not really required by the radio operator of that day.

March 1, 1928, one finds the first reference to a regular daily transmission of radio time signals from the Observatory. 9CC (now designated VE9CC) on 52.5 metres was on the air for 5 minutes from 2:55 to 3:00 p.m. The tube was a De Forest, operating with a plate input of about ¼ kilowatt (150 milliamps and 1500 volts). Occasional transmissions were also sent after 10 p.m., and seconds beats from the sidereal clock as well as the mean time clock were placed on the air.

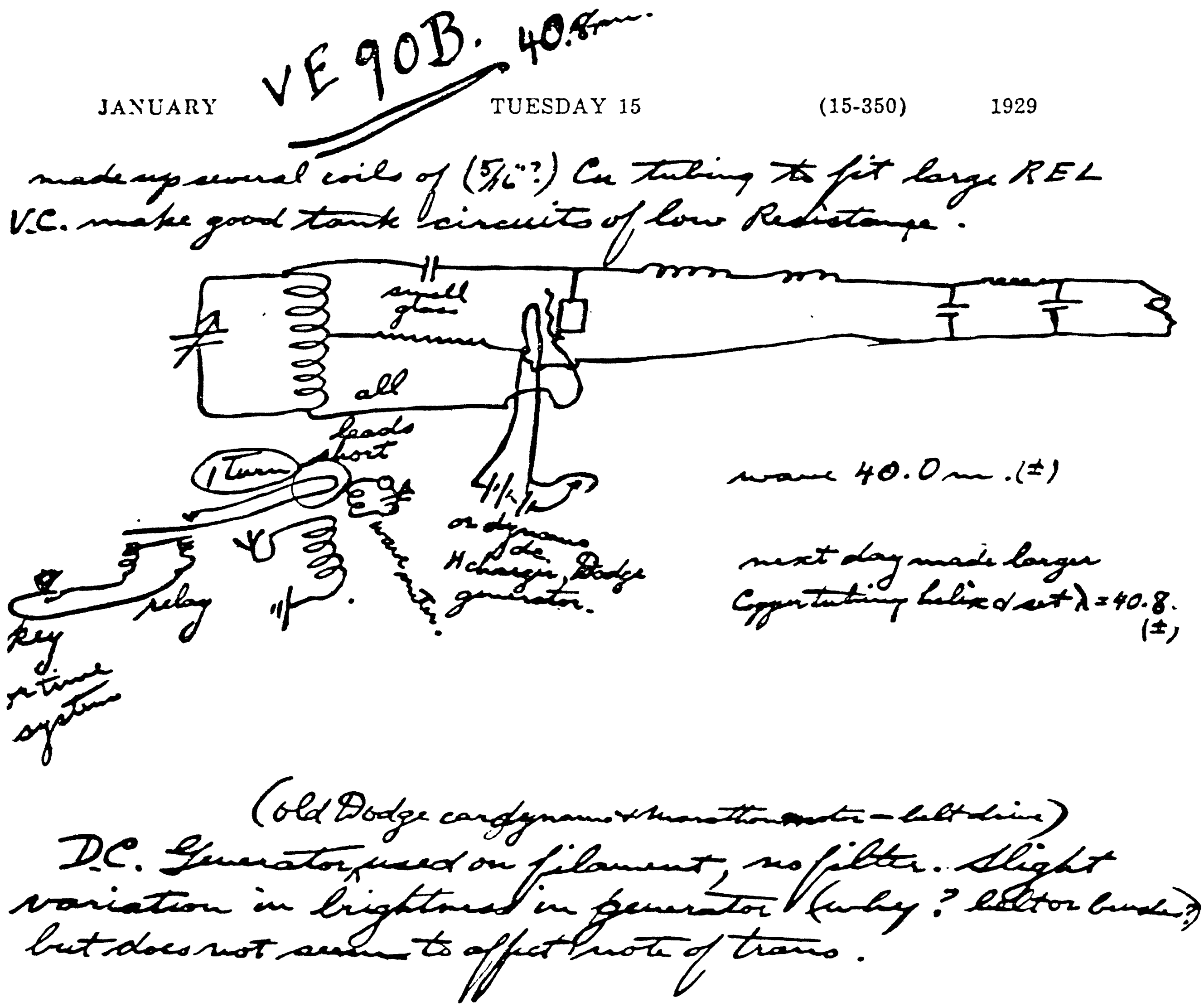


Fig. 83 Page from the diary of J.P. Henderson showing a diagram of a
Pg. 317 Hartley oscillator used as a transmitter. Courtesy Earth Physics Branch, EMR.

By now most of the survey parties were equipped with receivers to pick up the long wave time transmissions from Washington, D.C. and elsewhere. There were also some field men whose operations were adjacent to the telegraph line, and for whom the old familiar method of exchanging time, using the wire connection back to the Dominion Observatory, was less complicated. Again from Henderson's diary one finds the following notations: "CPR telegraph to Saskatchewan border $20 per exchange - tonight 2 exchanges $40" (July 16, 1925). "Mr. McDiarmid (F.A.) was quoted as saying telegraph last year cost $1000 for 30 nights - $30 per night" (July 5, 1928). Doubtless this justified the cost of developing radio equipment which would ultimately make time available everywhere in Canada.

The Observatory short wave transmitter continued to send time from 2:55 to 3:00 p.m. on a wavelength of 52.5 metres (later 52.6 metres) till Jan. 15, 1929, when the wavelength was changed to 40.8 metres and the call letters VE9OB. A sketch from Henderson's diary of this date indicates that a simple Hartley oscillator circuit was used. The key closed an absorption loop which was placed close to the tank coil, effectively changing the tuning, so that the signal had a "front" and a "back" wave. Correct tuning was indicated by a simple wavemeter consisting of a coil and condenser and a small series lamp that would glow when the wavemeter was in resonance with the transmitter. The antenna was strung between masts 80 feet or more high and about 400 feet apart. It consisted of two wires spaced about 8 feet apart by spreaders at each end of the span. Fig. 83

It was gratifying later that year to learn that C.H. "Marsh" Ney of the Geodetic Survey had been able to receive VE9OB while working north of Churchill on the 60th parallel.

During 1929, in addition to 40.8 metres, wavelengths of 80 and 102 metres were used experimentally. By the end of the year a 5 watt transmitter on 90 metres, just outside the amateur band, was being operated continuously during the daytime. The high voltage or B supply of about 90 volts consisted of an array of Edison cells made up in test tubes held in a parafined lattice wooden box. A drop of oil in the top of each test tube prevented evaporation. The input power of 5 watts to the transmitter meant that the B battery required recharging every two or three days.

By 1931, with the acquisition of the type 80 rectifier tube, it became possible to experiment with B eliminators, and by 1933 to maintain low power transmitters on a 24 hour basis, the wavelengths now being 20.4, 40.8 and 90 metres. With condenser tuning, the stability was not good. Fortunately Mr. Ed Davey of the Radio Branch, Department of Marine and Fisheries (later Dept. of Transport), was now operating the newly established Monitoring Station from quarters on the Experimental Farm, not far from the Observatory. His careful monitoring prevented the three VE9OB transmitters from deviating noticeably from their assigned wavelengths.

Quartz crystal oscillators for 40.8 and 90 metres were acquired in 1933. Crystals for 20 metres were available, but were rather fragile. So it was general practice to double the frequency from a 40 metre crystal. Because of the high Q factor of a quartz crystal the oscillator could be maintained within a very narrow tolerance of a fixed frequency. In addition, the output of a crystal controlled transmitter had the desirable clear tone that closely resembled the pure "dc" tone of a battery operated tube oscillator. It was usual for a tube oscillator to include a portion of the ac ripple in its output when the high voltage was derived from a generator or a rectifier instead of a battery.

If the crystal happened to be dirty or marred in some way, it could jump to a nearby frequency. In this event the first step was to clean it carefully in carbon tetrachloride to remove any dirt or grease. A chipped or cracked crystal, of course, would not be improved.

In 1934 the Department of Marine notified the Observatory that the time transmission channels, as indicated in the Berne list were 3332, 7350 and 14700 kilocycles, corresponding to 90.00, 40.82, and 20.41 metres. This marked an official change in nomenclature from wavelength to frequency, and also an increasing emphasis on closer tolerances within the assigned frequencies. Since 1933 these tolerances had been 0.03% for frequencies between 1500 and 6000 kc, and 0.02% for frequencies between 6000 and 30 000 kc. Hence the assigned frequency of 7350 kc meant 7350 ± 1.5 kc.

The next change came in 1938 when CHU became the official designation of the Dominion Observatory time transmissions. In January 1937, the frequency assignments were modified to 3330, 7335 and 14 700 kc, and by the end of 1938 the high frequency channel was modified to 14 670 kc, the exact harmonic of 7335 kc.

Following the example of WWV, a tone of 440 cycles from a tuning fork was imposed onto the seconds pulses. This was later changed to 1000 cycles derived from the quartz crystal frequency standard. There was no phase relation between the pulses and the superimposed tone, because they were derived from two independent sources. The pulses were controlled initially by a pendulum clock, and after 1938 were produced by the time machines built by R.M. Stewart. The ability to count down to one per second and generate time pulses directly from a standard frequency was a postwar development, and not applied to CHU till the 1950's. The superimposed 1000 cycle tone had two purposes; it was of assistance in finding the signal, and it was accurate to a part in 10^7 for anyone who could use it as a calibration frequency.

The little transmitters were built and set in operation in the wireless room, and each fed by a single wire to one of three horizontal antennas located on the roof. By the end of the 1930's each frequency fed into a tuned half wave dipole with a twisted pair of ordinary lamp cord which terminated at the antenna with a "V" symmetrically flared about the centre of the antenna, and with a pick-up loop at the output tank coil of the transmitter. During 1941 the three transmitters were removed from the wireless room to the attic or midway room of the Observatory.

"The method employed by the U.S. Naval Observatory for Fig. 84
identifying continuous signals was adopted by the Dominion Observatory in 1934. At first a tape was used to provide the omissions at the right time. But since 1938 this was done by the time signal machine. Identification is accomplished by a series of omissions at the end of each minute, the series repeating itself each five minutes as follows:

1st minute - 29, 51, 56-59
2nd minute - 29, 52, 56-59
3rd minute - 29, 53, 56-59
4th minute - 29, 54, 56-59
5th minute - 29, 51-59

TIME SIGNALS AND HYDROGRAPHIC INFORMATION BY RADIO.

The U. S. Naval Radio Service is furnishing information to vessels at sea, as follows:

TIME SIGNALS.

Time signals will be sent out broadcast by the following stations on the Atlantic and Pacific coasts of the United States:

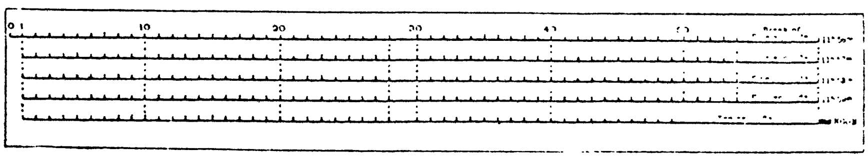
STATION.	WAVE LENGTH.	WHEN SENT.
	Meters	
Arlington	2,500	Every day at 11.55 a. m. to noon and 9.55 to 10 p. m., Standard Time, 75th meridian.
Key West	1,000	Daily, except Sundays and holidays, at 11.55 a. m. to noon, Standard Time, 75th meridian.
New Orleans	1,000	Same as Key West.
North Head	2,000	Daily, except Sundays and holidays, at 11.55 a. m. to noon, Standard Time, 120th meridian.
Eureka	1,400	Same as North Head.
San Diego	2,000	Do.
Mare Island	2,500	Every day at 11.55 a. m. to noon and 9.55 to 10 p. m., Standard Time, 120th meridian.

If for any reason the Arlington Station is out of commission the time signal will be sent daily at noon, Sundays and holidays excepted, by the Naval Radio Stations at Newport, New York, Norfolk, and Charleston.

The time is sent from the Naval Observatory, Washington, for the Atlantic coast, and from the observatory at the Mare Island Navy Yard for the Pacific coast.

The radio sending or relay key in each radio station is connected to the Western Union lines by a relay at about 11.50 a. m., and the signals are made automatically direct from Washington or Mare Island.

Time signals from each of the observatories mentioned continue for the five minutes preceding noon and 10 p. m. During this interval every tick of the clock is transmitted, except the 29th second of each minute, the last five seconds of each of the first four minutes, and finally the last ten seconds of the last minute. The noon (and 10 p. m.) signal is a longer contact after this longer break.



It is not necessary that an elaborate radio installation be employed for the purpose of receiving these signals nor that a skilled operator be in attendance. Any vessel provided with a small receiving apparatus with one or two wires hoisted as high as possible and insulated from all metal fittings, or preferably stretched between the mastheads with one wire led down to the receiver, may detect these signals when within range of one of the seacoast radio stations.

These time signals have been used successfully by vessels for rating their chronometers and have been used by surveying vessels in the accurate determination of longitudes.

HYDROGRAPHIC INFORMATION.

Information concerning wrecks, derelicts, ice, and other dangerous obstructions to navigation whenever received from the Hydrographic Office or from a branch hydrographic office is sent broadcast four times daily, viz. at 8 a. m., noon, 4 p. m., and 8 p. m., local (standard) time of station. Ships within range of a naval radio station should be prepared to receive these hydrographic messages at the hours mentioned and should avoid sending radio messages at these times. One vessel sending may prevent several others receiving information necessary to their safety.

Naval radio stations will furnish this information to passing vessels on request, whenever practicable, at other hours than those mentioned above. Should it not be practicable to send out this information on one of the hours scheduled it will be held until the next scheduled time and sent out as soon as practicable after each hour scheduled.

Each night at 10 p. m., 75th meridian, immediately following the time signal, the Naval Radio Station at Arlington, Va., will broadcast such information relating to safe navigation as may be furnished it by the Hydrographic Office during the preceding 24 hours. The same wave length, 2,500 meters, used in the time signal will be employed.

Reprinted from Pilot Chart of the North Atlantic Ocean of August, 1913.
Published by the Hydrographic Office, under the authority of the Secretary of the Navy.

Fig. 84 Time signals provided by the U.S. Naval Radio Service in 1913.

