Progress report for January, February, March, 1948

National Research Council of Canada. Radio and Electrical Engineering Division

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LABORATORIES

OF

THE NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

PROGRESS REPORT

FOR

JANUARY, FEBRUARY, MARCH, 1948

OTTAWA

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Report no. ERA - 151

Laboratories

of

The National Research Council of Canada

Radio and Electrical Engineering Division

PROGRESS REPORT

FOR JANUARY, FEBRUARY, MARCH, 1948

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Ottawa, May, 1948.

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PROGRESS REPORT

FOR JANUARY, FEBRUARY, MARCH, 1948

I
ELECTRICAL ENGINEERING

VAN DE GRAAFF GENERATORS

Summary. Two Van de Graaff generators are under construction. One, a five-megavolt generator, will be employed in nuclear research at the Chalk River laboratories of the National Research Council; the other, a 500-kilovolt generator, will be used in the study of reactions between ionized gas molecules by the Division of Chemistry. In this capacity it greatly expedites studies formerly carried out by means of the radiation from radium.

Five-Megavolt Generator. In preparation for testing this machine under high pressure, all fittings required for the introduction of control and power wiring, high-voltage connections for the belt-charging corona device, and water for the cooling coils have been installed in the tank base. In addition, the laboratory cranes have been modified to permit the pressure tank to be placed over the stack.

The generating voltmeter, which is used to measure the terminal voltage of the generator, was rebuilt to improve the accessibility of components and wiring. It was calibrated at 50 kv, by the use of a galvanometer in a measuring circuit whose resistance was made equal to that of the measuring instrument that will be used in normal operation.

Tests were then made on the generator at atmospheric pressure. Under the conditions existing during the first tests, it was possible to attain higher positive than negative voltages. A positive voltage of 780 kv was read, while a negative voltage of only 440 kv was obtained. The currents read under short circuit were 240 micro-amperes, with both polarities.

During the voltage tests it was found that some of the high-voltage surges originating in the machine caused a breakdown in the 550-volt wiring to the drive motors. Accordingly, the thyrite protectors in the motor leads have been moved from their former position in the tank base and placed directly on the motor frame.

At the request of the NRC Nuclear Physics Division, the high-voltage power supply is being completely re-designed. This work will include the complete mechanical re-design of the reversing switch and of the supporting structure of the components of the power supply.

The design of the piping and control system for the hydraulic cylinders, used to operate the clamping rings, has been completed.

Five-Hundred-Kilovolt Generator. One of the requirements of this machine is mobility. For this reason, the whole assembly has been mounted on a truck. The 30-kv power supply is now completed and has been mounted in the lower section of the truck, while the upper section carries the pressurized generator.

The metering and control panel and the cable connections between this and the truck carrying the generator and power supply have been designed. A different type of corona potential-dividing system, capable of being adjusted externally, has been installed, but sufficient tests have not been made to determine whether it will perform properly under pressure.

Extensive tests have been made on a set of insulators which were constructed of glass and dural, bonded by Plastilock. These insulators appear to have adequate electrical strength but the tendency to mechanical cold flow is still a serious problem. A set of Textolite insulators has also been constructed for use as an alternative to the glass insulators but they have not yet been tested.

HIGH-SPEED RECORDING OSCILLOGRAPH

Summary. This instrument is being designed to record the voltage waveform of our one-million-volt surge generator. A sealed-off tube and a fluorescent screen will be used.

Progress. An attempt is being made to build a phase inverter which will be direct-coupled throughout, in order to simplify positioning of the spot. All of the circuits tried to date have suffered from instability.

A timing calibrator generating 1000 pulses per second, synchronized with a one-megacycle wave within 0.02 microseconds, was built. It will be used to trip the sweep circuit. The calibrator also generates pulses at a frequency of 100 kc. These are superimposed on the one-megacycle wave to facilitate the measurement of periods of time up to 60 microseconds. This calibrator has been used extensively in the development of the sweep circuit. A considerable amount of modification and revision has been made to the sweep circuit and the present design seems to be quite satisfactory.

Work has commenced on an intensifier circuit to maintain uniform intensity across the face of the tube when an exponential sweep is used. A preliminary circuit for fixed intensification has been built, which will be used until the design for the new circuit has been established.

A few photographs have been taken on single-triggered sweeps in order to determine the extent of defocussing across the face of the tube. These have indicated that defocussing is more severe on recurrent sweeps than on single sweeps, but even on single sweeps only about 2 1/2 inches of the tube face can be used satisfactorily with the accelerating potentials which are now employed.

In the course of the above work, a circuit was devised which was considered to be of sufficient interest to warrant a separate investigation. This was a dual-sequence kipp circuit and a brief description of its construction and operation has been put on file.

ELECTRONIC SYNCHRONOUS SPEED REGULATOR

This device will make available for laboratory use an a-c sinusoidal voltage supply of about 30 kva, with a frequency stability equal to that of our 60-cycle standard frequency service. The regulator operates in the field of the d-c motor driving our Westinghouse 30 kva sine-wave alternator.

The constants of a motor-generator set at McGill University have been obtained and the regulating system has been set up. In an attempt to increase the sensitivity of the system, the effect of various feed-back systems on the damping of oscillations is being investigated. Work at present is directed toward developing suitable filter circuits for these feed-back systems.

BREAKDOWN TESTS OF LOW-VOLTAGE DISTRIBUTION CABLE

Samples of four different types of low-voltage distribution cable have been received from the Northern Electric Company. These comprise a single-conductor, 750,000 cir mil, PILC cable; a single-conductor, rubber-covered cable, with PVC jacket; a single-conductor, rubber-covered cable, with copper tape shield over-all, and a three-conductor, 300,000 cir mil, PILC belted cable.

Surge-testing of these cables was commenced in June 1947, and by December 1947, the tests on the single-conductor cables were successfully completed. A comprehensive report has been written summarizing the development of satisfactory test procedures and the results of the tests.

No work was done on the three-conductor cable during the period January-March of this year because of modifications being made to the surge generator.

BRUSH RESEARCH

The aim of this project is to investigate the unusual behaviour and extremely rapid wear of carbon brushes at high altitudes.

A review of the literature disclosed that impregnation of brushes with certain inorganic salts, or with metallic lead, met with partial success in reducing brush wear at altitudes below 25,000 feet, but that at higher altitudes the wear may still be very rapid.

In order to simulate conditions of brush wear at high altitudes, a small low-pressure chamber will be used. The test equipment to be set up inside this chamber will include apparatus for the measurement of brush wear, brush friction and slip-ring temperature.

The slip-ring used for these tests will be mounted inside the low-pressure chamber. It will be driven by a shaft passing through a sealing gland in the side of the chamber to an electric motor.

For the measurement of brush friction, two brush holders will be mounted at the ends of a beam whose mid-point will be pivoted on the axis of rotation of the slip-ring. This beam will be restrained from rotating by a spring. The torque caused by brush friction will be indicated by a strain gauge mounted on the spring and brush friction will be calculated from the reading of the strain gauge.

CONTROL BOX FOR STANDARD-TEMPERATURE LAMPS

This box was designed to provide the necessary power controls for the standard-temperature lamps used by the Heat Section of the NRC Division of Physics. It includes the variable resistors and meters for the control and measurement of lamp current, as well as provision for adjusting the charging rate of the battery.

CSA-APPROVAL TEST WORK

During the period January to March, 1948, eleven oil burners were given initial examination and five revised models of previously rejected burners were tested. Electric component parts were checked for four companies and found to deviate from the requirements of the Canadian Electrical Code.

The above tests were covered in twenty preliminary reports, four of which contained recommendation for tentative CSA listing. Ten manufacturers were notified that revisions must be made to their equipment before further tests could be undertaken.

Eight final reports were drafted on oil-burning apparatus that had been given tentative listing previously.

II
ELECTRONICS

pH MONITOR

Summary. This instrument was developed for the Division of Applied Biology and is used for precise measurement and control of the pH of solutions in the study of biological reactions. Three such reactions can be monitored simultaneously by each unit. One three-channel unit has been installed in the laboratories of the Division of Applied Biology, where it has been in continuous use for the past six months.