Alternatively this may be shown as follows, remembering that the 29th second is omitted from every minute.

Seconds	50	51	52	53	54	55	56	57	58	59	60
1st minute	-		-	-	-	-					-
2nd minute	-	-		-	-	-					-
3rd minute	-	-	-		-	-					-
4th minute	-	-	-	-		-					-
5th minute	-										-

Hence, when the 51st second is omitted and 4 more beats are sent, it indicates that there will be 4 more minutes to a 5-minute interval. At the end of the 2nd minute, 52 is omitted and 3 more beats are sent, indicating that there are 3 more minutes to the 5-minute interval, etc. The end of the 5th minute has the long gap from the 51st to 59th beats. During the first minute of each hour, the call sign C-H-U is sent slowly in Morse code twice. The 2nd and subsequent minutes of the hour correspond to the 2nd and subsequent minutes of a 5-minute group.

"If a timepiece is in error by not more than a minute or two it is possible to identify the radio signal immediately and to adjust the timepiece precisely. In the case of a larger error, it may be necessary to wait for the hour identification. The beginning of each second beat marks the exact time." (Canada's Time Service by M.M. Thomson, Jr. RASC, 42, 105, 1948)

It is little wonder that the increase in transmitter power, coupled with the electrical radiations from a multitude of mechanical relays, made the Observatory an intolerably noisy location for radio reception. The private line was as a consequence installed between the Observatory and 50 Perth, the home of J.P. Henderson.

The line provided a further avenue for research and experimentation. When 60 cycle ac was available from the frequency standard, Henderson superimposed it on this line to find out if it could be detected and used without being contaminated by the 60 cycle in the power lines. The experiment was a success. He ran a clock at 50 Perth for several weeks from this source. A clock was then operated for a short while in the CBC studio in the Chateau Laurier. The system did not survive because there were too many uncertainties in the electronics as well as in the telephone line itself.

In 1953 the telephone line was used to test successfully the transmission of 100 kc, from the Observatory to 50 Perth following which this frequency was sent by telephone line to NRC Sussex Street to intercompare the ring crystal timekeepers of the Observatory with those at NRC. It is not known just how 100 kc travelled through the Bell Telephone system. Theoretically the frequency was too high for that type of transmission. It was also too high to cause any interference to the normal telephone circuits, and therefore could be imposed onto the line at 10 volts, which was higher than normal. At NRC Sussex Street it was reduced to 500 microvolts and had to be detected by a radio receiver. C.F. Pattenson used the same method to provide monitoring in Kalra's laboratory of the performance of his Essen ring crystal. A 10 kc line from the Observatory to Pattenson's lab on the Montreal Road provided a satisfactory way to close the loop between the three labs. Bell Telephone assisted in this network by removing all repeaters and ensuring that continuous copper wire was on each line.

The report by Marsh Ney that he had heard the Observatory time signal while on field duty north of Churchill during the summer of 1929, encouraged the optimistic hope that sometime in the future Canadian surveyors, wherever they might be in Canada, would be able to rely on time from the Dominion Observatory. Ney had heard the 10 p.m. signal that had a power input of about ¼ kilowatt derived from a motor generator. About 1931 this transmission was discontinued. Thereafter it was necessary to rely on the gradual improvement in the power and efficiency of the three low power CHU transmitters. During the depression years it was a slow process, and in fact might not have advanced at all had it not been for Henderson's ability to pick up bits and pieces of equipment at bargain prices and generously make them available for general use. By 1938 it was noted that CHU had an output of about 10 watts, scarcely enough for Canadian coverage. A direct line was established between the Dominion Observatory and the Department of Transport transmitting site which permitted direct keying of VAA, on 11990 kc, by the R.M. Stewart time signal machine from 10:55 to 11:00 a.m. each day. The lag was measured as 0.010 second. With a power of two kilowatts, much better coverage of the north was achieved, particularly in the direction of Churchill toward which the antenna was oriented.

There were times when the survival of CHU hung on a slender balance. Some disturbing opinions were to the effect that the daily noon signal radiated by the CBC perhaps obviated the need for CHU.

The following memorandum, dated October 30, 1941, from the Dominion Astronomer, R.M. Stewart, to J.M. Wardle, the Deputy Minister of the Department of Mines and Resources, reflected his feelings with respect to CHU, and perhaps sparked a more kindly interest towards it within the department, as well as towards J.P. Henderson and his associates.

"Imitation is the sincerest flattery. We have just recently learned that the U.S. Bureau of Standards has, within the last few months, begun a continuous broadcast of time signals such as we have been sending for a number of years.

In this connection I should like to put it on record that the inception of our continuous broadcast, which was the first of its kind in existence, was largely due to the enthusiasm and insistence of Mr. J.P. Henderson of our staff. Without very much encouragement he built up our first transmitting equipment, partly from apparatus of his own, and put it into experimental operation. Since that time it has, of course, been improved very considerably, though the power is still quite low.

Respectfully submitted,

R. Meldrum Stewart
Dominion Astronomer."

The year 1941 is also noteworthy for the Order-in-Council P.C. 6784, promulgated August 28, which reads;

"Whereas the Minister of Mines and Resources reports that in Canada no agency has been officially designated to supply accurately standard time for Dominion official purposes;

"The various provinces and the Northwest Territories have by Act or regulation respectively designated standard time to be that at certain meridians of longitude west of Greenwich, but no official source of time has been mentioned;

"That it is in the public interest that an authoritative source of time for Dominion official purposes be designated, and that the Dominion Observatory, Ottawa, Department of Mines and Resources, obtains by observation time to the greatest degree of accuracy.

"THEREFORE, the Deputy of His Excellency the Governor General in Council, on the recommendation of the Minister of Mines and Resources, is pleased to order that the time determined at the said Dominion Observatory, and which is broadcast by standard and short wave radio daily, be and it is hereby designated as official time for Dominion official purposes.

(Sgd.) H.W. Lothrop

Asst. Clerk of the Privy Council."

There is no doubt that this proclamation greatly enhanced the importance of the Observatory time service and indeed provided the strongest argument for the acquisition of improved instrumentation for both the determination and the dissemination of correct time.

In 1942, VAA commenced all night transmissions of time signals for the benefit of scientific field parties during the summer months. For this service the frequency of 5405 kc was used in addition to the transmission each morning on 11990 kc. The following year, Sept. 24, 1943, the naval station CFH at Halifax commenced broadcasting Observatory time pulses at 10 a.m. and 10 p.m. E.S.T. for the benefit of navigation on the north Atlantic. The pulses were sent by radio teletype from the Department of National Defence communication centre in Ottawa to Halifax and from there by cable to CFH control centre at Albro Lake, just outside of Dartmouth.

There had been a wire connection to the GNW (later CNR) telegraph office since the inauguration of the Observatory in 1905, over which clock beats were sent. A loop from this line fed the signals to the Canadian Radio Broadcasting Commission (later CBC) studio, the Bank of Canada, the Ottawa Electric, whose fleet of street cars was each equipped with a clock, and Birks Jewelers. Officially, the two telegraph companies distributed over their respective networks the time which originated from McGill. With the removal of the transit hut from the campus in 1926, McGill ceased to provide a fundamental time service, depending instead on the radio reception of time signals from Washington or Ottawa to maintain the local clock from which the signal emanated. Upon occasion the signal fed from the Dominion Observatory to the Ottawa telegraph office was relayed to Montreal for direct transmission to the Canadian network.

The time signal machine provided a means for supplying a program on a regular daily basis to each of the telegraph companies, using a separate coded signal for each. The Railway Association of Canada agreed to the proposal, as presented by R.M. Stewart that clock beats from the Observatory be used, but stipulated that the signals should be relayed through the Montreal office. Accordingly, early in 1945 the service was established. This in turn made possible a daily time transmission of the CN signal from radio station VAP, at Churchill, Manitoba, on a frequency of 500 kc. The lag of this transmission as monitored at Ottawa was 0.274 second. By July 1946 the summary prepared by J.P. Henderson of the services which originated in the time room reads as follows:

"CBC, networks broadcast for 40^s until 1 p.m. Eastern Time, standard or daylight saving, whichever prevails at Ottawa (about 50 stations).

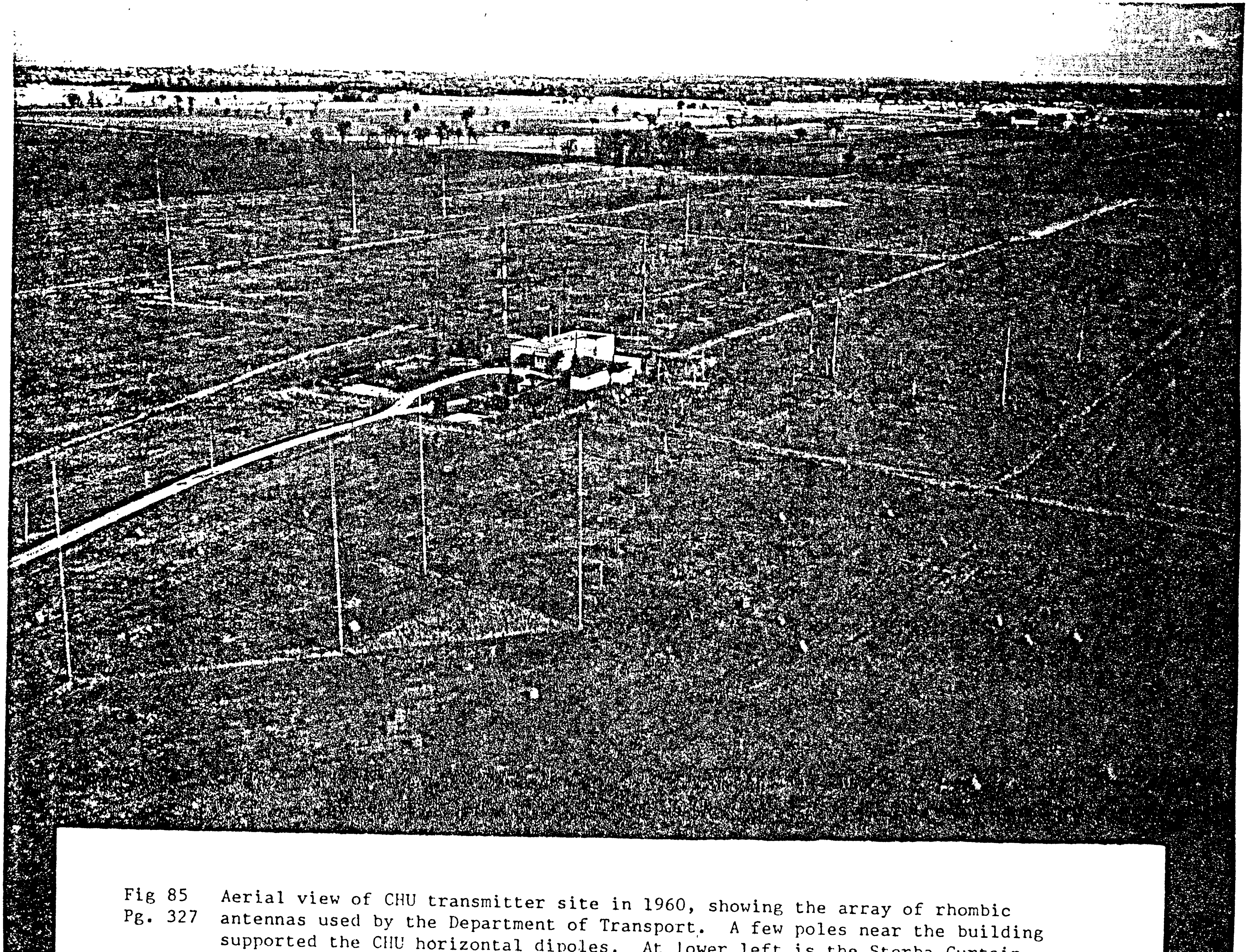


Fig 85 Aerial view of CHU transmitter site in 1960, showing the array of rhombic
Pg. 327 antennas used by the Department of Transport. A few poles near the building supported the CHU horizontal dipoles. At lower left is the Sterba Curtain with a long feeder line, discontinued in 1968. Courtesy Earth Physics Branch. E.M

C.P.R. telegraphs 11:54 - 11:56 E.S.T.

C.N.R. telegraphs 10:58 - 11:00 E.S.T.

VAP, Churchill, Man., 10:58 - 11:00 E.S.T. broadcast on 500 kc.

CFH, Halifax, 1500 & 0300 G.M.T. broadcast on 105 kc. 9040 kc, and 5502.5 kc.

VAA, Ottawa, 10:55 to 11:00 E.S.T. broadcast on 11990 kc.

CHU, Ottawa, continuous through 24 hours a day, broadcast on 3330, 7335, and 14670 kc.

VAA, Ottawa, dusk to dawn during summer months, broadcast on 5405 kc.

Telegraphs through CBO to carrier circuits, Eastern repeater network 7:45 - 7:50 E.W.T. (Eastern War Time).

Synchronization of Government clock systems, Bank of Canada, Ottawa Electric & Birks.

National Research, direct line carrying continuous time signals.

Frequency Monitoring, Dept. of Transport, direct line carrying continuous time signals."

CHU by this time was operating with a nominal power of 50 watts on each of the three frequencies. It was still quite inadequate for all parts of Canada, but the local radiation was sufficient to cause some interference on broadcast receivers near the Observatory. An increase in power, therefore, would have to be accompanied by a relocation of the transmitters. Space was generously made available at the transmitter site, because W.B. Smith of the Radio Division of DOT was a strong supporter of every step that would improve the reception of CHU by frequency monitoring stations across Canada. Fig. 85

Application was made in Nov. 1946 for the transfer of three RCA type AT3 transmitters, known to be war surplus, from the RCAF to the Observatory. Support to the application was given by the Canadian Radio Wave Propagation Committee, for whom a strong continuous signal would be useful for ionosphere, auroral zone and similar avenues of research. As a consequence the application was granted. The three transmitters were installed in the transmitter station on the Greenbank Road and placed in operation June 21, 1947. They each had a rating of 300 watts, a six fold increase in power for CHU. Simple dipole antennas were mounted between existing masts which had originally supported rhombic antennas. Hence there was no provision for selecting the optimum direction for the radiation pattern. Keying was done from the time room of the Observatory, and consisted, as before, of pulses of 1000 cycles approximately one-third of a second duration. Maintenance of the transmitters was performed by Department of Transport technicians, since the station was still on a 24-hour manned basis. Three cottages to house the three families were adjacent to the transmitter building. Subsequently the technicians were assigned other duties, the cottages vacated, and the station became unmanned. In preparation for this, an alarm was installed at the air radio console of Uplands Airport where it would have 24-hour observation. In case of a fault, either a DOT technician or someone at the Observatory time room could be notified. The transmitters, together with all the spare parts required for their maintenance, remained the responsibility of the Observatory. The very amicable relations that have existed between the staff members of DOT and staff members of the Observatory have in no small way contributed to the effective operation of CHU.