Progress. During the past three months, some time was spent assisting with the operation and adjustment of the instrument used by

the Division of Applied Biology. On the whole, the operation has been found to be relatively trouble-free.

The balance of the time has been spent in making minor modifications to the second three-channel pH monitor, which is to be installed in the Prairie Regional Laboratory of the Division of Applied Biology this summer. On the basis of experience gained in the operation of the first pH monitor, several modifications were suggested in order to improve the operation of the instrument. Chief among these was the addition of an indicator unit, using a so-called "magic-eye" tube to facilitate the initial adjustment of the pH monitor.

This modification, and a number of other less important ones, have been completed on the second model. Voltage readings, pulse waveforms, response curves and other relevant technical data are being collected, as required for reports which are in preparation.

The investigation of the patent possibilities of the instrument as a whole and of its various components is continuing.

INFRA-RED DETECTOR

Summary. The purpose of this apparatus is to locate faulty joints in power transmission lines. These faults are located by observing the temperature difference between the joint and the conductor, this temperature difference being detected by means of thermal radiation focussed on a bolometer by a parabolic reflector.

Two schemes which have been considered involve the use of the bolometer either with a radiation chopper or in an alternating-current bridge.

Progress. During the past three months sensitivity tests of a platinum and a thermistor bolometer in an a-c bridge circuit have been completed and a decision has been made to use the bridge in preference to chopping the radiation mechanically. During these tests, harmonics generated in the bolometer elements were found to create a troublesome residual in the output of the bridge at balance. This residual was not sufficiently attenuated by the selectivity of the amplifier, and a General Radio wave filter had to be used for additional attenuation. However, the amplifier has been re-designed to give greater selectivity and this is expected to solve the problem. Results of the tests have indicated that the thermistor bolometer is more suitable than the platinum bolometer on the basis of greater sensitivity, less harmonic distortion and smaller physical size.

The battery-operated, audio-frequency oscillator, which was constructed for use as a voltage supply for the bolometer bridge, was found to be unsatisfactory and it is being re-designed.

Preliminary work has commenced on the final mechanical design of the unit and in this connection the Optics Section of the Division of Physics has been consulted.

AIRCRAFT ANTENNA PATTERNS USING SCALED MODELS

Summary. Radiation patterns of aircraft in flight are obtained by scaling the model, the antenna and the wavelength down to one-fifteenth or one-twentieth, and then rotating the entire model in various planes on a plastic tower, mounted on a turntable.

Progress. The two difficulties in pattern-taking on aircraft models mentioned in the last report; viz., unbalance in the model antenna and reflection from neighbouring objects, have been successfully overcome. The method of preventing the flooding of troublesome neighbouring objects by means of suitably placed screens has proven a satisfactory solution to the second problem. The height and position of the screens to shield reflecting objects below the model, without disturbing the flooding of the model, are determined directly from the theory of diffraction over a knife-edge.

Pattern-taking has been completed on two of the suppressed antennas proposed for use on the aircraft under consideration. The combined localizer and omni-directional range antenna consists of a horizontal half-wave dipole, bent into a U-shape, similar to that of the well-known "deer-horn". It is located under a plastic cap on the tip of the vertical stabilizer. Patterns obtained on the model indicate that this choice of position is as good or better than that on other aircraft which have been observed.

The VHF communication antenna consists of a pair of horizontal slots located one on either side of the tail cone. Again, the patterns obtained on the model compare favourably with the patterns for the communication antennas on other types of aircraft.

The only important remaining problem in the location of suppressed antennas on this aircraft concerns the positioning and form of the HF communication antenna. This problem is an exceedingly difficult one because of the long wavelengths involved and it may be necessary, as a temporary expedient, to use the conventional wire stretched from the nose to the stabilizer of the aircraft.

Design of full-scale antennas for installation in the prototype aircraft is now getting under way.

MEASUREMENT OF THE PULSE CHARACTERISTICS OF RECEIVING TUBES.

Summary. During the development of a small radar equipment, data on the pulse characteristics of miniature tubes was required, and, as this information was not available, a program of measurement of pulse characteristics was begun with limited personnel. The program was undertaken primarily to determine this data for the miniature series, but the scope has been widened to include most JAN receiving types.

The apparatus includes a five-microsecond pulse generator with suitable attenuators and pulse-measuring circuits.

Progress. The recorded data for 21 types of receiving tubes, used where possible with pentode, triode and diode connections, has been plotted. Shortage of drafting time has delayed the publication of these characteristics. Life tests will be run when personnel becomes available.

GUIDANCE DEVICE FOR THE BLIND

Summary. This device will provide indication of the presence, distance and direction of obstacles in the path of the operator, within a range of three to fifteen feet.

Progress. A promising system of relaying distance-indicating information to the operator has been developed. In this system a slight electrical shocking impulse is applied to any one of the five fingers of one hand, each finger corresponding to a predetermined distance.

The guidance device will be frequency-modulated. A beat note is produced between the transmitted signal and the reflection from the obstacle. The frequency of this note will be directly proportional to the distance of the obstacle from the unit. The new warning system, mentioned above, consists of five series-tuned circuits connected from the output of the stage which amplifies the beat note to the five fingers of the operator's hand. The other side of the output is connected to the palm of the hand. Each of these circuits is tuned to a frequency which corresponds to some predetermined obstacle distance. When a beat note frequency corresponding to one of these predetermined distances appears across the output terminals, a slight electrical shock is given to one of the fingers and the operator immediately knows his distance from the obstacle. If the frequency of the beat note happens to fall between that of two of the tuned circuits, the Q of these is low enough so that a slight shock is felt in both fingers, indicating that the distance lies between two of the predetermined values.

REGULATED POWER SUPPLIES FOR LABORATORY USE

It has been found from experience with pulsed circuits, such as are commonly used in radar range-measuring systems, that a low output impedance is essential in regulated power supplies. The units described here have, in addition to excellent regulation, an output impedance of less than 0.3 ohms. They are being made in two ranges. One is a 400-ma unit, operating over a range of 250-325 volts, while the other is a 125-ma unit, with a range of 650-800 volts.

The regulation with respect to line voltage and load current changes was given in NRC report ERA-149, in so far as the 300-volt unit is concerned. Data is now being collected on the 800-volt unit, but some difficulty has been encountered as a result of an output voltage drift which is comparable in amplitude to the variations in output voltage resulting from changes in line voltage and load current. The drift, which is of the order of 0.5 volts, is not in itself serious, but makes it impossible to get consistent readings. Its cause is being investigated.

Several units of each type have been ordered from the shops.

Six 300-volt units have been completed and are at present in use in the Sussex Street Laboratory.

Wide-Range Regulated Power Supplies

A wide-range regulated power supply, having an output variable from 300 to 3500 volts at 250 ma, has been designed and tested.

Due to the pressure of other work the laboratory model of this unit has not been built. Work will be resumed when personnel is available.

Miniaturized Regulated Power Supplies

As an example of miniaturizing techniques, a voltage-regulated power supply, using miniature tubes throughout, has been designed. The outside dimensions are only 9 by 9 by 7 1/2 inches. It provides 100 ma at 250 to 300 volts, -150 volts, and 4 amperes at 6.3 volts. The electronic design is similar to that of the larger regulated supplies previously mentioned, and comparable regulation has been obtained. Six of these supplies are being constructed for use in the laboratory. All manufactured parts are now available and, with the exception of the output terminal assembly, all parts to be fabricated by the shops have been completed. One unit has been wired and is awaiting the terminal assembly.

MASS SPECTROMETER

Summary. At the request of the Fundamental Chemistry Branch of the Division of Chemistry for assistance in building a 90-degree mass spectrometer, the Radio and Electrical Engineering Division agreed to undertake the construction of the electronic portion of the instrument. The circuit design follows very closely that of a mass spectrometer employed at McMaster University, but the mechanical design is being converted from the conventional "pan"-chassis construction to relay-rack construction, which, it is expected, will greatly facilitate servicing.

Progress. The construction of all individual units of the mass spectrometer to be built by this division is rapidly approaching completion. Preliminary assembly and layout of unit inter-connecting cables has started. The equipment as a whole may be subdivided as follows:

(1) High-voltage supply, regulator and potential-divider system. This unit supplies 2000 volts d-c at 20 ma. It has been completed, except for painting and engraving the control panel.

(2) Magnet-current supply, regulator and control panel. This unit provides a regulated magnet current in the range 11 to 150 ma. It has been completed, except for

painting and engraving the control panel.

(3) D-C amplifier and associated power supply. This unit amplifies the ion current to actuate a recorder on the galvanometer. It has been completed and tested.

(4) Filament emission control. This unit controls the electron bombardment of the sample in the spectrometer tube.

(5) An ionization gauge is being incorporated in order to safeguard the filament of the mass spectrometer tube by indication on a meter of excess gas in the body of the tube.

(6) A-C distribution panel and a-c voltage regulator.

Of a total of thirteen chassis, seven have been completely wired, three are partially finished, and three remain to be wired. The main rack wiring is being started.

III
RADAR

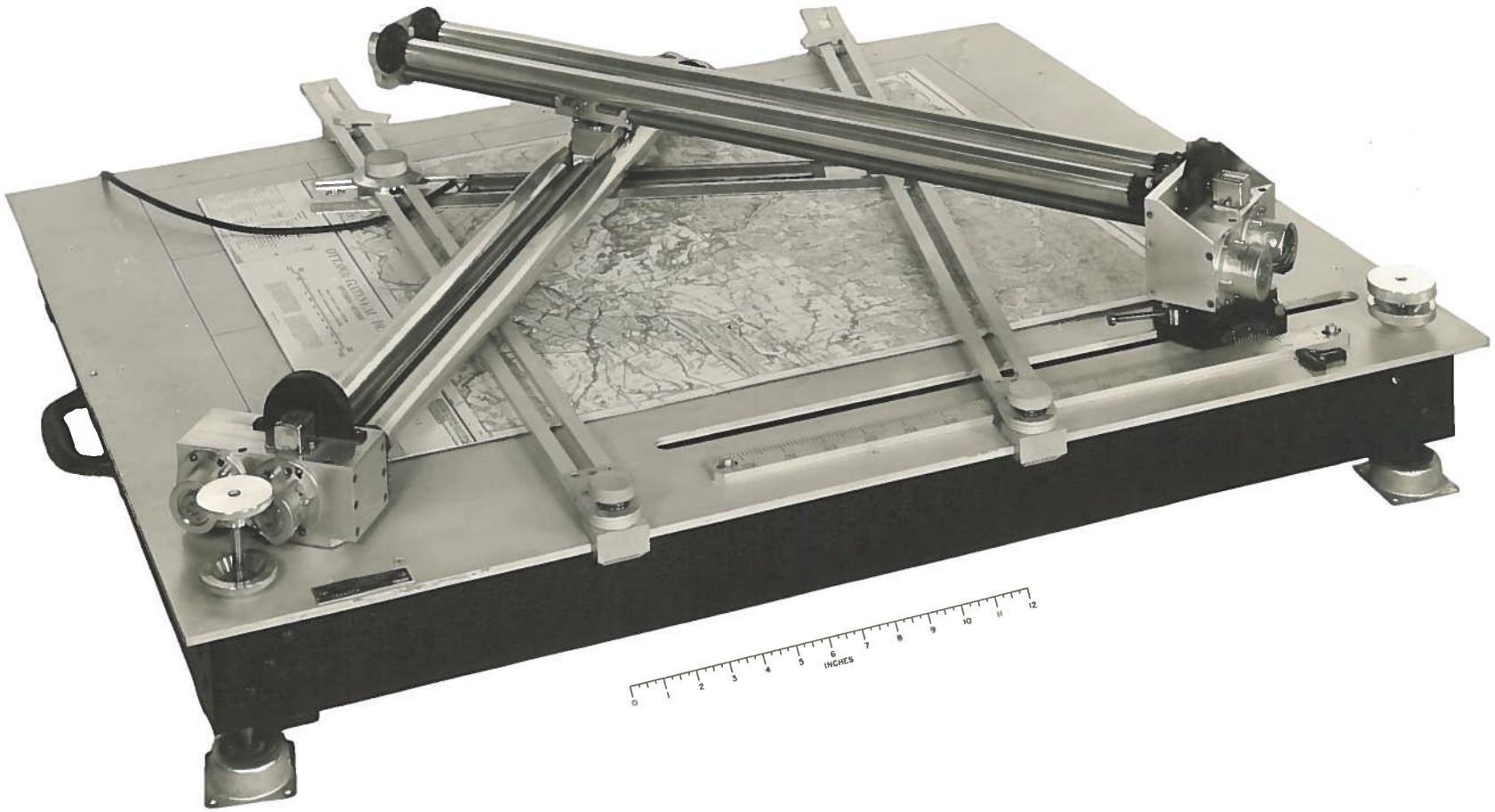
SHORAN AIDS TO AERIAL SURVEY

Shoran may be employed to measure the distance between two fixed points on the ground with an accuracy sufficient for geodetic purposes or it may be used to determine the position of an aircraft at intervals along a flight line when taking vertical photographs.

The Shoran system consists of a receiver and transmitter installed in the aircraft, together with responder beacons at each of two fixed points on the ground. The airborne transmitter emits signals on two slightly different frequencies, which are picked up at the fixed ground points by receivers tuned to one of the two frequencies emitted from the aircraft. The two ground stations retransmit these signals to the aircraft on a third frequency. The airborne receiver, tuned to this third frequency, picks up the signals returned from each ground station. The distances between the aircraft and the two fixed points is determined by measuring the elapsed time for the signal to make the return journey.

During the period under review, a large truck was fitted with Shoran ground station equipment and with the necessary radio equipment for communicating with the aircraft or other ground stations. A power supply was mounted in a trailer for complete mobility and the unit was sent to the Scarboro Field Station for trials.

A straight line computer (see photo) was constructed during this quarter to facilitate flying straight, parallel lines for mapping



STRAIGHT-LINE FLIGHT COMPUTER

for

Shoran-controlled topographic survey

purposes. Essentially, the computer consists of a plotting table, two radial arms linked by a movable carriage, an electrical contact on the table carriage, and a resistor strip on which the electrical contact runs.

The radial arms are clamped on the plotting table at a distance apart corresponding to the separation between the two fixed ground points. Lead screws on each radial arm, driven by selsyns from the dials turned by the Shoran operator when determining the unknown distances, displace the movable carriage and contactor to a position on the plotting table corresponding to the approximate plan position of the aircraft. The resistor strip is clamped to the plotting table along the desired flight line. Two parallel electrical conductors run along the top edges of the resistor strip. A wheatstone bridge is formed from two fixed resistances and the two resistances between the contactor (secured to the movable carriage) and the two parallel conductors. A nul instrument, indicating when the contactor is in the center of the strip, acts as a right-left indicator for the pilot. Some difficulty was experienced in getting a suitable contactor at first and the instrument has yet to be flight-tested.