Dr. Beals, who assumed the duties of Dominion Astronomer in 1946, actively supported every move which might improve the facilities of each division of the Observatory. He suggested to McClenahan that one large transmitter be acquired and placed on the frequency that would offer the best Canadian coverage, namely 7335 kc. In 1951 Treasury Board granted the application for $20 000 for the acquisition of a Collins 231D-20 transmitter, designed to give a continuous output of three kilowatts. DOT was willing to look after it at Greenbank, but pointed out the need to enlarge the building. Fortunately Beals was able to assign $10 000 of Observatory funds to the cause which accounted in large part for the required 30 foot extension. Finally in January 1953, the transmitter was placed in service, broadcasting on 7335 kc, the AT3 being retained as standby. At first it was maintained at full load only during the day time, being reduced to half load at night. In the spring of 1954 the radio teletype time signal from Ottawa to Albro Lake, the control centre for CFH, was discontinued. The following August an attempt was made to key the transmitter directly from the CHU pulses, using this stronger signal. Vagaries of reception, static, and other overriding transmissions made the experiment short lived.

Several events occurred during the next few years. J.P. Henderson retired March 2, 1956, after nearly 37 years in the government service. He had kept abreast of the latest developments in electronics, and was deeply appreciated by other staff members for his skill and patience as an experimenter and instructor. He took no offence at anyone who appeared to take over what he was doing, but philosophized that it merely left him free to do something else. W.S. (Bill) McClenahan retired July 10, 1957, after 43 years of service, nearly 14 of which were as head of the Positional Astronomy division. He had been responsible for publishing all the early observational records of the meridian circle transit telescope, had piloted the PZT through its early years, and had seen the time service finally abandon the pendulum in favor of the quartz crystal oscillator. He was a capable man and well liked by his staff. At the time of this writing, 1974, Henderson is still enjoying his retirement, but McClenahan passed away a decade ago as a result of an accident in his apartment. M.M. Thomson succeeded McClenahan in office, witnessed the adoption of the atomic second, the consolidation of Canadian government astronomy under the jurisdiction of the National Research Council of Canada, and the formation of the Time and Frequency section in the Physics Division of NRC. Dr. C.C. Costain took over in March, 1972, and Thomson officially retired at the end of that year.

When the American code of time signal identification was adopted in 1934 for the Canadian time transmission, it was assumed that a properly equipped surveyor would in all probability have a timepiece which would indicate the correct time within a minute or so. The simple code would then indicate to him which minute of a five minute interval he was listening to. It turned out that code, no natter how simple, is unacceptable if some other easier method is available. Voice had largely replaced code in wireless communication, and by 1952 a voice announcement of time seemed to be a logical advance. Henderson recommended that a rental contract be negotiated with Audichron of Atlanta, Georgia. Departmental policy at the time, however, was opposed to the binding effects of long term rental agreements, preferring instead to make an outright purchase if possible.

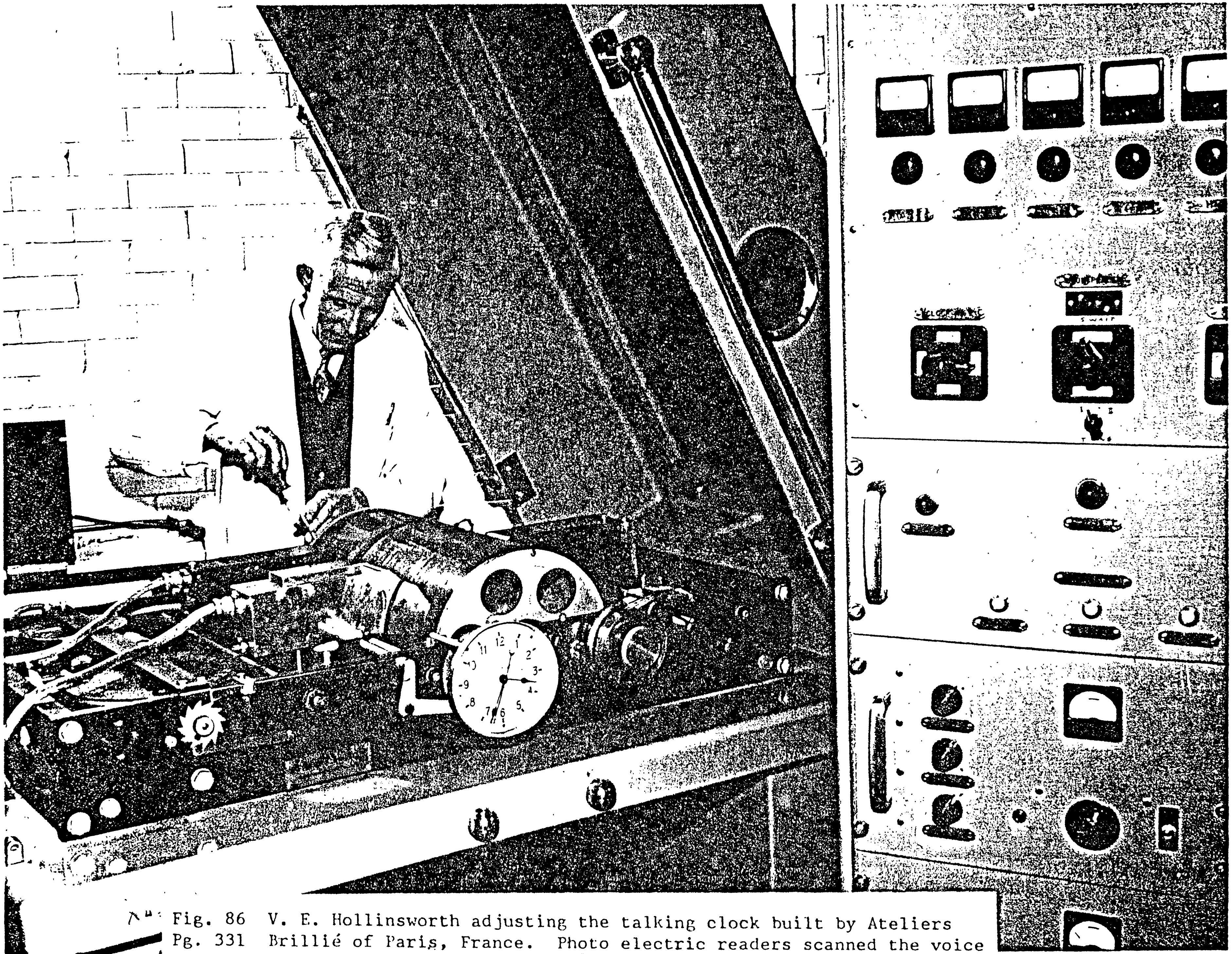


Fig. 86 V. E. Hollinsworth adjusting the talking clock built by Ateliers
Pg. 331 Brillié of Paris, France. Photo electric readers scanned the voice strips which were wrapped around the drum in grooves, one for each of the 24 hrs and 60 mins, and two for the preamble. Courtesy

An examination of several voice announcement systems, both in North America and Europe, was made. There were also discussions with people from NRC and from Crawley Films, Ottawa, about the possibility of a locally designed system. The outcome of it all was that Atiliers Brillié Frères of Paris, France, were awarded a contract to supply two of their standard units. They appeared to combine ruggedness and fidelity at a price that was within reach. It was stipulated in the agreement that the announcements be made by a male voice with a Canadian accent. Frederick Martyn Meach of the Canadian Embassy in Paris was seconded by the company to make the recording, and for a few years thereafter his voice was on the Canadian airwaves more than any other Canadian voice. The speaking clocks were housed in the basement clock room from which the piers had been removed. The voice announcement each minute of the twenty-four hours commenced December, 1954. It took the form "Dominion Observatory, Canada, eastern standard time, fourteen hours, forty-five minutes", and was in English only. On the hour the announcement took the form "... fifteen hours exactly". Fig. 86

Recording for the Atiliers Brillié Frères speaking clock was made as a sound track on photographic film. The individual strips, one for each of the sixty minutes, and one for each of the twenty-four hours, were wrapped around two drums in grooves. Light from the exciter lamp penetrated the film and was reflected back through the film to the photo cell by the reflectant coating of the drum. Photo cell and exciter lamp were mounted on a unit called a reader which was moved mechanically along a track in discrete steps so that it faced successive grooves. There were three readers, one for the preamble, one for the hours and one for the minutes. The very short life of four to six weeks for the exciter lamps was of concern until the photo cells were replaced by lead sulphide cells, which were sensitive to red light. Then, glowing at only half illumination the exciter lamps had an indefinite life.

The very nature of double passage of the light beam through the sound track film seemed to cause a reduction in fidelity. The announcements were sufficiently intelligible when monitored right at the speaking clock. By the time they had traversed the various circuits to the transmitter and returned as a radio signal there was a further drop in fidelity which occasionally involved monitoring two or three successive announcements to be sure of the correct time. The problem was aggravated, of course, as reception conditions deteriorated at greater distances.

When the change in speaking clock was made some six years later, several changes were incorporated. Perhaps the most important was the change from purchase to rental of equipment. Audichron was invited to draw up a contract for the rental of one of their speaking clocks which they would service regularly, and in addition respond to an emergency call immediately. With the expectation of such good service it did not seem necessary to rent a duplicate clock as standby. As a matter of fact the high quality of the Audichron clock and the effectiveness of the regular service calls have justified this decision. The recording was done by Harry J. Mannis of the Canadian Broadcasting Corporation, Toronto, and was transferred from magnetic tape to magnetic drum, preserving a high order of fidelity. The long line of communication from the Observatory to the transmitter site was made obsolete by installing the speaking clock in a room adjacent to the transmitter.

Commencing May, 1960, the voice of Harry Mannis announced the time via CHU. The older equipment was retained intact in the event of a breakdown, which fortunately never occurred.

The old speaking clocks in the basement clock room did not become idle with this change. One of them had been adapted to an automatic time announcement into the Ottawa telephone system. Preliminary discussions of a time service of this nature commenced in 1955. In December, 1957, a formal request for an unlisted telephone line was made. It was supported by a count V.E. Hollinsworth had made showing as many as 444 calls for time in one week, 89 in one day with a peak of 22 in 30 minutes, involving much of the attention of one person. Treasury Board, in a ruling dated January 3, 1958, turned down the request and "directed that the present practice of answering government or private calls for correct time be discontinued". Dr. Beals strongly resisted this ruling, stating in effect that the distribution of time by the Observatory was an obligation to the Canadian public. On August 15, Treasury Board reconsidered, and under TB536214 granted the installation of an unlisted line to the time laboratory by Bell Telephone. On January 13, 1959, the automatic answering service was installed. It provided a 10 second listening period to the talking clock, during which two complete announcements of the form "five hours, five minutes" would be heard. Entry to the talking clock was random, so that any part of the announcement might be heard first. Twelve hour instead of twenty-four notation was used, and the time was advanced one hour during the summer daylight saving period. The number, 994-5852 soon became generally known, and the daily count of calls rose steadily. Interestingly enough the number of calls during the night seemed to equal those during the day. A private line of this type was considered by Bell Telephone to be fully loaded when handling about 800 calls in a 24-hour interval. By 1967 there were occasions when the count on the automatic answering line exceeded 3000. Bell Telephone was unhappy with the situation, and there was a growing volume of complaints from the public. The one solution, requiring additional lines, and a French as well as an English announcement, involved a tariff scale by Bell as well as technical arrangements that were quite unacceptable to the Observatory. The other solution was to discontinue the service, which was done in March, 1968. J.H. Hodgson, who succeeded C.S. Beals as Director of the Observatories Branch on June 23, 1964, warned in a memo, dated February 16, 1968, to the Minister of Energy, Mines and Resources, the Hon. J.J. Greene, "This may result in a good deal of public resentment for which you and the department must be prepared". There was some resentment, it is true, but most of it fell on the ears of Mrs. B.M. Crawford, secretary of the Time Service Division. She handled the complaints with diplomacy and skill. Public feeling in Ottawa might have been more vocal had there not been other alternatives. There was, for instance, the 1 p.m. signal over the CBC network. There was also the increasing use of inexpensive multi-band transistorized receivers that could readily be tuned to one or other of the CHU frequencies.

The demand for easy access to a time signal has resulted in one or more companies producing a set which contains pre-tuned components. A turn of a switch is all that is required to select a WWV or a CHU time signal. For more local use, a few fixed frequency receivers were assembled by V.E. Hollinsworth and S.H. Sheard at the Observatory. One was made available to the gunner responsible for firing the noonday gun from Major Hill Park, and another to a government office responsible for the calling of tenders on public projects.

The new speaking clock, whose announcements showed the advantages of improved technology, attracted the attention of amateurs and short wave listeners, and brought requests for QSL (acknowledgment) cards from many parts of the world. One Canadian listener, A.G. Williams of Ville La Salle, Quebec, wrote proposing that the official time announcement of the Canadian government would be considerably enhanced if it were in both French and English. There were no funds available in the Observatory vote to make such a change, but this reply only spurred Williams on to more action. In the fall of 1962 he addressed a letter to The Hon. Paul Comtois the Minister of Mines and Technical Surveys, of which the Dominion Observatory was a Branch, and the following year he sent a further memorandum to the new Minister, The Hon. Wm. Benidickson. The reply this time was that the matter was under active review. So it was that with departmental approval a new contract was entered into with Audichron. Harry J. Mannis of the CBC, Toronto, provided the English recording and the late Miville Couture of CBC, Montreal, the French, giving an announcement of the form "CHU Canada eastern standard time fourteen hours forty-four minutes quatorze heures quarante quatre minutes" followed the next minute by "CHU Canada, heure normale de l'est quatorze heures quarante cinq minutes, fourteen hours forty-five minutes". As the example indicates, 24-hour notation has been used in order to avoid any ambiguity with respect to a.m. and p.m., or noon and midnight. The bilingual announcement commenced April 1, 1964.