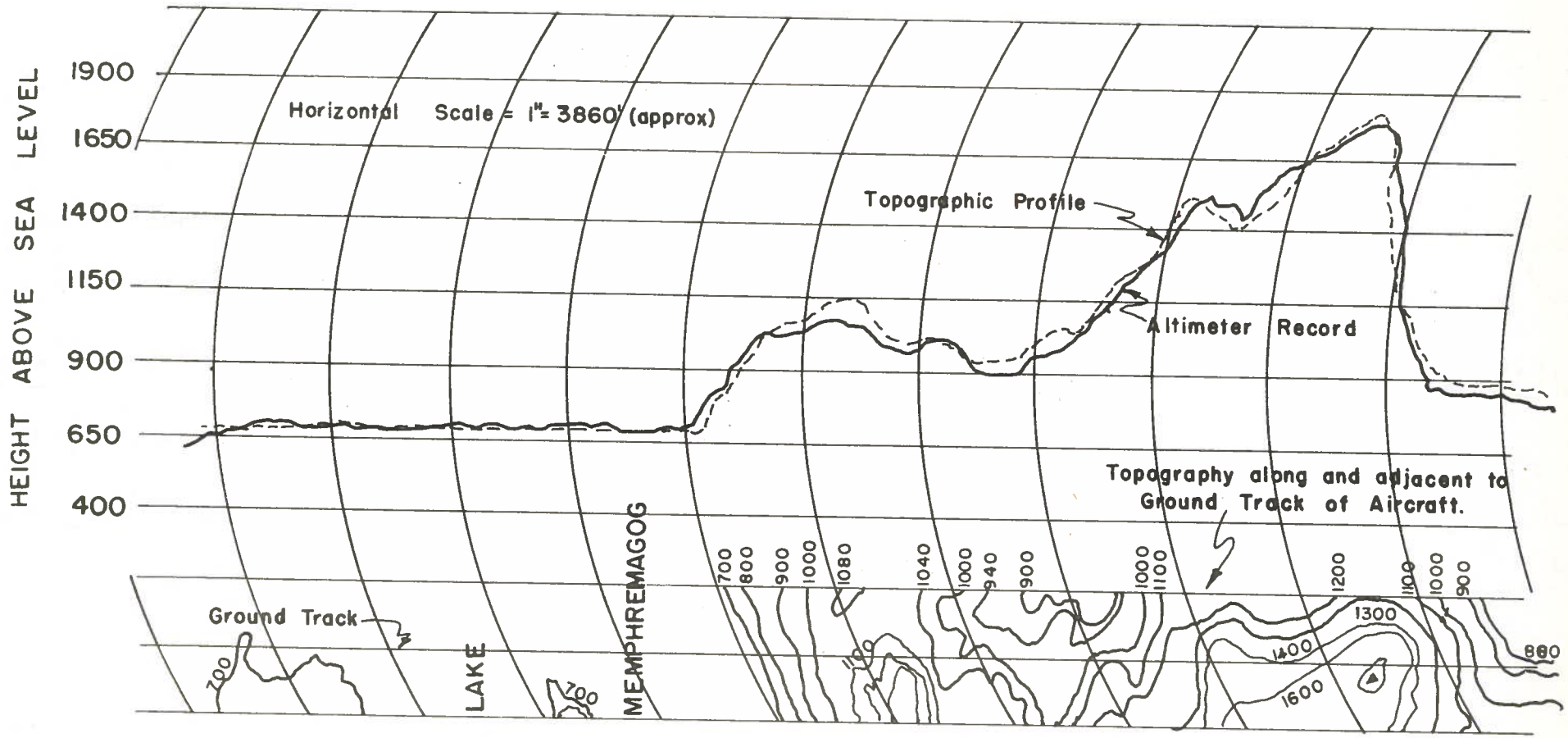
During this quarter some preliminary flights were made to obtain experience in measuring distances with the Shoran equipment. Progress has been slower than expected and the project is still handicapped by insufficient personnel.

PRECISION RADAR RECORDING ALTIMETER

Summary. This instrument was designed to expedite contouring in the preparation of topographical maps. A narrow beam of three-centimeter pulses, transmitted from an aircraft, illuminates a small area of ground. The height of the aircraft above the ground is measured in terms of time delay and the results presented as a continuous graphic record.

Progress. Flights at several altitudes were made over an isolated clump of deciduous trees situated on level ground. It was found that leafless deciduous trees affected altimeter readings to the same extent as trees in leaf. It will be necessary, therefore, to estimate the heights of such trees in order to determine the elevation of the underlying terrain.

No successful mapping flights were made because of the cold weather of the past three months. It was found that the photographic equipment did not function in the low temperatures encountered at high altitudes. Upon completion of the mapping of the 8,000 square miles area, the Anson aircraft will be loaned to the Topographic Section of the Department of Mines and Resources for the summer months so that their personnel may become familiar with the operating technique of the altimeter.



PRECISION RADAR RECORDING ALTIMETER

ALTIMETER RECORD SHOWN WITH TOPOGRAPHIC PROFILE FOR COMPARISON

A piece of test gear for servicing the altimeter is under construction. This instrument will be used for checking the range calibration of the altimeter and for general servicing of the equipment.

Some time was spent in the construction of a demonstration model of the altimeter for exhibition at the Annual Convention of the Surveyors' Institute held in Ottawa on February 4th to 5th.

A differential altimeter, which automatically applies to the graphic record, during flight, corrections for fluctuations of the aircraft from level flight, has been under development. Considerable instability was found in the discriminator circuit of this instrument, due to changes in temperature, until the 1N34 crystal diodes were replaced by tubes. The necessity for temperature-compensation was greatly reduced by a re-design of the pressure-actuated capacitor. Further work is in progress to reduce the small drift remaining in the instrument.

RADAR DISTANCE INDICATOR

Summary. The pilot of an aircraft is provided with the slant distance of his aircraft from one or more pre-selected ground points. The information is presented on a meter in the cockpit, the scale of which is graduated from 0 - 100 miles.

Status. The operational period of the Montreal-Windsor beacon chain was extended for one month in order to obtain additional data, and operation was terminated on January 31st. The shut-down terminated a seven-month period of operation commenced in June, 1947. Operation of the Ottawa and Montreal beacons was instituted in April and September, 1946, respectively. During these periods two TCA aircraft flew the RDI equipment over the beacon chain route. A technical report is being prepared on operational data obtained with this system.

The status of the RCAF application of RDI has not yet been clarified.

Maintenance of the RDI installation in the RCAF aircraft used for icing experiments was discontinued owing to the shut-down of ground beacon facilities.

No further work was done on the portable test gear because the requirement for the apparatus no longer exists.

During the past few months the circuits associated with the ADF antenna have been tested experimentally with signals simulating responses from a beacon. The circuits were found to function satisfactorily under these conditions.

Pattern measurements show that the ADF antenna provides a good representation of the ideal cardioid pattern required. However, matching difficulties have not been completely solved.

PRECISION RANGING GONIOMETER

Summary. A small goniometer, accurate to within ±0.3°, was required for range-measuring applications. Several designs were tried, each being an attempt at further improvement, by elimination of some of the sources of error. The most promising unit so far constructed consists of a three-section cylindrical search coil wound on a polyiron core, and three-section cylindrical field coils wound on a bakelite form around the search coil. This unit, the "Type IA", is approximately 1 1/2 inches in diameter by 2 inches long and has an error of ±0.2°. A "Type IB" unit was designed on the same principle as the "Type IA", but incorporated several improvements in the construction, and was made slightly smaller in size.

Two other units have been built and tested, one with rectangular two-section field coils, and one with clover-leaf-type field and search coils, but neither was very successful.

Progress. The construction of the Type IB goniometer was completed and the unit tested. This goniometer incorporated a cylindrical housing which proved very successful. The first tests on the unit showed an error of ±0.3°. This was largely fourth harmonic coupling error whose magnitude the harmonic analysis showed to be ±0.22°. The other errors were small, especially the second harmonic error, which was approximately ±0.03°, showing almost perfect field coil symmetry.

A cylindrical housing was also built for use with the Type IA goniometer. This made necessary the rewinding of the field coils on this unit. A re-check of the completed goniometer revealed an error of ±0.25°, the increase being mainly due to the non-symmetry of the new field coil windings.

Up to this point, the tests had been conducted on the goniometers alone, using the resistance-divider method. It was now necessary, for the final test, to check the goniometers with the necessary added resistances and capacitances which give a constant-amplitude, continuously phase-shifted, output voltage from the goniometer.

To this end, the construction of a phase-shift test unit was started. This unit was copied from one used at Research Enterprises Limited, with several minor modifications introduced to provide greater versatility and, it was thought, improved sensitivity. Check points on the accuracy of the goniometer are provided every 18°.

Briefly the test apparatus operates as follows. The twentieth harmonics of the input and output voltages of the goniometer are amplified and mixed. This combined output voltage will go through 20 maxima and 20 minima as the phase of the output voltage is changed through 360°, thus giving a set of calibration points for the goniometer. The chassis and wiring of this unit have been completed but the testing of it has just started.

Several miniature capacitive goniometers have been obtained through the War Assets Corporation. Two of these have been adapted for mounting on the gear box for testing. For one of these units, a cardioid-shaped rotor plate (instead of the present circular one) has been constructed. It is hoped to improve the accuracy somewhat with this rotor plate. Both of these goniometers are now ready for testing.

Because of the large attenuation of the capacitive goniometers, (50 or 100 to 1) a new, three-stage output amplifier, having a high-impedance input stage, was built. This unit is now operating satisfactorily.

MERCHANT MARINE RADAR - (MMR-B)

Summary. The aim of this project is to develop a simplified, low-cost marine radar, intended particularly for the use of vessels in such services as inland and coastal shipping, fishing fleet service, etc. The emphasis in design has been placed on a high-definition display, very short minimum-detection range, and reduction of the cost of construction by dispensing with such secondary features as azimuth-stabilized display, multiple displays, and by paying careful attention to such structural details as weight, size, power consumption and ease of fitting.

Progress. An experimental rack has been constructed which measures 14 inches wide by 19 inches deep by 27 inches high approximately, and provision has been made for the mounting of the display unit on the top, so that the whole can be operated as a console unit. The display unit, which measures 12 by 12 by 18 inches deep, approximately, can be removed from the top of the rack and operated remotely up to distances of approximately 100 feet. When mounted on the top of the rack, the display unit can be tilted up or down to accommodate variations in the height of operators.

By means of a simple slide runner system, the units can be slid out of the rack and operated in the "out" position with the power turned on. By releasing the slide runner system, the units can be completely withdrawn for replacement or repair.

The display unit uses a 7-inch cathode-ray tube and a continuously variable range control so that any coverage from 1.5 to 20 miles can be obtained. The operator can select either 1000-yard or 4000-yard range rings by means of a rotary switch, which also has an "off" position.

A great deal of time was spent on the development of a circuit to provide automatic sweep centering, and a compromise circuit was finally devised, using pre-set controls. Some further work is being carried out to improve and simplify the automatic centering feature.

The design of the receiver and automatic-frequency-control circuits has been completed. A special type of gain control is used to maintain essentially 8-mc bandwidth at low gain settings.

The design of the r-f system has been completed. This is an entirely pre-tuned system, the only adjustments being those of the T-R cell and local oscillator and two screw adjustments for setting the automatic frequency control and receiver-crystal currents. Some difficulty was encountered in eliminating interaction over the whole frequency band between the two crystal current adjusting screws. This has been practically eliminated by the addition of two fixed matching screws of proper dimensions.

The discrimination trials carried out last fall on the M.V. "Radel", showed that two-degree bearing discrimination could be obtained with an antenna beamwidth of approximately three degrees, by proper adjustment of the gain control. However, it was felt that a beamwidth of approximately two degrees (half-voltage) was desirable, as the range discrimination was considerably better than the bearing discrimination, being of the order of 6000 yards, or better, for two targets 100 yards apart. Consequently, a new antenna reflector design was tried, using a 10-inch-wide parabolic slice, with a focal length of 10 inches instead of 12 inches, and an aperture of 48 inches. It was found that this still gave too wide a beam (approximately 2.5°) when fed in such a manner as to give negligible side lobes. It has, therefore, been decided to use a larger aperture (54 inches) and a focal length of 12 inches, so that the increased aperture is obtained with as little extra metal as possible. It is felt that this is about the largest antenna which can be conveniently fitted on smaller vessels. The vertical dimension of this antenna will be made about 1 1/2 inches greater than that of the previous antennas in order to widen the vertical pattern to at least 15° (at half-voltage), which should be sufficient to allow for the roll of the ship.

RADAR AID AT HARBOUR ENTRANCES

Summary. The aim of this project is to determine the usefulness of shore-based radar equipment as an aid to navigation at harbour entrances. The work is carried on jointly by the Department of Transport and the National Research Council.

Present tests are being made at Camperdown Wireless Station, at the entrance to Halifax Harbour. The equipment in use is a modified Canadian Type 268 Radar, which has been in operation experimentally since December, 1946.

Progress. No additional equipment has been installed at the Camperdown site during the period January-March. Work at the site has consisted of routine test operation, and the experimental establishment of operating procedures.

The severe winter weather in the Halifax area during this period resulted in two failures in operation. Condensation in the waveguide, at the point at which the waveguide passed through the wall of the building, resulted in the formation of ice in the waveguide. This condition was remedied by the sealing off of the waveguide with polystyrene film gaskets, and no further trouble was experienced. A second operational failure was caused by failure of the 10-foot antenna motor and gear train to start in zero weather. This was remedied by placing a small heater in the motor and gearbox housing.

A test was undertaken with the RCN ship, HMCS "New Liskeard", in which the ship was directed from the site over as wide an area as possible. It was found that for a ship of this type (Algerine Escort) radar visibility, and consequently control, can be used to a range of 45,000 yards, over an angle of 180 degrees, from zero degrees to 180 degrees. Further tests are required to ascertain the visibility within the angle 180 degrees to 270 degrees, as shadows from natural features exist in this area, and their precise definition is not known.

Tests were also made to determine the bearing accuracy by comparison with visual observations made with a transit. Agreement was within ±1° over the angle of visibility.

Comparison of bearings on the two displays at present in use were also made and agreement was within ±1°.

During March, regular communication with the Halifax pilot boat was established as part of the normal routine operation of the wireless station. No data is available yet on the role which radar may play in this set-up.

During January, February and March, the radar equipment at Camperdown was in operation 700 hours, making a total of 2100 hours since installation.

The truck, which will be used to facilitate the choice of suitable sites for other harbour radar aid installations is now being fitted with radar gear.

X/S TRIALS

Summary. The object of this project is to make absolute measurement of rain and snow clutter signals on both X-band and S-band, and to correlate this data with measurements of precipitation rate, drop size and drop distribution, taken simultaneously. These measurements are being made with particular reference to the use of radar in marine navigation.

Progress. All the equipment necessary to make snow clutter measurements on both X-band and S-band has been in operation since last November, but no storms occurred in the Scarboro area of sufficient intensity to produce useable results. Snowfall was generally very light and accompanied by high winds, so no appreciable clutter signal was observed.

It was found that the recorder on the X-band field strength receiver covered too great a range of signal level, and that normal changes in attenuation due to storms could not be read with sufficient accuracy. Therefore, a new recording receiver has been designed which will give a ±5 db range about a particular level, as set by a threshold control. An automatic frequency control system has been added to improve the accuracy of the instrument.

A photoelectric densitometer has been constructed to measure and record received light variations due to changes in storm intensity. The light source is a spotlight, 8 inches in diamter, operated from a regulated voltage supply and is located about 200 feet from the photocell. The light source is modulated at 90 c.p.s. by a mechanical shutter. Collimation of the light at the photocell is secured by means of a simple optical system. The light which strikes the photocell is thus restricted to that emitted from the modulated light source.

This device has been found to be very sensitive to variations in precipitation rate, and although no steps have yet been taken to attempt to calibrate it in terms of precipitation rate, the relative record obtained will be valuable when correlated with the data obtained from the rain gauges. Very little experience has been obtained in the use of this instrument to date, as there have been no storms of sufficient intensity to produce useable data.

MOTOR VESSEL "RADEL"

During the winter the vessel was dry-docked in the Rideau Canal. No work was done on her until spring when re-circulation connections were made to the cooling system on the main engine. These connections were not used on the original cooling system and there had been difficulty in bringing the engine up to a suitable running temperature, due to the fact that control of the cooling water was only possible by throttling the seacock valve. Painting of the hull and re-caulking were delayed until the ice and snow melted from the Canal lock.

A sample radar buoy, for use in buoy-pattern trials, was constructed. This buoy was designed with special attention to ease of launching and removing from the water. The over-all weight of float, reflector and counterweight is approximately 75 pounds. It is fitted with "disconnect" pins so that it may be dismantled for easier storage on deck. Four additional buoys will be made so that pattern trials may be conducted at the opening of navigation.