A new requirement for a local signal involved more frequent voice announcements and fewer pulses. It gave rise to a format involving six announcements per minute, followed by a pulse every tenth second. An additional lease agreement with Audichron in 1969 involved two complete sets of announcements, one in English and one in French, covering every tenth second in the 24 hours. Three possibilities are available on the output of the new speaking clock. The announcements may be alternately English and French, all English, or all French, with simultaneous output of all three options. Harry J. Mannis and Claude Miguet, both of CBC Toronto, provided the announcements, which take the form "NRC, eastern standard time, fourteen hours forty-four minutes, twenty seconds, BEEP". The BEEP is a short burst of about 200 cycles of a 1000 cycle tone, and is accurate in time to about a millisecond.

The total service which is performed by this new speaking clock is not known. Five lines carry the information to Bell Telephone, the RCMP, the Resource Administration (research) Division of Energy, Mines and Resources Department, the Communications (research) section of the Department of Transport, and the CBC-CBOT master control studio. It is a direct wire service, and in no way interfers with CHU.

As soon as CHU advanced from a purely local phenomenon to a service that could be extended to the wider Canadian community, due to increased output, two objectives were proposed, that the frequencies of the three channels be synthesized from a frequency standard, and that the signal pulses be made uniform by the same source. When the keying was controlled by the R.M. Stewart time signal machine, the long term value of the time was fairly uniform, but there were short period variations. The correction imposed upon the small control pendulum by the primary clock, S29, caused the length of the seconds pulses to be shorter or longer than normal by a few thousandth of a second during the brief interval of advance or retard. The total correction then could change the time by a hundredth of a second or more. It was possible for variations of this sort to occur every six minutes, which is the coincidence interval between mean time and sidereal time. The 1000 cycle tone superimposed on the seconds pulses was derived from a separate source, tuning fork or frequency standard, and hence bore no phase relationship to the pulses or to the carrier frequency.

When the Muirhead time machines replaced the pendulum controlled time machines in 1951, it was possible to adjust the phase of the pulses so that they commenced with a 1000 cycle wave peak, since both were controlled from the same 1000 cycle source. The transmitters were still dependent upon commercially designed crystals for frequency stability, so there was no phase relationship between carrier frequency and signal pulse.

Several groups were interested in the development of CHU as a frequency standard whose carrier frequencies and seconds pulses would be completely in phase. The Department of Transport was responsible for issuing radio licenses and for monitoring the frequencies of transmitters, NRC was responsible for research into primary frequency standards and time, and relied upon a source of accurate time for much of the research. Accordingly a committee was formed to recommend suitable action. The Department of Transport was prepared to pay $35 000 for a device called a "Carrier Frequency and Time Signal Control of Station CHU". Specifications were submitted to several companies, and three replies were received, the lowest tender being nearly three times the amount DOT was prepared to pay. The Observatory and NRC were prepared to provide additional sums but not to that extent. On July 3, 1958 the following group met:

Mr. W.B. Smith - Department of Transport - Telecommunications Branch (Chairman)

Dr. J.T. Henderson - National Research Council, Division of Applied Physics

Dr. S.N. Kalra - National Research Council, Division of Applied Physics

Mr. C.F. Pattenson - National Research Council, Division of Radio and Electrical Engineering

Mr. M.M. Thomson - Dominion Observatory Time Service

Mr. D.L.G. Miller - Dominion Observatory Time Service

Mr. E.W. Groves - Department of Transport - Telecommunications Branch

Their decision was to continue with the project study and attempt to reduce the cost without sacrificing any features of the specifications. The result turned out to be far better than anticipated. J.C. Swail, the blind electronic engineer who worked with Pattenson, Fig. 87 proposed doing the job themselves. So it was that using his own circuitry, Swail produced the three CHU carrier frequencies from a Western Electric Fig. 88 primary frequency standard D175 730 (100 kc), and from one of the Muirhead time machines the sequence of seconds pulses was arranged. Swail had the assistance of a competent technician, but his own genius extended to the point that he not only worked out the practical details from the theory, but he was also able to do some of his own soldering. The completed device was assembled and installed in 1959 at the transmitter

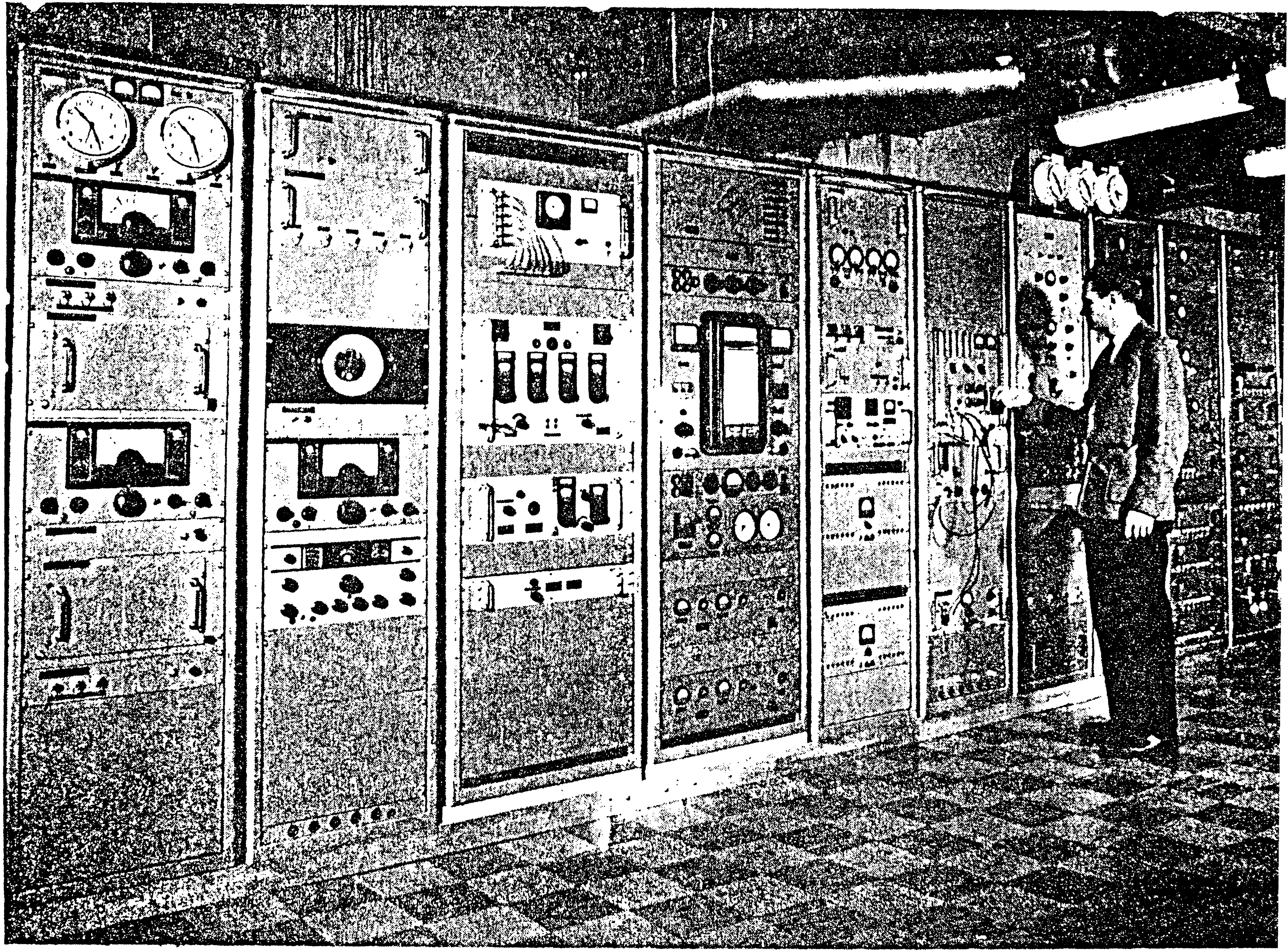


Fig. 87 J. Swail, the blind electrical engineer of NRC who was
Pg. 338 responsible for synthesizing CHU seconds pulses and carrier frequencies from a sta rd frequency. Courtesy NRC.

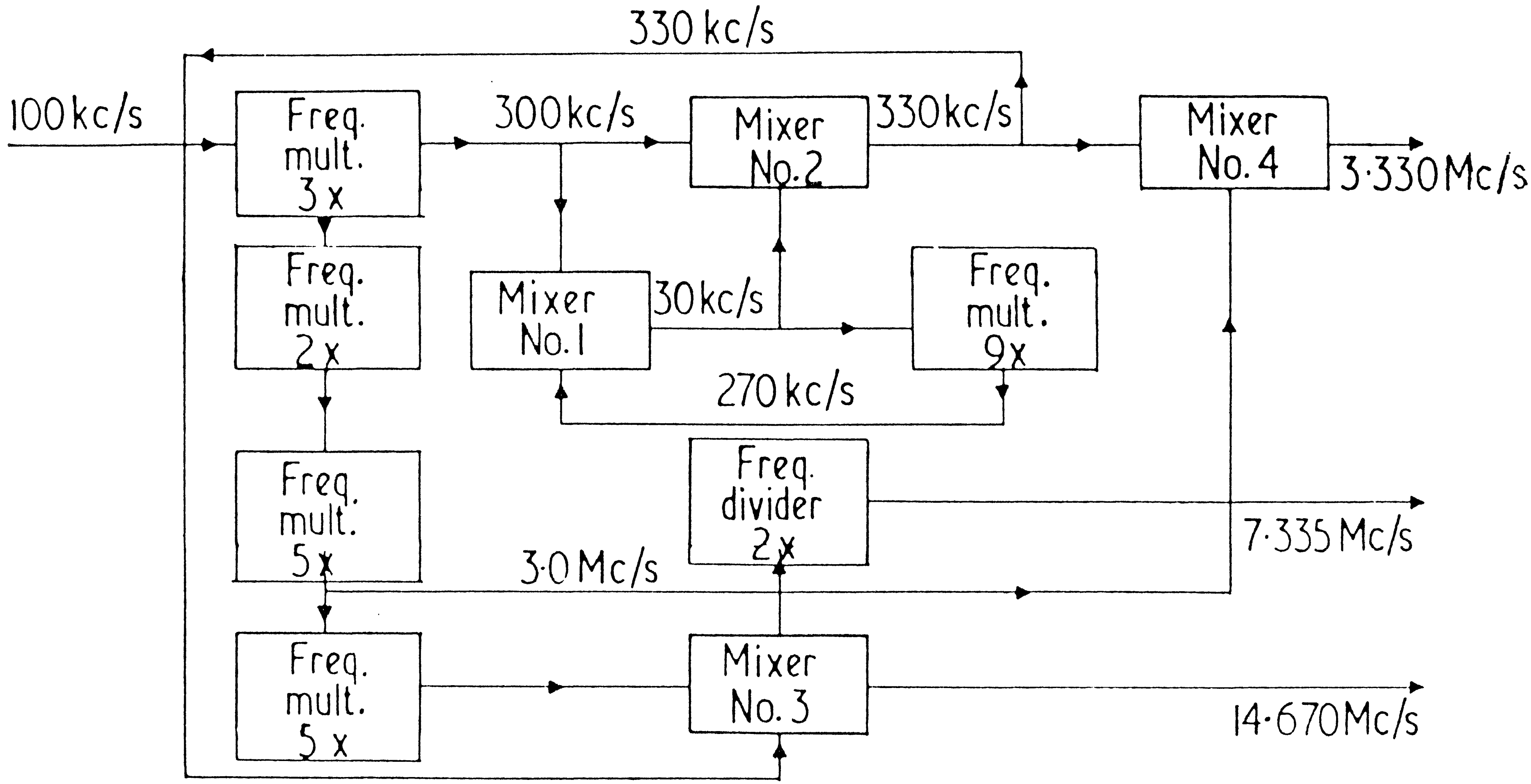


Fig.88 Functional diagram of CHU carrier frequency synthesizer.
Pg. 338 Courtesy NRC.