Magnetic Compass Torque Amplifier

This equipment will provide an economical means of stabilizing PPI displays on magnetic north and will also provide automatic steering from magnetic compass control. The present experimental equipment uses a repeating-type of compass in which the compass card carries a rotor coil excited by 500-cycle power. A three-phase stator, placed around this rotor carries bearing information to a Selsyn-type of receiver. One phase of the field winding of this receiver is used to supply error voltage to an amplifier and torque unit. Preliminary trials in the laboratory indicate that an accuracy of ±1° of bearing may be expected of the control mechanism. This equipment will be installed in the "Radel" at an early date for operational trials.

IV
RADIOPHYSICS

PANORAMIC IONOSPHERIC RECORDER

Summary. A pulsed, vertical-incidence, fully-automatic ionospheric recording equipment is being designed and constructed at the request of the Canadian Radio Wave Propagation Committee. It is to be used for the study of quick-change phenomena in the ionosphere.

Progress. The system finally devised for accurate timing will employ two crystal-controlled frequencies, one of 1 mc, which will control frequency markers and the high-frequency fixed oscillator; the other of 150 kc, which will control range markers, fundamental recurrence frequencies and frequency sweep. It was decided to add the 150-kc crystal control because it was found impractical to derive a control frequency of 60 cycles from 1 mc, since the former is not a simple sub-multiple of the latter.

Provision will also be made, alternatively, for the use of the 60-cycle power-supply frequency as a source of synchronization. This source of synchronization may occasionally be required in order to reduce the effect of power-line interference on the ionospheric records. The 60-cycle synchronizing system, exclusive of the 150 kc-to-60 cycle reduction unit, has been in existence for some time.

The second control unit, incorporating the 31-50 mc oscillator, has been mounted and wired into the rack and is now in operation.

Work has been resumed on the A-scope. This instrument will serve the dual purposes of auxiliary display and monitor scope.

The modulator, display unit and low- and high-voltage supplies have been mounted in the rack and wired into the system. The general rack wiring of power and control circuits has been completed and the main control panel has been mounted and wired into the rack system. This panel will provide manual control at present.

SOLAR NOISE OBSERVATIONS

Continuous daily recordings of 10.7-centimeter energy arriving from the sun and from the zenith were made and it is planned to continue the solar observations for a long period.

Testing of the two new 10.7-centimeter radiometers to be installed at the Goth Hill site for sky noise observations continues. Measurements of the conversion loss and noise temperature of silicon crystals have been made but measurements of the noise factors of the i-f amplifiers are not yet completed.

Electric power will be available at the new site as soon as the power transformer is delivered.

The design of the variable-frequency radiometers, covering the range 7 1/2-15 cm, is well advanced and construction is continuing.

Work on the improved model of the 200-mc radiometer, to be used for measurement of day-time solar noise and night-time sky radiations, has been discontinued, as personnel were transferred to the 10.7 cm work.

SHOOTING-STAR RADAR

Analysis of the Geminid data continues. An interesting feature of the statistical analysis of the radar data alone is the computation of the right ascension and declination of the Geminid radiant with an accuracy of ±3°. An omni-directional single dipole antenna was used and no angles were measured physically, nor was the antenna moved. The large numbers of radar meteors seen is responsible for the success of the statistical determination of the radiant - the hourly rates running as high as 1,800 echoes. The hypothesis on which the determination was based was the experimental fact that a meteor trail reflects most favourably normal to the line of sight. Conversely, working backward from the close agreement of the calculated radar radiant with the visual radiant, one deduces that practically all, if not all, the myriads of echoes on the display are actually due to meteors - a contentious point among workers using a radio frequency in the neighbourhood of our frequency, 32.5 mc.

A paper* is now in process of preparation outlining the phenomenological theory of radar echoes from meteors. In this, the existence of sub-layers, strata, or patches, in the M-region (the M-region is defined as the region in which visual meteors occur and is slightly below the E-region) is shown to account for all the effects observed on 32.5 mc. In addition, the theory is extrapolated to account for the observations of others made on both higher and lower frequencies. At frequencies above 60 mc, for example, it is shown that very few, if any, of the multilayered echoes should be seen, while at frequencies below 30 mc these compound and long-enduring echoes may be quite numerous. It is shown that the delay in appearance of a radar echo after the passage of a visual meteor is both a function of the angle between the meteor trail and the line of sight, and also of the height within the M-region at which the meteor occurs. Delays vary from zero, for meteors normal to the line of sight, to as much as thirty seconds for meteors coming head on. It is pointed out that the Doppler whistles observed at lower frequencies are more likely to be a measure of the delay phenomena than the actual meteor velocities, and consequently are interpreted as slower velocities than the true velocities.

* To be presented at the meeting of the Royal Society of Canada, this year, at Vancouver, B.C.

Equipment

Package Transmitter. Work on the package transmitter, using a pair of RCA 6C24's, was continued to the point where a useful output to the antenna of the order of 50 kw was achieved on 35.5 mc. Under typical operation into an antenna load, the peak d-c pulse power applied was 108 kw and the r-f power output was 45 kw, giving an efficiency of 41% for the oscillator.

For statistical meteor observation from a single station, where the sole requirements are the detection of the meteor and determination of the approximate range to the meteor, a long pulse length is desirable because it gives more useable echoes, without hampering range determination. For this purpose, a pulse line of 12.4 microseconds was designed and is being used. For simultaneous operation from two or more stations for the purpose of triangulating, a shorter pulse length is desirable in order to improve the range accuracy and for this purpose a 6-microsecond line was designed. (Similar lines with long and short pulse lengths were designed for the main transmitter. In this case, the long pulse was 23 microseconds and the short pulse 4.5 microseconds, but the condensers for the short pulse line have not yet been received.)

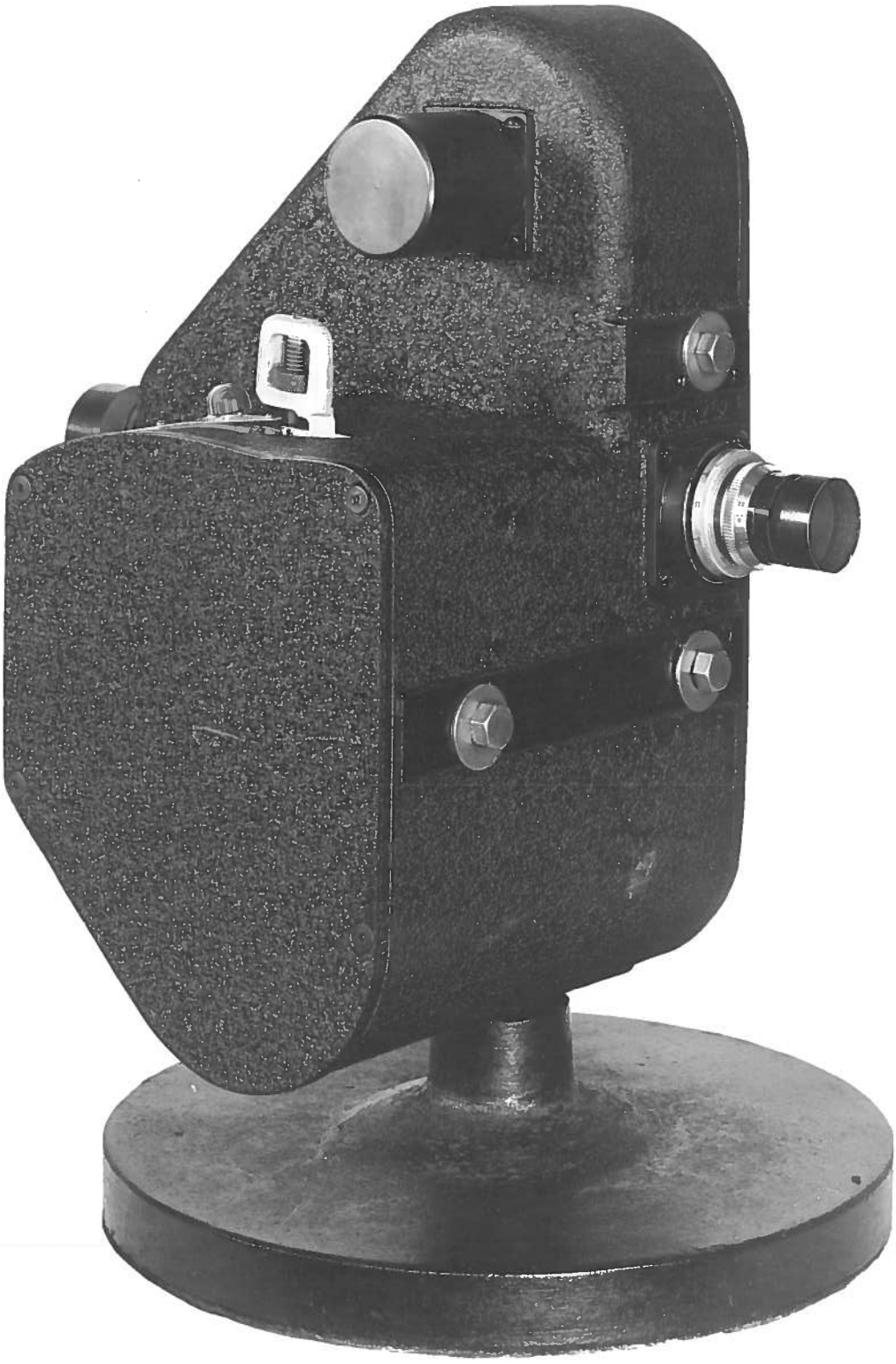
An additional mode of SSR system operation has been proposed. This consists of simultaneous dual-frequency operation from one station, for the purpose of investigating the variation in meteor echoes with frequency. Preliminary study has been made of the production of r-f pulses on two frequencies; e.g. 32.5 mc and 72 mc, from the same modulator pulse, but no actual equipment has been built for this purpose.

In the second package display equipment, provision was made for simultaneous dual-frequency display and photographic recording, and the equipment has been built and operates successfully.

Miscellaneous lining-up and calibrating equipment has been constructed.

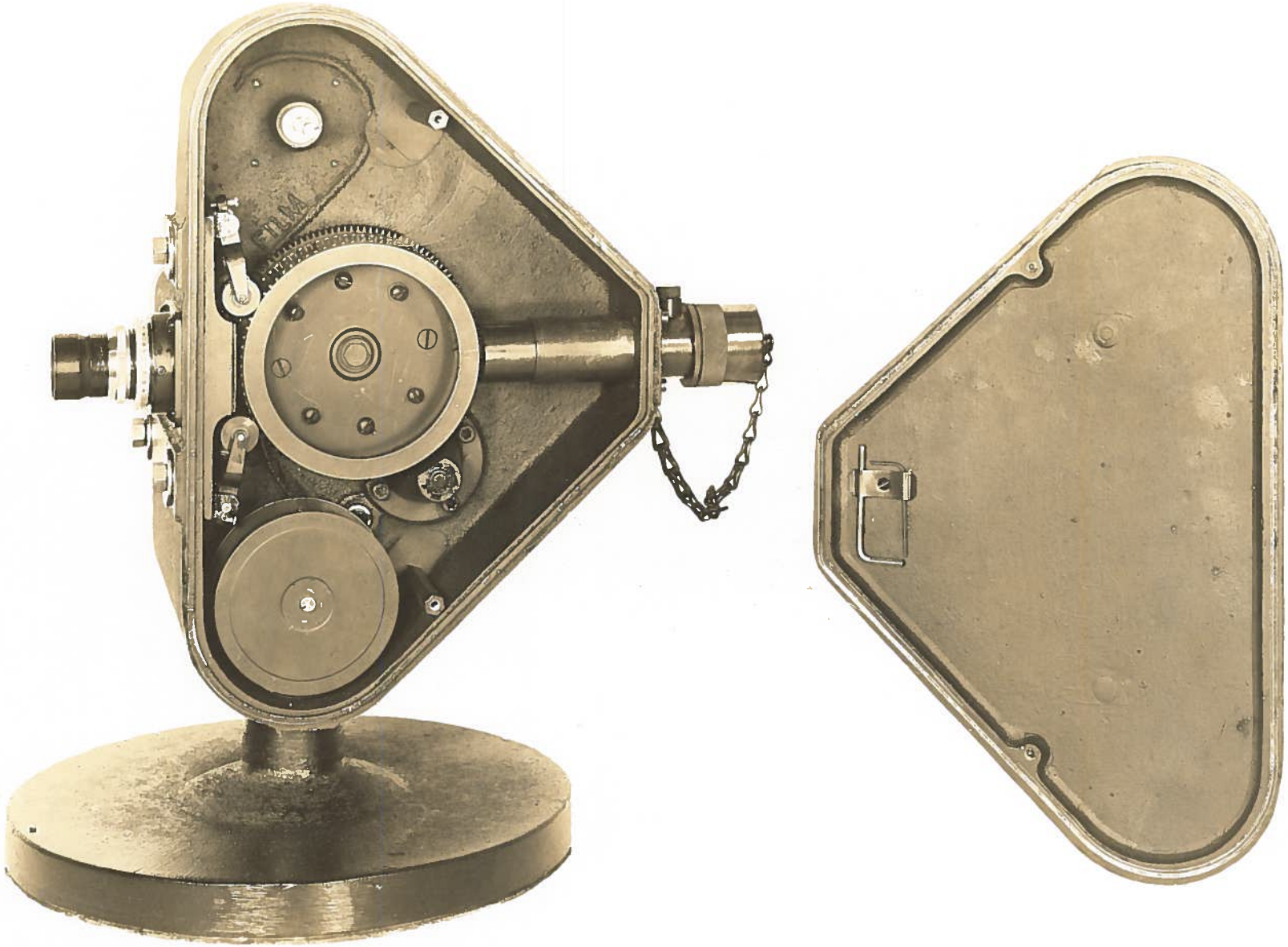
Film Projector. Some time was spent in building a film projector incorporating components made by the Society for Visual Education.

The meteor-echo data supplied by the SSR equipment is recorded on a 35 mm photographic film in a special continuous-motion camera that smears the intensity-modulated range trace of a cathode-ray oscilloscope broadside along the slowly moving film. The normal film speed is one inch per minute; thus, for a twenty-hour run, the record is a strip of film 100 feet long. To examine this length of film inch by inch for individual echoes and for statistical count, it was desirable to have a projector of special characteristics. Accordingly, in the new projector the motion of the film was made continuously adjustable and reversible. Standard Eastman 35 mm, 100-foot reels are used. A technical report is being prepared on this projector.



SIX-SPEED SLOW-SPEED CAMERA FOR SHOOTING-STAR RADAR

view from gear-shift side



SIX-SPEED SLOW-SPEED CAMERA FOR SHOOTING-STAR RADAR

interior view--film side

Six-Speed Slow-Speed Camera (See photos). This camera was built for the purpose of taking continuous photographic records of meteor echoes as displayed on the 5-inch cathode-ray tube of the SSR equipment. The design of the camera provides a range of speeds sufficient to allow for the detailed study of individual meteor records at the higher speeds, as well as for the taking of a complete 24-hour record with one 100-foot roll of film at the two lowest speeds. Six different film speeds are provided, ranging from 1/2" a minute to 4" per minute.

ELECTRON ACCELERATOR

An experimental set-up was constructed to investigate the possibility of accelerating electrons by successively passing them through a cavity resonant at ten centimeters and situated in a magnetic field. Orbits were observed immediately out to the edge of the magnet. There were eight, and the energy observed in the outside orbit was about four million volts. Attention was then directed to increasing the voltage across the cavity and the current in the orbits.

Because of the high Q of the load to which the magnetron is connected, unstable operation is always possible and it is difficult to distinguish circuit instability from high-voltage breakdown.