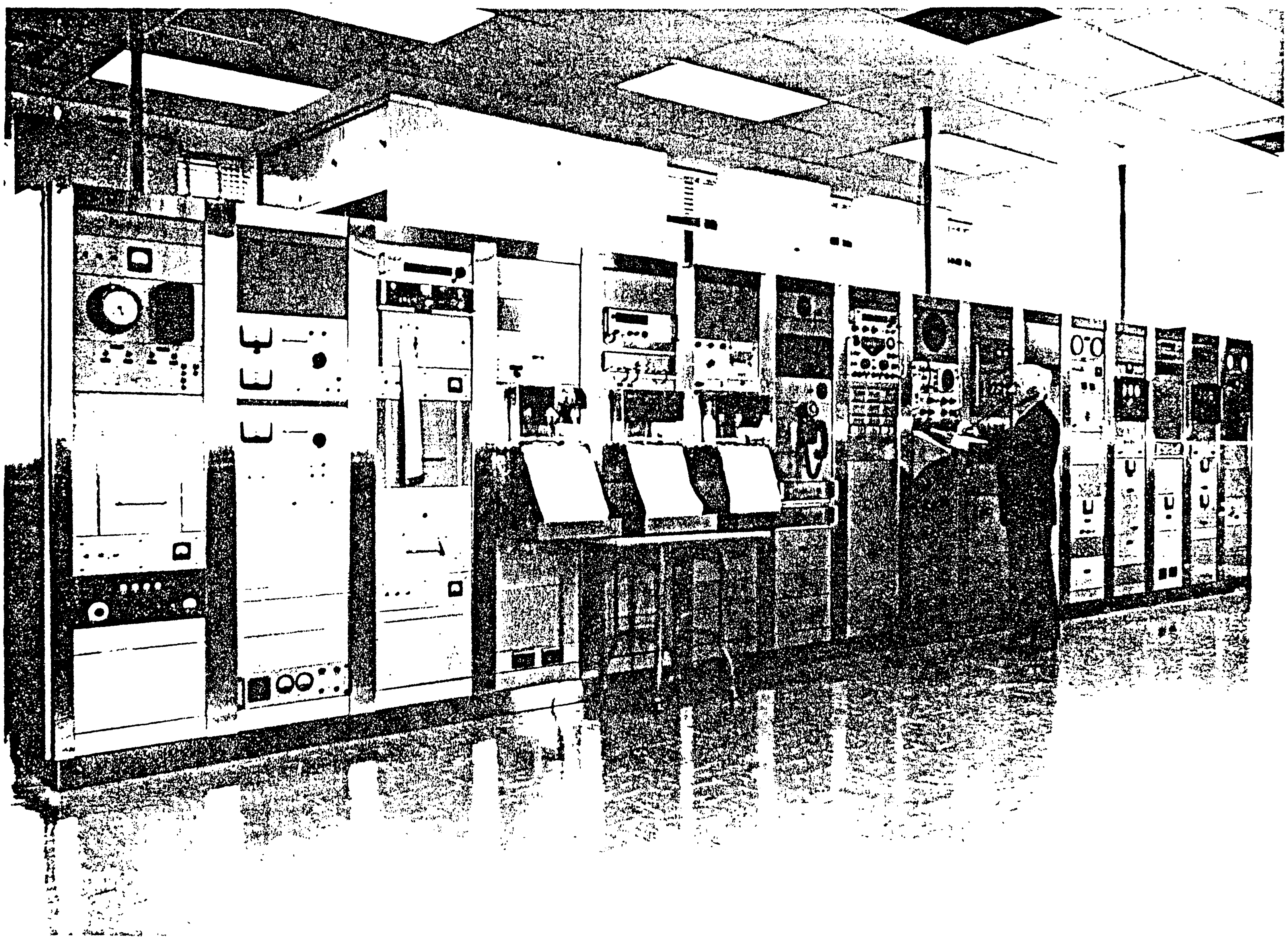


Fig. 89 Pg. 339 The transit annex became a bright air conditioned time laboratory, containing two Hewlett-Packard cesium standards, recording charts, radio receivers, and time distribution circuits. V.E. Hollinsworth is making a clock comparison. Courtesy Earth Physics Branch, EMR.

site, making it a self contained time source. Lines of communication from the transmitter site to the Observatory permitted monitoring both the control and the standby signal generators. A continuous strip chart on the output of three receivers provided a good record of the performance of each of the three transmitters. Early in 1961 James Knights transistorized frequency standards, type FS-1100T, replaced the older Western Electric units. At the time of writing the control is a cesium standard, with a rubidium standard and one of the Sulzer crystals as an ultimate standby. In 1964 Swail and Pattenson delivered an updated version of the frequency and signal control in which all the rotating parts and mechanical contacts were replaced by solid state logic circuitry.

S.N. Kalra, R. Bailey, H. Daams and Brian Rafuse of NRC completed construction of a long beam cesium standard in 1958. A 2 kc signal by telephone line from the transmitter was referred to it directly, so that frequency was maintained close to the desired value. In 1961 it was noted that the Dominion Observatory was responsible for time, NRC was responsible for frequency, and DOT maintained and serviced the transmitters. The rather specialized equipment which controlled the signal pulses, such as frequency standards, synthesizers, decade counters, etc., were the responsibility of V.E. Hollinsworth and D.L.G. Miller, and Fig. 89
later S.H. Sheard of the Dominion Observatory.

In 1959 it became possible to install another high power transmitter, and it was decided to place it on 14670 kc, leaving 3330 kc on low power for local distribution. Two interesting events followed. It was on the air for only a short while when the top of the wooden mast supporting one end of the doublet antenna caught fire and burned like a torch. It required a rigger to square off the top and readjust the guy wires, and the feed to the antenna had to be tuned more carefully. The increased power caused some interference to a station operating in Peru, South America. Accordingly a vertically supported dipole with a corner reflecting system (Sterba Curtain) was designed by W.A. Cumming of NRC to give a lobe from Ottawa in a direction 350° to serve NW Canada. Its efficiency was reduced because of a feeder system approximately 300 yds. long.

Technical Material Corporation (TMC) was chosen as the supplier of the new transmitter, after a satisfactory demonstration to the Department of Transport that their equipment could provide the required output free from spurious radiations. Although it was a New York based company, a branch assembly plant in Ottawa provided close liaison. One of their lower power units, 750B, capable of an output of 750 watts was installed in 1960 to provide an improvement on 3330 kc. Two years later a second one was acquired to serve as a standby on any of the three frequencies.

The radiation pattern of CHU had been dictated by the direction of the doublet antennas, which was not satisfactory. Nor was it possible to tune the output of any of the transmitters with maximum efficiency because wind and ice and other meteorological factors changed the antenna capacity and hence the tuning. It was therefore necessary to operate below maximum output. The solution to this dilemma lay in a vertical antenna coupled to the transmitter by a coaxial feeder. Fig. 90

In 1967 a new TMC transmitter, model GPT-40K, capable of 20 kilowatts output was ordered, complete with vertical antenna. It was

Fig. 90 Interior of CHU transmitter building showing the transmitters.
Pg. 340 Heavy coaxial cables may be seen on the right. Courtesy NRC.

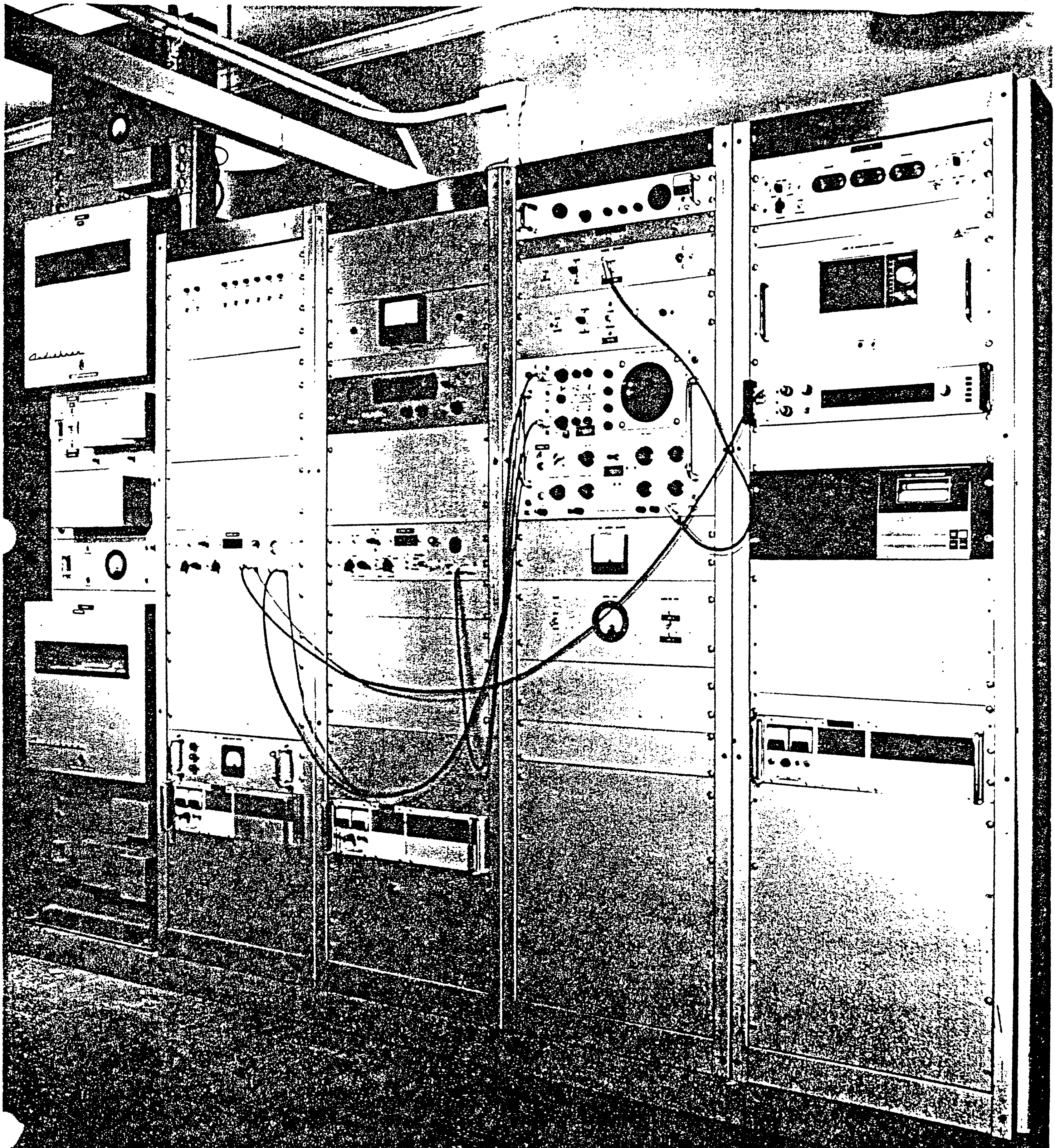


Fig. 91 Control panel at CHU with Audichron French and English speaking
Fg. 341 clocks, atomic frequency standard, TV synchronizing link with the time lab of NRC, and test equipment. Courtesy NRC.

placed in operation on 7335 kHz in October. By the end of 1969 all three frequencies were radiating with vertical antennas, with a marked improvement in efficiency. The Collins transmitter would have been retired by now had it not been that in 1968 R.E. Hadfield of Lake Simcoe, Ontario, was disposing of a similar unit. For the sum of $250 plus cartage, S.H. Sheard with the help of R.C. Foster secured the extra unit, and was thus able to extend the life of the Collins for another three years.

Although the term hertz, meaning cycle (or event) per second, had been recognized since the late 1940's, it did not come into general use at the Dominion Observatory until about 1965. In the new notation, the three CHU frequencies are designated 3330 kHz, 7335 kHz, and 14670 kHz. It is no particular improvement over the former notation, but it does preserve the name of Hertz, a great physicist.

When the Department of Transport declared the transmitter site an unmanned station, they disposed of the cottages which had housed the three families, but not before making any or all of them available to the Dominion Observatory. It was requested that one be left intact, to provide isolation for the rubidium atomic standard and standby quartz frequency standard. This was done. And as a further gesture of good will a new diesel generator was installed, capable of providing standby power for all but the 20 kilowatt transmitter. When the third vertical antenna was installed in 1969, the stray radiation in the main building largely disappeared. The cottage was then disposed of and all the sensitive equipment, together with a copper mesh screen room, was contained in the transmitter building. Obsolescence, which overtakes Fig. 91
all such equipment, was recognized by NRC in 1971 with the acquisition of

two TMC transmitters. The Collins was retired to the Museum of Science and Technology, and the original AT3's had long since been reduced to salvage. At the time of writing, the essential equipment at the CHU transmitter consists of a main and a standby unit for each frequency, all of them TMC manufacture, a vertical antenna for each frequency, and a dummy load that can be used when testing any of the transmitters. A primary frequency standard provides all the frequencies down to one pulse per second. Solid state logic circuitry provides all the sequences involved such as omitted or elongated pulses or split pulses, while a speaking clock gives the minute-by-minute bilingual time announcement.

A new system of time distribution has been developed by Edmunde Newhall Associates, following specifications outlined by NRC. It involves a master digital clock regulated by the cesium atomic standard at NRC, and a number of crystal controlled secondary digital clocks distributed across the country wherever they are required. The secondary unit has a free running accuracy of 1 in 10^7 (about one hundredth of a second a day), and battery standby to bridge power failures. It also is equipped to dial in to the master unit at NRC Ottawa by DDD (direct distance dialing) telephone line and receive a signal which will correct it to the nearest millisecond. DDD contact can be programmed to operate daily or at some longer interval, and it can also be initiated by push button control.

The serial time code, which is described technically as 300 baud FSK (frequency shift keying) using 103 modems, is an adaption of a system widely used for commercial data transmission, and is found to be very reliable. The message from the master clock includes the second, minute, hour, and day number of the year, all of which requires but a few seconds of transmission time. Various safe guards are built into the field clock to prevent it from receiving an error due to noise or a transmission fault.

Satisfactory transmission tests of the FSK serial time code have been made by synchronizing a field clock at NRC through long distance telephone loops to Vancouver, Winnipeg, Toronto, Washington, Montreal, Moncton, Halifax and St. John's, Newfoundland. Travel time of the signal over the eight loops is given in the following table.

DDD loop delay from Ottawa

Location	Delay	Distance
St. John's, Nfld.	22 msec	1100 miles
Halifax, N.S.	13 "	600 "
Moncton, N.B.	14 "	540 "
Washington, D.C.	15 "	470 "
Montreal, Que.	3 "	105 "
Toronto, Ont.	6 "	225 "
Winnipeg, Man.	19 "	1050 "
Vancouver, B.C.	34 "	2200 "

The distances are not exact transmission distances followed by the message, but rather a straight line-of-sight estimation as indicated by a ruler on a map. The delay from Ottawa to the field site is half the loop delay, i.e. 17 milliseconds to Vancouver. A rough comparison of half the delay time with the distance traversed indicates that the speed of transmission of the message is considerably slower than the speed of light. It indicates that after update St. John's, Nfld. will be 11 milliseconds slow compared to Ottawa, and Vancouver will be 17 milliseconds slow. These measurements were made using leased government lines. They may not be expected to be the same on the public DDD network. A delay of nearly 300 milliseconds will be introduced if the link is by satellite, but this discrepancy would be readily detected with reference to a time signal such as CHU or WWV.

The coded message is generated in FSK format (frequency shift key) using frequencies of 2725 and 2925 Hz. It can be recorded directly onto a tape together with voice, and displayed on a digital clock at a later time as the tape is examined. "There appears to be a wide requirement for this option to legally index command and control communication system voice recording. These include police, airport control, navigation control and railway dispatching. In addition there are tape recordings made by various government agencies - such as the Canadian Parliamentary Proceedings", (from a report to the 1974 Frequency Control Symposium by C.C. Costain and L.G. Miller). It remains to be seen how widely this new system of time distribution will be adopted.

Atomic Timekeepers

ATOMIC TIMEKEEPERS

It had been hoped that the Essen ring crystal oscillator would have served as a very precise frequency standard, particularly when a group of 5 was initially installed in the Ottawa laboratories, the number later being increased to 9. The history of their performance at the National Physical Laboratory during and after World War II had been good, and at the time of purchase they were the finest on the market. However, the Ottawa laboratories were dependent on interconnection by telephone lines which were not entirely free from interruption. Also the oscillators were subject to unexplained frequency shifts of a part in 10^9, thus limiting the precision with which they could be used to interpolate and extrapolate time and frequency. An attempt to use them as a time base to detect variations in earth rotation was not successful.

Even as the ring crystal was being pushed to the limits of its capabilities, advances were recorded in atomic physics which had a profound effect on timekeeping. As early as the 1930's, the idea of a perfect clock based on a natural frequency of the atom had appealed to the imagination. Advances in atomic physics during the war paved the way. In the 1940's a clock was built using an absorption line of ammonia. Other experimenters devised a method for successfully utilizing the resonance due to the hyperfine splitting of the cesium 133 atom.

The first device based on this principle to be used as a frequency standard was placed in operation by Essen and Parry at the National Physical Laboratory (NPL) in 1955. It gave the value of the mean solar second as 9 193 631 830 ± 10 cycles of the frequency of the central line. In a three year cooperative program between NPL and the

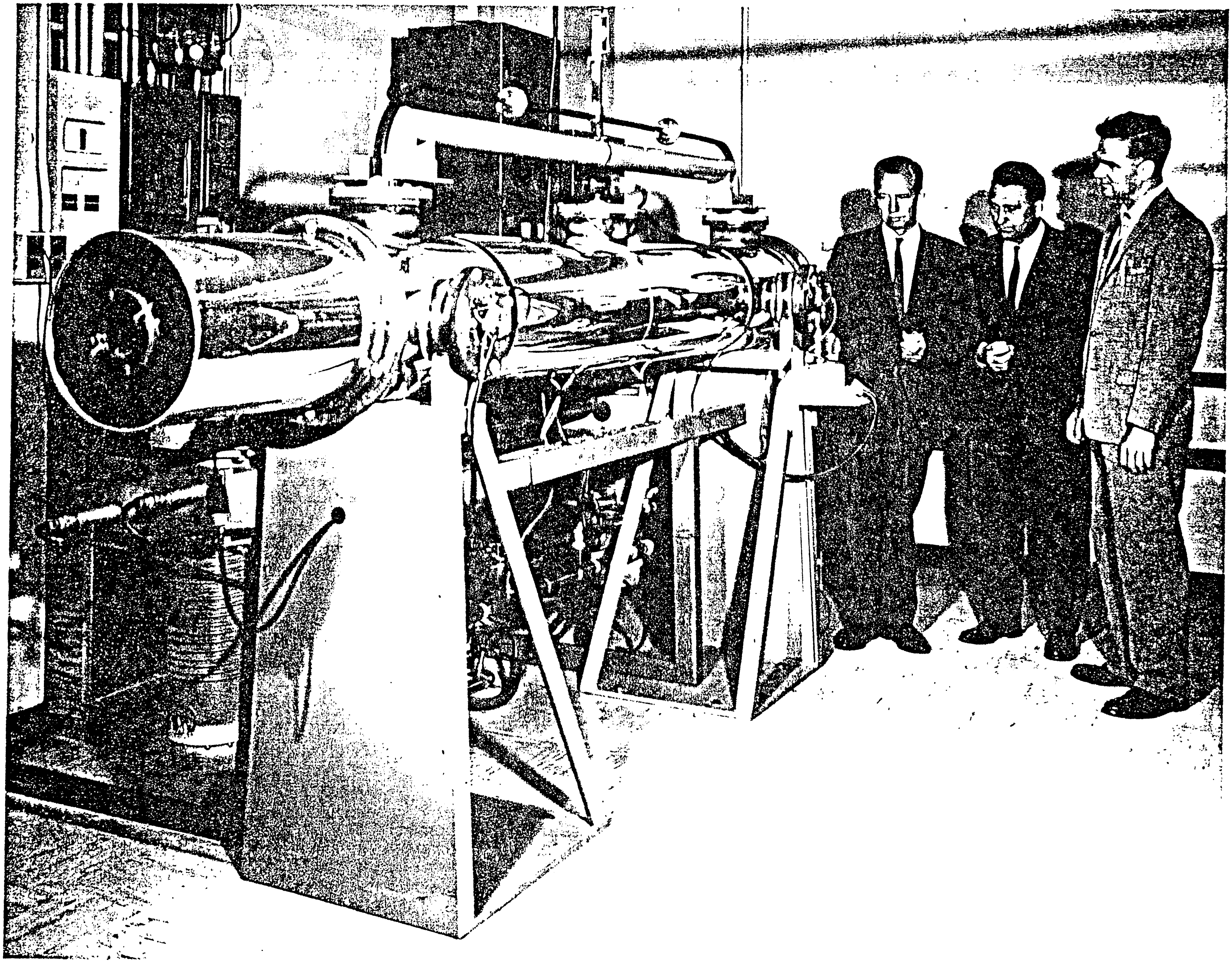


Fig. 92 Cesium III, the NRC primary frequency standard since 1965.
Pg. 346 R. Bailey, H. Daams and A.G. Mungall were responsible for the

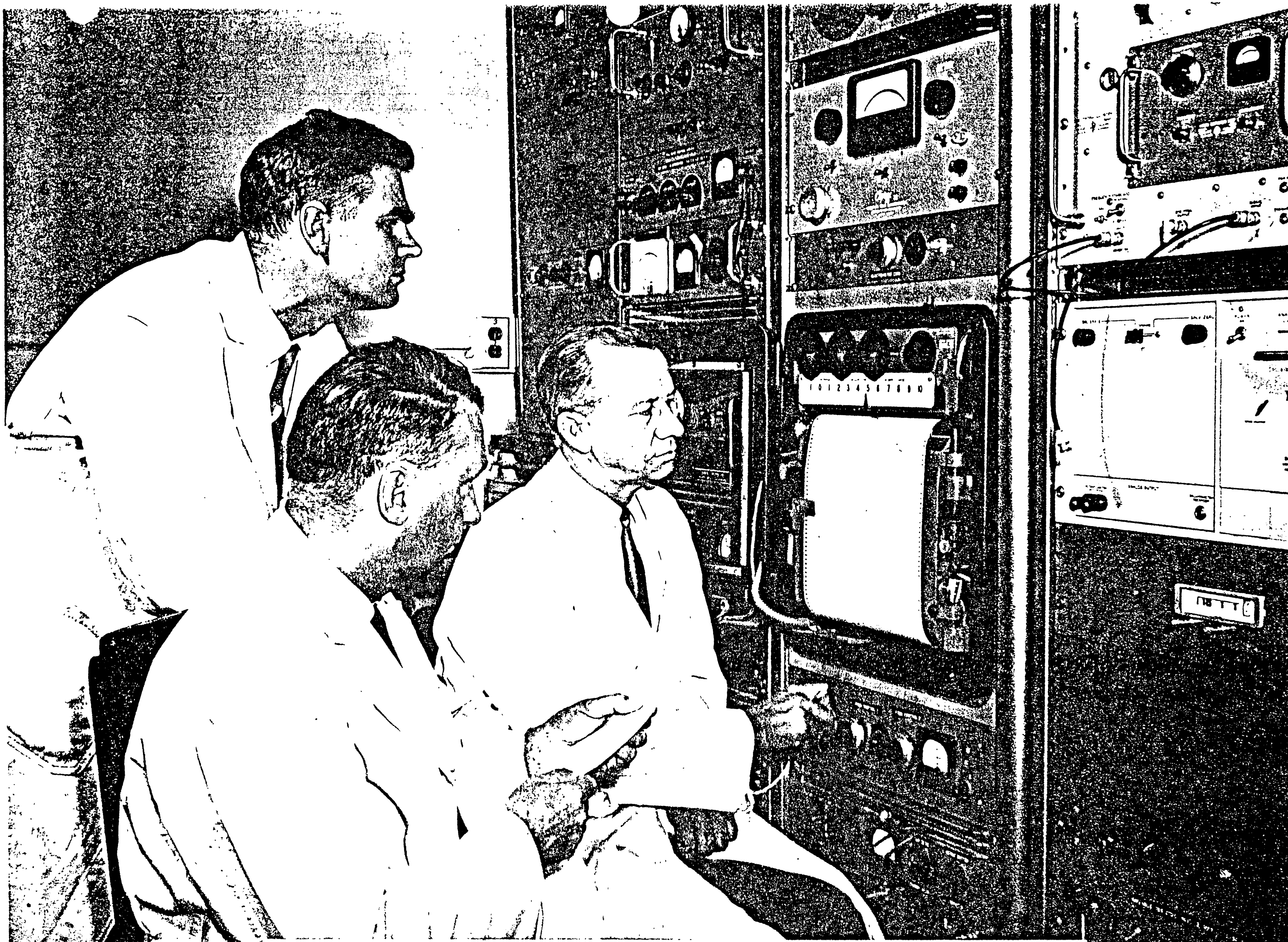


Fig. 93 Pg. 346 A.G. Mungall, H. Daams and R. Bailey observe the point of maximum resonance of the cesium beam as the input frequency is varied. Courtesy Physics Division, NRC.

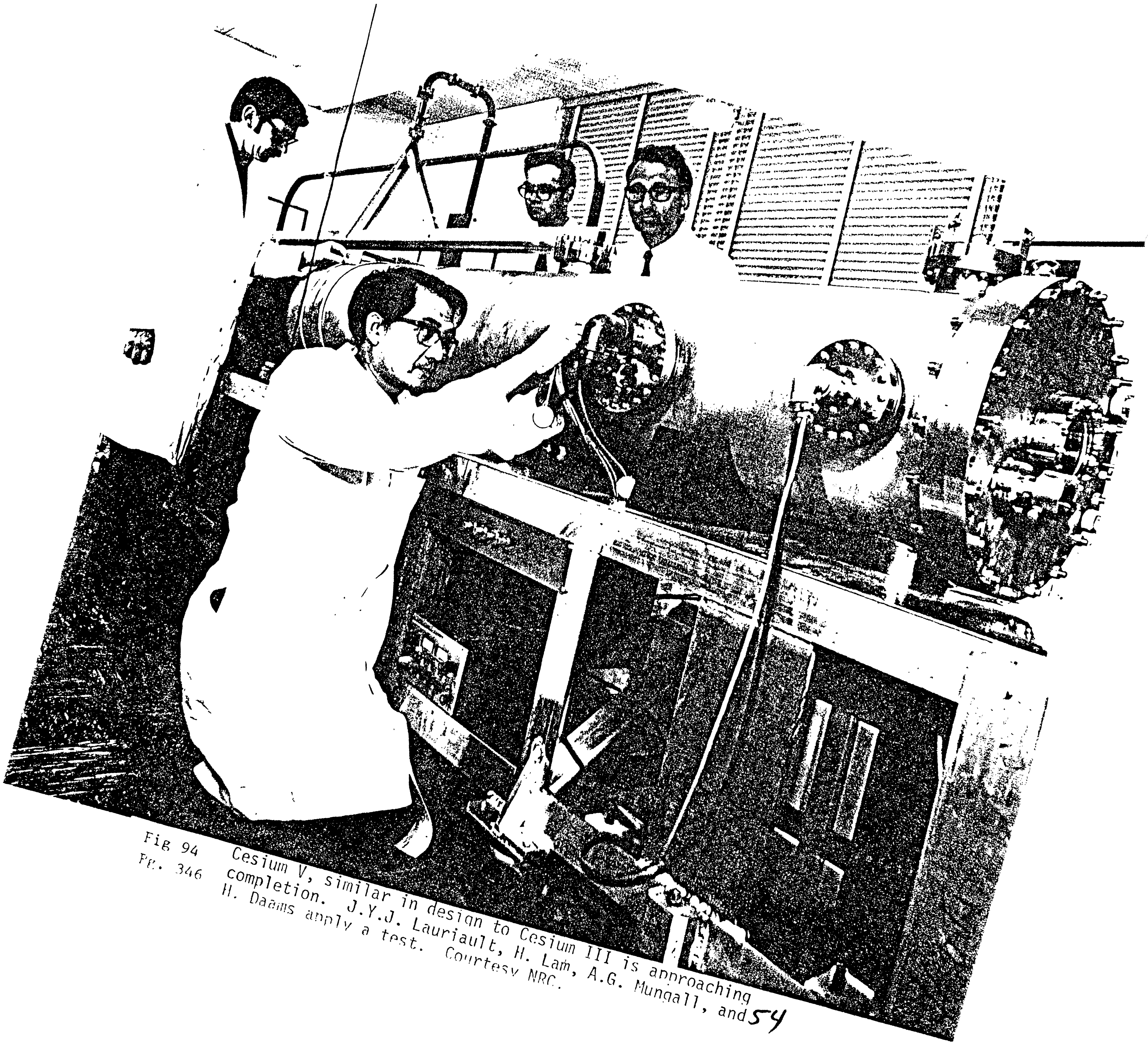


Fig 94 Cesium V, similar in design to Cesium III is approaching
Fg. 346 completion. J.Y.J. Lauriault, H. Lam, A.G. Mungall, and 54
H. Daams apply a test. Courtesy NRC.