Recent experiments have indicated that breakdown across the gap is the more serious problem, and the cavity pole pieces have been re-shaped to decrease local fields. Some of the shapes tried have given improved stability and substantial increases in voltage.

REFLECTION COEFFICIENTS OVER SNOW AT THREE CENTIMETERS

A study of the possibility of radar camouflage of obstacles to marine navigation by loose snow has been commenced.

The assembly of towers and equipment for the determination of reflection coefficients over snow was not completed early enough to make any tests this season. Measurements must be postponed until next winter, but meanwhile experimental techniques will be perfected using bare earth as the reflecting surface.

TUBE LABORATORY

Millimeter Wavelength Generators

A general investigation into the generation of wavelengths shorter than 5 mm is being undertaken. Consideration has been given to the design of reflex oscillators at these wavelengths. Although a successful 5.5 mm reflex oscillator has been constructed by Samuel (Proc. IRE 33, 233 (1945)) it has become increasingly apparent that this is approximately the shortest wavelength at which this type of tube can be made to operate. Two considerations preclude operation with reasonable power output at shorter wavelengths, firstly the mechanical

difficulty of alignment of the extremely small electron optical system, and secondly, the limitation on power input caused by the necessarily minute apertures through which the electron beam must pass. With these considerations in mind, it was decided that the reflex oscillator would not be a suitable source for radiation of wavelength shorter than 5 mm.

The limitations on the shortest wavelength at which a cavity magnetron can be made to operate are firstly, the difficulty of mechanical alignment of anode and cathode and secondly, the low values of current at which flashing occurs with small anode-cathode separation and existing cathode designs and materials.

The 4-mm magnetron under construction is an open-ended, 18-segment, "rising-sun" type of structure. It is of package-type construction, with a co-axially heated cathode (40-mil diameter). It is hoped that a thoria cathode will be used; the use of thoria is commented on below. With this design, and with the use of thoria as a cathode material, it should be possible to overcome the two limitations mentioned above.

A dummy tube has been assembled to test cathode mounting and general brazing techniques. The hob for the production of the copper anode structure is under construction. A special steel, with great strength at elevated temperatures, is being used (INCONEL X). The vane thickness of the anode hob will be 5 mils. The anode will be hot-hobbed at about 600°C.

Some experiments have been done in pressure-casting the tapered output system in silver.

Since it appears unlikely that a cavity magnetron can be constructed below 3 mm, investigations into other types of generators is proceeding. A tube in which an electrostatically-focussed orbital beam is externally coupled to a slotted cylindrical resonator has been designed. The first tube designed to operate in the K-Band was unsuccessful. A second tube has been designed in such a way as to allow easy alteration of dimensions of the focussing system. This tube is not yet completed. A theoretical analysis of the operation of such an oscillator is proceeding.

Magnetic Counter-Tube

It can be shown that in crossed electric and magnetic fields the "drift" velocity of the electrons is given by

$$\bar{V} = -\frac{C}{H^2}\bar{H} \times \bar{E}$$

for small values of E. This simplified analysis shows that the electrons will follow equipotential lines.

This phenomenon has been made use of in the design of counter-tubes in which the electron beam is "locked" onto any particular digital

plate by the following mechanism. The beam striking the plate causes a large drop in potential at that plate due to a high load resistor. This drop in plate potential causes the equipotential lines to bend round onto this particular plate and "lock" the electron beam onto it.

Two tubes have been constructed, one a scale-of-five and the other a scale-of-ten. The locking mechanism was found to work in a stable fashion. As no non-magnetic material was available for construction of the electrodes, it is probable that the magnetic field is badly distorted by the nickel electrodes used in the present tubes. This has prevented the measurement of change-over time from one digital plate to another. As soon as material is available, a tube will be constructed with non-magnetic electrodes and measurements of change-over time will be made.

Cathode Investigation

Since the primary limitation on the operation of magnetrons at very short wavelengths is cathode flashing, some investigation into the causes of flashing appears relevant.

It is known that thoria has a much better flashing performance than the normal oxide coating, but no satisfactory way of heating the thoria to its very high operating temperature (1400°C) had previously been found. Following a technique used at Columbia Radiation Laboratories, a cathode has been designed in which the active material (the thoria) is contained within a perforated molybdenum cylinder used as the cathode. The thoria (or more probably thorium) appears to migrate through the perforations onto the surface of the metal cylinder and form a monatomic layer. It is expected that this type of cathode will have excellent flashing characteristics. It will operate at a much lower temperature than a pure thoria cathode.

Flashing performance of this type of cathode will be investigated in a diode structure.

Miscellaneous

Various pieces of equipment for tube processing have been completed and a second pumping system has been installed.

Some noise sources have been constructed for the University of Toronto.

Two argon ionization-potential-measurement tubes and a cathode-ray tube for the measurement of e/m have been constructed for the University of Saskatchewan.

V
STANDARD FREQUENCY SERVICES

Routine maintenance and operation of the Standard Frequency Services was continued.

VI
PAPERS AND PUBLICATIONS

"Fault Location in Electric Power Systems",
W.G. Hoyle, Ottawa Section, AIEE, January 6th, 1948.

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"A Note on an Omni-Directional Array of Stacked V-Antennas",
T.P. Pepper, Canadian Journal of Research, January, 1948.

An omni-directional antenna array, which might find use in the frequency-modulation broadcast field, is described.

"A Simplified Broadside Dipole Array",
J.H. Bell, Canadian Journal of Research, March, 1948.

A broadside dipole array, or 'billboard', with a greatly simplified feed and matching system, is described. Radiation patterns compare favorably with those of the conventional billboard.

"Circuit Design for Gas-Discharge Regulator Tubes",
W.G. Hoyle, Tele-Tech, February, 1948.

A formula is derived which insures that the tubes are always operated within their ratings, and carry no greater tube current than is necessary. The general effect of the formula is to limit the minimum permissible supply voltage. For the common regulator tube (types VR75, VR105 and VR150) simple versions of the formula are obtained and are presented in the form of nomograms which should cover the majority of practical cases.

"Combined Radar, Photographic and Visual Observations of the Perseid Meteor Shower of 1947",
P.M. Millman*, D.W.R. McKinley, M.S. Burland*, Nature, Vol. 161, no. 4086.

.....

* Dominion Observatory Staff.

The following publication has been issued by the Radio and Electrical Engineering Division:

"Some Problems in the High Fidelity Reproduction of Music", J.E. Breeze (ERB-177).

The characteristics of the various sounds to be reproduced are considered. Their range of loudness and frequency ranges are mentioned. These characteristics are then considered in relation to the acoustic properties of the average living room and the characteristics of the ear. This is followed by a discussion of the various types of loudspeakers and baffles which may be used, with emphasis on their relative advantages and disadvantages. Distortion is the next point discussed and five types of distortion are identified and the relative amounts of the various types contributed by the loudspeaker and amplifier are discussed. Finally, the amplifier itself is considered with reference to its frequency response, power output and freedom from distortion.

VII
ESTABLISHMENT OF THE RADIO AND ELECTRICAL ENGINEERING DIVISION

Acting on a decision taken by the National Research Council at its December, 1947, meeting, President C.J. Mackenzie authorized establishment of the Radio and Electrical Engineering Division, effective February 1st, 1948. Mr. B.G. Ballard, O.B.E., previously in charge of the Electrical Engineering Laboratory since joining the staff in 1930, has been appointed director of the new division.

The work of the new division was carried on under the Division of Physics and Electrical Engineering until the year 1942. By that time, the expansion of research and development in the fields of electronics and radar had been so great that a separate branch, known as the "Radio Branch", was established. The activities of this branch, and of the electrical engineering staff continued at a high level until the end of hostilities. Since that time the program has comprised such work as the application of radar techniques to aerial and marine navigation and to the detection of faults in power transmission lines, the study of extra-terrestrial phenomena, and various applications of electronics.

The new division has a staff list of about 230, including about 50 scientists and engineers. The division maintains the Metcalfe Road Field Station, situated about four miles outside of Ottawa, the Scarboro Field Station on Lake Ontario, as well as laboratories in the Sussex Street building in Ottawa.

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