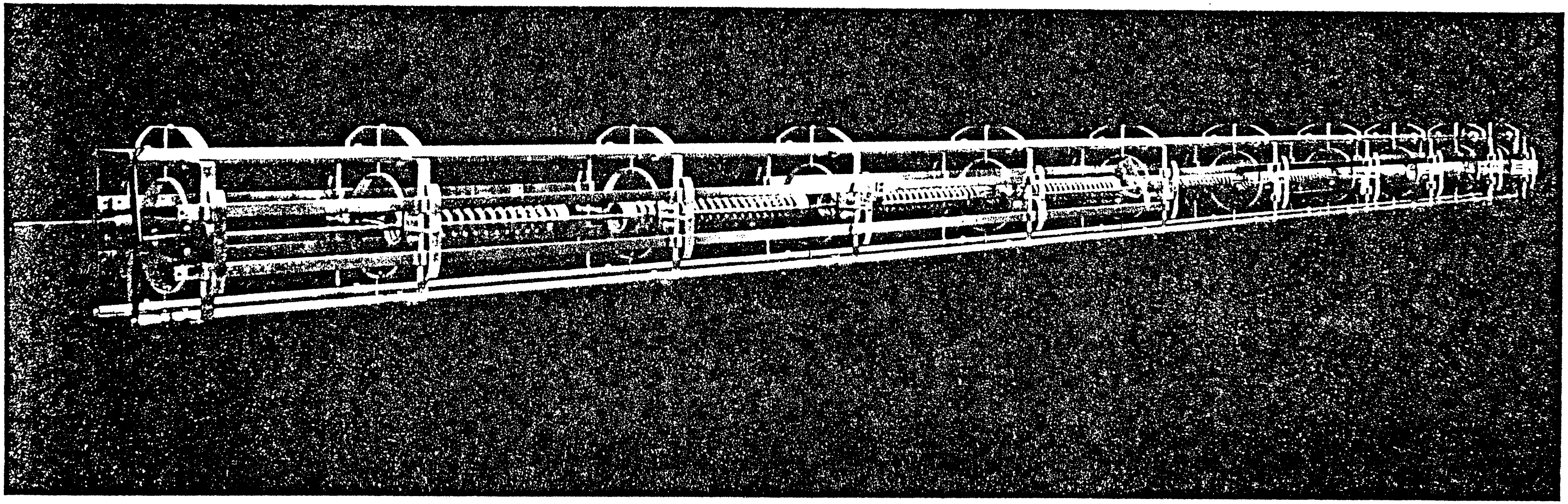


Fig. 95 Glass spacers hold the internal components of Cesium V in
Pg. 346 precise alignment. Courtesy NRC.

United States Naval Observatory,(USNO) Markowitz, Hall, Essen and Parry determined the central frequency of the cesium transition as 9 192 631 770 ± 20 Hz of ephemeris time.

The National Company of Malden, Massachusetts, produced in 1956 what they called an Atomichron, which was a crystal oscillator whose frequency was controlled by a cesium beam tube. It was the first of a number of Atomichrons which were built within the next few years. Two units were taken to NPL and placed alongside the laboratory standard built by Essen and Parry to study the differences which caused a small discrepancy in output frequency.

Canadian scientists, aware of the progress, were quick to develop a research program. Work on a cesium resonator, similar to that of Essen and Parry was undertaken at NRC by S.N. Kalra, R. Bailey and H. Daams in 1956, and the resonator was brought into operation in 1958. The accuracy of the first NRC cesium standard, CsI, was several parts in 10^{10}. It immediately became the Canadian standard of frequency to which the observatory clocks were referred daily.

When Kalra left NRC the team leader became A.G. Mungall, under Fig. 93 whose leadership CsIII was developed and set in operation in 1965. Initially it had an accuracy of a part in 10^{11}, but this was subsequently improved to a part in 10^{12}. Currently under test is CsV, developed by Fig 93 the team of A.G. Mungall, R. Bailey, H. Daams, D. Morris, and C.C. Costain. CsIV was an experimental model incorporating ideas which were not successful. CsV, a greatly improved resonator built on the same general Figs. 94 &95 design of CsIII, indicates an accuracy of one or two parts in 10^{13}. In addition it is designed to operate continuously as a clock, and not be restricted to the role of a primary frequency standard. With this in mind it is equipped with a large capacity 24 volt battery, float operated, with 24 volt inverter power supplies, all protected by diesel generator standby.

In 1967, after some four years of research, two hydrogen masers were brought into operation. This class of atomic oscillator, because of its excellent short term frequency stability of better than a part in 10^{14}, is an invaluable tool for assessing the performance of the cesium resonator. It is hoped to extend the period of maximum stability, which at present is about 1000 seconds, and perhaps discover a way to use the hydrogen maser as a primary frequency standard. Fig. 96

From about 1965 the atomic time scale at NRC was supported by a group of four 2.5 MHz crystal oscillators. The best of these was calibrated daily with respect to CsIII, and all were continuously intercompared. Digital divider chains from the crystal oscillators produced seconds pulses for the physical realization of time scales. In 1968 a Hewlett Packard 5061A cesium standard was acquired. This, measured at weekly intervals with respect to CsIII, proved to be greatly superior to a crystal oscillator as an interpolation oscillator for the cesium resonator.

Meanwhile at the observatory a rubidium vapor frequency standard by Varian Associates (V-4700A) was acquired in 1963. This was followed in 1966 and again in 1967 by the acquisition of HP 5060A cesium standards, #139 and #217, and in 1969 with an HP 5061A. The rubidium standard was moved out to the transmitter laboratory in 1966, but was transferred to standby duty in 1968 with the installation of an HP cesium standard as the time and frequency control of CHU.

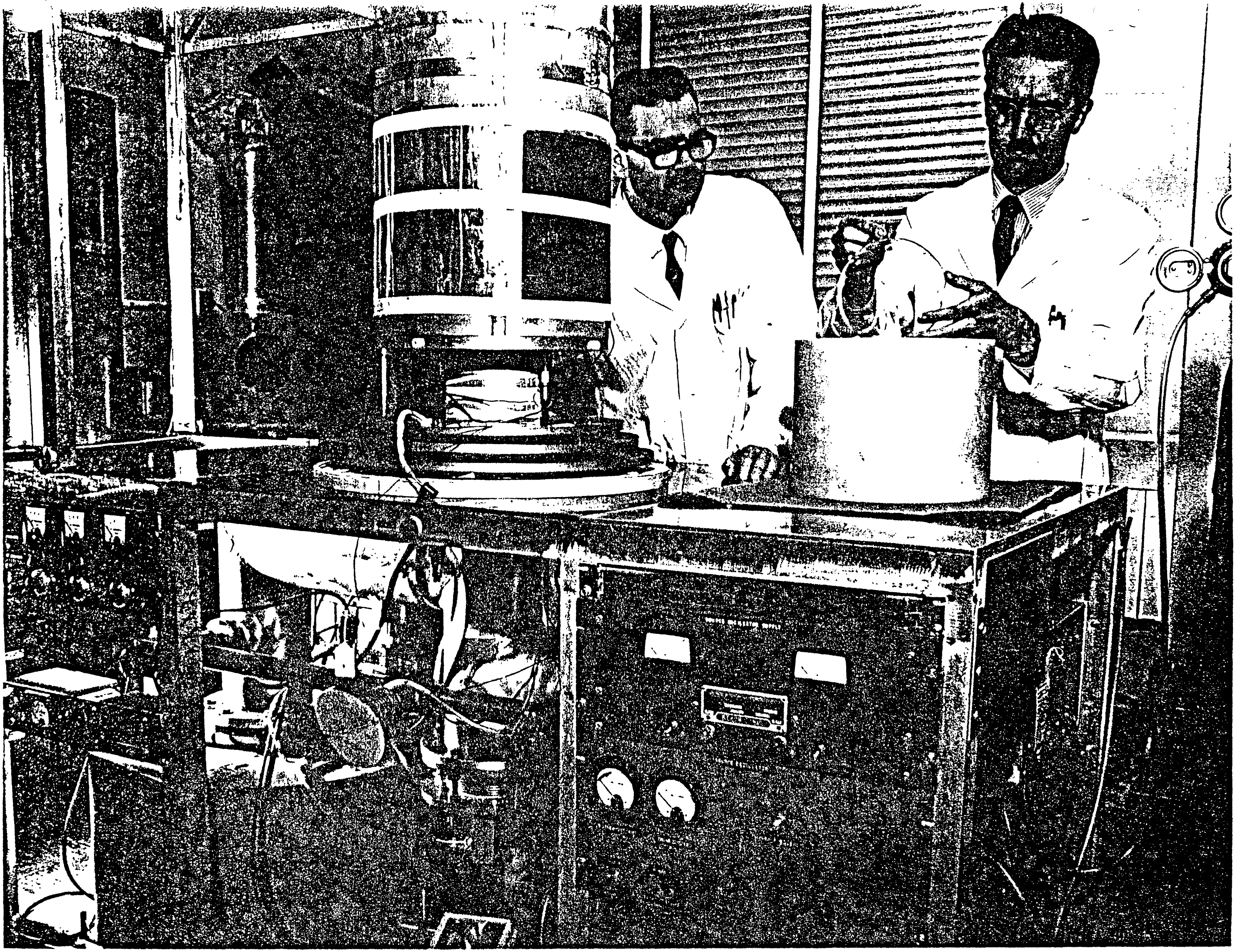


Fig. 96 Pg. 347 A.G. Mungall and D. Morris examine the glass bulb of one of the two hydrogen masers at NRC. Courtesy Physics Division, NRC.

SIZE 05

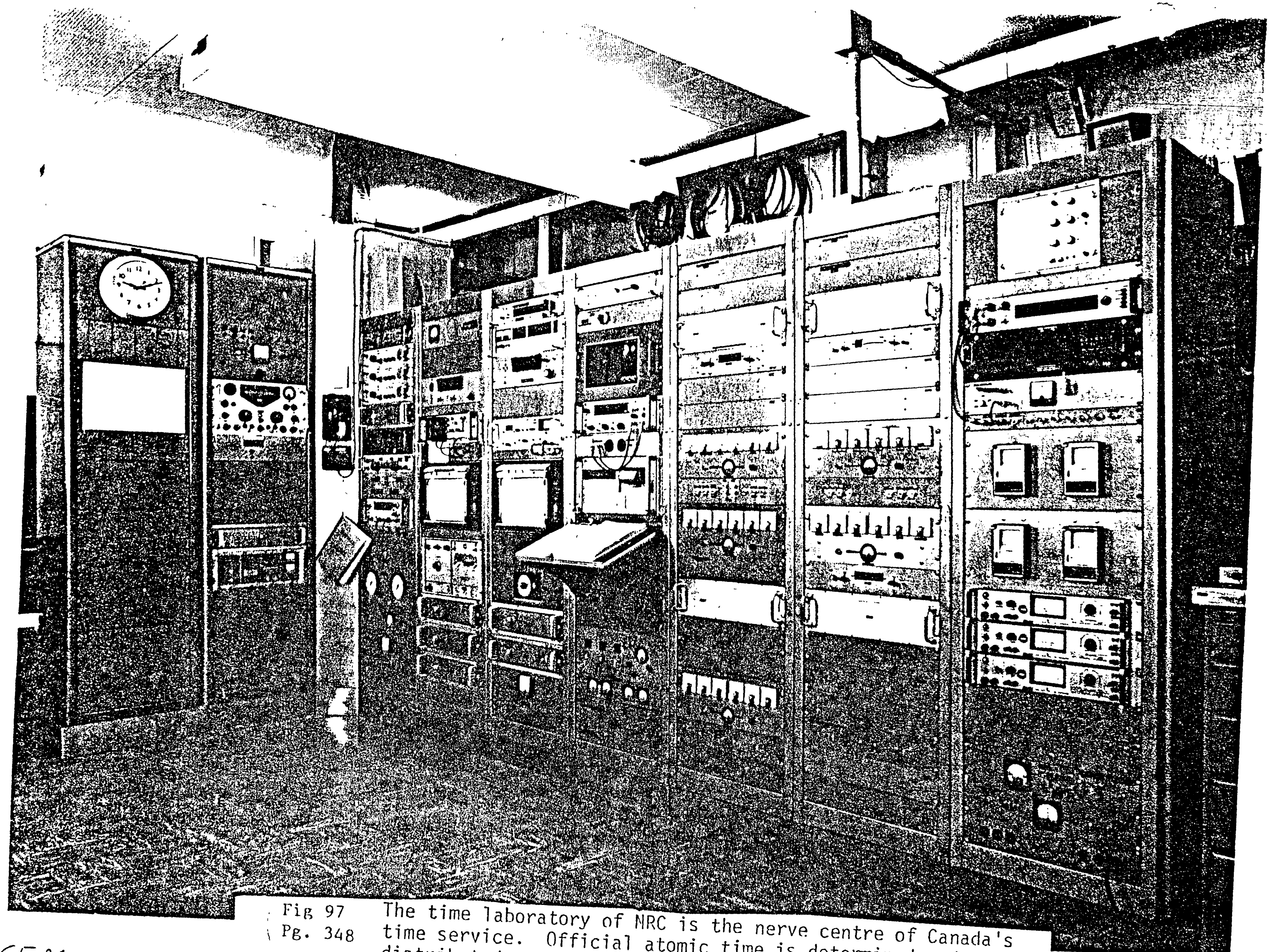


Fig 97 Pg. 348 The time laboratory of NRC is the nerve centre of Canada's time service. Official atomic time is determined and distributed, and is compared by radio and T.V. methods with the atomic time of other laboratories. Courtesy Physics Division, NRC.

SIZE 65%

When the control of CHU carrier frequencies and seconds pulses were synthesized from a 1 MHz crystal oscillator by J.C. Swail and C.F. Pattenson in 1959, provision was made to monitor it by direct wire so as to maintain the oscillator within a part in 10^8. The success of the operation permitted Ottawa to join with other national time services in a program launched at the end of 1960 by Greenwich and Washington whereby the seconds pulses as transmitted were synchronized to the nearest millisecond. Time coordinated in this way was called UTC (coordinated Universal Time). The next step in precision control of CHU was made with the acquitisision of James Knights 2.5 MHz transistorized crystal frequency standards type FS-1100 T with battery floated power supply. One was installed at the transmitter lab in 1961, providing a stability of a few parts in 10^{10}. After five years of good service it became standby to the rubidium atomic standard.

By the time the third Hewlett-Packard cesium standard had arrived at the Observatory in June 1969, conversations had already commenced concerning the consolidation of government responsibility for astronomy under the National Research Council. It was as a result of these discussions, and also as a fitting climax to the several years of close collaboration between the time service group of the Observatory and the frequency group at NRC, that they were brought together to form the 'time and frequency section' of the physics division of NRC on April 1st 1970. Fig. 97

Paradoxically, the only part of the time service that did not move across to NRC was that part headed by R.W. Tanner which was most astronomically oriented, namely the PZT group. In the Canadian context the PZT observations of time and latitude which revealed a variable rate of earth rotation and a wander of the pole, had within the previous year or two contributed more to geodynamics than to timekeeping. Time was now the responsibility of the physicist, and the second was defined in terms of the atomic standard, of which NRC was Canadian custodian. The actual operation of the Canadian PZT program was unaffected. Observations continued to be made every clear night at Ottawa and Calgary, and the results of the plate measurements, which yielded time and latitude, continued to be forwarded on a weekly basis to the Bureau International de l'Heure and the International Polar Motion Service. Also close liaison was maintained with the Royal Greenwich Observatory at Herstmonceux because of the twinning of the Calgary PZT, it having been established on the same latitude as the older U.K. PZT. In Ottawa, reception of the ground wave CHU transmissions continued to assure a close attachment of the PZT observations to the NRC atomic time scale.

The introduction of commercially designed atomic timekeepers brought in its wake the phenomenon of the flying clock. The older method of comparing time at a distance by the monitoring of radio signals remained valid for the comparison of time interval. For the comparison of time as opposed to time interval the radio link was inadquate. There was a loss of precision and purity of the radio wave, and there was an uncertainty in the travel time of the radio signal. It was tolerable when uniformity to the millisecond was satisfactory. Now, with microsecond precision within each lab, the only satisfactory method of intercomparison was to transport a timepiece with the same characteristics of accuracy and precision.

Fig. 98 Pg. 351 Swiss Atomic standard en route to Expo '67, was brought to the time lab of the Dominion Observatory. Left to right: M.M. Thomson, Helmut Brandenberg, Peter Kartaschoff, V.E. Hollinsworth and L.G. Miller. Courtesy Earth Physics Branch, EMR.

10%

The feasibility of time comparison at a distance by satellite link had been demonstrated in two separate experiments, one in 1964 across the Atlantic to England, and the other in 1966 across the Pacific to Japan. (The method has been exploited successfully with the development of communication satellites.)

One of the first flying clock experiments was reported by F.H. Reder and R.M. Winkler of the U.S. Army Research and Development Laboratory at Fort Monmouth N.J. In November 1959, an Atomichron was test flown in an aircraft and the following February it was used to compare Atomichrons in Fort Monmouth and Patrick Air Force Base, Florida. The experiment demonstrated the feasibility of comparing atomic clocks to the microsecond on a world wide basis. J.A. Barnes and R.L. Fey of the National Bureau of Standards transported a high precision quartz crystal clock between Boulder, Colorado, and Greenbelt, Md, in April 1963, establishing a synchronization of clocks within ± 5 microseconds.

Hewlett-Packard of Palo Alto, California, took over the National Company of Malden, Mass., as the major producer of cesium clocks during the 1960's. In 1964 two H-P cesium clocks were made portable and flown to Europe to compare the time between Neuchatel, Switzerland and Boulder, Colorado. The time difference was established to about a microsecond, and the travel time of the VLF propagation between Boulder and Neuchatel was evaluated with an uncertainty of about 200 microseconds. Also the frequency of the long beam cesium standard at Boulder was compared to the one at Neuchâtel within a few parts in 10^{12}. Similar experiments were conducted by Hewlett-Packard for three successive years, the distance travelled being extended and the instrumental equipment being improved each time. In 1967 the experiment required 41 days, during which 53 places in 18 countries were visited.

The Dominion Observatory and NRC were included in the H-P flying clock measurements in 1966 and 1967, thereby relating the time and frequency at both these laboratories to the visiting flying clock to a tenth of a microsecond and a part in 10^{12} respectively. Early in the summer of 1967 the Swiss company, Ebauches, transported a cesium standard from Switzerland to Montreal to serve as the control timepiece for Expo '67. On the way the clock was brought to the time lab of the Dominion Observatory for a time and frequency comparison. Fig. 98

In 1960 Atomichrons were placed as frequency controls at the Omega navigation stations at Oahu, Hawaii and Forestport, N.Y. Subsequently atomic standards have replaced quartz oscillators at all Omega and Loran-C stations. The network of Loran-C stations, maintained as navigational aids by the U.S. Navy, now involves the use of large numbers of cesium clocks. They require monitoring by regular visits with a portable clock. In the performance of this duty, the U.S. Naval Observatory field team commenced in 1968 to pay regular visits to Ottawa. Not only did these visits establish a time comparison to the tenth of a microsecond between Washington and Ottawa labs, they also established with the same precision the travel time of the Loran-C signal. Special receivers designed to identify the pulses of the transmitted signal were then used to compare both the time and frequency of the laboratory standard with the Loran-C station, and with other laboratories who similarly report their Loran-C observations to the Bureau International de l'Heure.

The unit of time, the second, has been defined as a specific frequency corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom. Seven laboratories, of which three, the National Research Council, the National Bureau of Standards and the Physikalisch Technischen Bundesanstalt have long beam laboratory standards, contributed to the initial establishment by the BIH of a uniform frequency and a time scale. There are now 23 collaborating laboratories. Since most of the weight is placed upon commercial cesium standards, there is the possibility of a systematic drift in the internationally adopted atomic time. NRC, with CsIII operating, and CsV soon to be commissioned, is in a position to make a unique contribution to the realization of the frequency of the cesium transition and to the evaluation of the atomic second.

Two further methods of clock synchronization have recently been developed and will be mentioned briefly. They are the aircraft overflight experiment, and the T.V. synchronization link. Each was developed to serve a local national need, but the first one has global significance.

The Office National d'Etudes et des Recherches Aerospatiales (ONERA) of France had developed the technique for synchronizing the clocks at several observing sites in the Mediterranean area in connection with rocket launching. An aircraft equipped with a cesium standard and microwave equipment for time pulses would fly over each site at a precise altitude. With matching equipment on the ground, the several sites would have their local standards related to each other within about 10 nanoseconds. In September 1970, ONERA undertook to conduct the much more extensive experiment between Europe and North America. Matching ground equipment was installed in advance and the aircraft flew in succession over the time laboratories of the Observatoire de Paris, the Royal Greenwich Observatory and NRC. Security regulations prevented a direct flight over the U.S. Naval Observatory, but a two way exchange from a nearby airport accomplished the same result. The four time scales were compared to a few tens of nanoseconds, an improvement of about one order of accuracy over that currently available with the portable clocks.

The TV synchronizing pulse can be used as a very precise time signal by laboratories (and by industry) within range of the same program. First developed in Europe, it was recognized by the National Bureau of Standards as a vehicle whereby time across the USA could be synchronized. The three major American TV networks are each controlled by a rubidium atomic frequency standard and their nation wide programs are programmed through their New York studios. The synchronizing pulses are monitored at NBS and USNO and Ottawa, with results that are comparable to Loran-C. Ottawa is close enough to the USA border to have access to one of the American TV outlets.

A similar plan is not at present practicable in Canada because there is no central studio from which TV programs are broadcast nation wide on a regular basis. The 5½ hour time difference from Newfoundland to the Pacific coast is just too wide a spread except for some special event such as the annual Christmas message from the Queen.

It had been hoped that the Algonquin Radio Observatory (ARO) and NRC might be able to intercompare time scales by monitoring a TV signal common to both locations. ARO is not well located for this.

CHU transmitting station is well within range of a TV signal common to NRC. As a result the CHU time signal is now maintained within a microsecond of the NRC time scale, synchronization having been established by the portable cesium standard of the U.S. Naval Observatory. Fig. 99

The scientific and technical staff of the time lab at NRC are extending their researches into improving the precision of their atomic timekeepers, and providing the most efficient methods for the distribution of legal time throughout Canada.

This concludes the story of timekeeping in Canada. It has been a review of the response of government authorities to the time requirements of navigation, meteoroloty, surveying, frequency control, and other branches of scientific research, and is mainly restricted to the interval from about 1840 to 1973. During this interval the astronomical pendulum achieved its finest performance as a timekeeper in the concept of the Synchrome Free Pendulum. It was replaced by the products of the physics laboratory, first the quartz oscillator, then the atomic resonator. The definition of the fundamental unit of time, the second, has had two modifications in the last two decades, and is now defined in terms of the cesium atom. The story has included men of vision and ability who have been trail blazers in this area of Canadian history. Their legacy is a time service in Canada which is to the forefront of international standards.

The search for perfection is not an end in itself. The demands of other branches of science, including space research, are pushing hard on the heels of the timekeeper. Even so, among the fundamental units of science, no other unit is known with greater precision than the unit of time.

Fig. 99 Pg. 354 - The CHU transmitter as seen from road. In the background is one of the three vertical antennas. The telephone cable feeds as an aerial from the road, while the power cable is underground.

Credits: Public Archives of Canada 1, 6, 7, 19, 20, 23, 24, 38, 41, 42, 43, 56, 60

National Parks Branch, Indian and Northern Affairs Dept. 3, 4

University of New Brunswick Archives 8

New Brunswick Museum, Saint John, N.B. 18

Earth Physics Branch (formerly Dominion Observatory) Energy, Mines & Resources Dept. 5, 37, 39, 40, 46, 48, 50, 55, 58, 59, 61, 62, 63, 64, 65, 67, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 86, 87, 90, 94

Atmospheric Environment, Department of the Environment 9, 10, 11, 12

Air Photo Library, Surveys and Mapping Branch, Energy, Mines & Resources 44

McGill University Observatory 13, 14, 15, 16, 17

Queen's University Archives 26, 27

Photo Image, Kingston, Ontario 25

Wallace R. Berry, Kingston, Ontario 29

Vancouver Public Library 30

Mrs. Winnifred Dickinson 31

Victoria Press Ltd., Victoria, B.C. 32

Regional Climate Data Centre, Victoria, B.C. 33

Provincial Archives, Victoria, B.C. 34, 35

Royal Canadian Mounted Police, Ottawa 21

Malak Photographs Ltd., Ottawa 47, 52, 54, 57, 85

National Capital Commission, Ottawa 53

National Research Council 49, 51, 66, 68, 88, 89, 91, 92, 93, 95, 96, 97, 98, 99, 100

Acknowledgements

A work of this nature, modest in its completed form, involves many people. The help and advice has been generous. Dr. Derek Morris, a colleague in the time and frequency section of the Physics Division, NRC, kindly read the manuscript and suggested minor rearrangements of material. Prof. J.E. Kennedy has a special interest in the work of Dr. W. Brydone Jack of Fredericton, and helped with Chapter 3. A similar contribution was made by Prof. J. Stewart Marshall in Chapter 6; Dr. A. Vibert Douglas of Kingston and Mr. W.J. Patterson, Superintendent of Historic Sites, The St. Lawrence Parks Commission, for Chapter 9; Mr. Willard E. Ireland of the Provincial Archives, Victoria, B.C. for Chapter 10; and Mr. R.W. Tanner, formerly of the Dominion Observatory for Chapter 15.

For the typing and retyping of the manuscript I am indebted to Mrs. J.S. (Bunny) Crawford, Miss Shirley Wall, and Mrs. H.J. Letaif, all of NRC.

Much of the early history has been gleaned from micro film of the Admiralty records and from the Sessional Papers of the Canadian government which are stored in the Public Archives. It is a pleasure to acknowledge the cooperation so readily extended by several people of this organization. The same cooperation was experienced in correspondence with officials at several archives in Canada, the National Maritime Museum of London, England, and the Harvard University Archives.

In addition to those named above, I would like to record my indebtedness to:

Miss Marilyn Arthurs, New Brunswick Museum, Saint John, N.B.

Mr. Roland-J. Auger, Archivist, Dept. of Cultural Affairs, Quebec City.

Miss Jean M. Boone, Harriet Irving Library, UNB, Fredericton, N.B.

Mrs. Lyle G. Boyd, Harvard College Observatory, USA.

Judge W.M. Cory, Ottawa, Ontario.

Mr. Ed Davey, Chatham, Ontario.

Mrs. Winnifred Dickinson, Vancouver, B.C.

Mr. Clark A. Elliott, Harvard University Archives, USA.

Mr. Robert Fellows, Provincial Archives, Fredericton, N.B.

Dr. Bruce C. Fergusson, Provincial Archivist, Halifax, N.S.

Mr. R.H. Field, Barbados.

Mr. L.K. Ingersoll, New Brunswick Museum, Saint John, N.B.

Mr. Jesse Ketchum, Toronto, Ontario.

Mr. J.L. Knox, Atmospheric Environment Service, Vancouver, B.C.

Prof. R.J. Lockhart, University of Manitoba, Winnipeg, Manitoba.

Mrs. D.F. MacDermaid, Queen's University Archives, Kingston, Ontario.

Mr. Donald C. Mackay, Halifax, N.S.

Mr. Keith A. McKinnon, Ottawa, Ontario.

Mr. C. Kirkland McLeod, Victoria, B.C.

Mr. A.F. McQuarrie, Atmospheric Environment Service, Victoria, B.C.

Mr. Philippe Mailloux, Montreal, P.O.

Prof. W.L. Morton, Trent University, Peterborough, Ontario.

Mr. Fred Phillips, Provincial Archives, Fredericton, N.B.

Mr. George L. Pincock, Atmospheric Environment Service, Toronto, Ontario.

Mr. E.F. Porter, Ministry of Transport, Ottawa, Ontario.

Mr. J.H. Rector, Rothway, N.B.

Mrs. M. Robertson, New Brunswick Museum, Saint John, N.B.

Superintendent D.T. Saul, R.C.M.P., Ottawa, Ontario.

Miss Mary Skinner, Atmospheric Environment Service, Toronto, Ontario.

Hon. H.H. Stevens, Vancouver, B.C.

Mr. Morley K. Thomas, Atmospheric Environment Service, Toronto, Ontario.

Mr. Don W. Thomson, Author, Energy, Mines & Resources Dept., Ottawa, Ontario.

Mr. D.W. Waters, National Maritime Museum, London, England.

Mr. Ian Wilson, Archivist, Queen's University, Kingston, Ontario.

Mr. Sidney A. Woods, Victoria, B.C.

INDEX

C

D

D (Cont'd)

E

F

G

G (Cont'd)

H

I

J

K

L

M

M (Cont')

N

O

O (Cont'd)

P

Q

R

S

S (Cont'd)

T

T (Cont'd)

U

V

W