Progress report for January - March 1951

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NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

PROGRESS REPORT

FOR

JANUARY - MARCH 1951

OTTAWA

APRIL 1951

National Research Council of Canada

Radio and Electrical Engineering Division

PROGRESS REPORT

JANUARY-MARCH, 1951

Comments or inquiries regarding subjects appearing in this report should be addressed to the Radio and Electrical Engineering Document Office, National Research Council, Ottawa, Canada.

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I

RADIOPHYSICS

SECOND-ORDER BEAMS OF SLOTTED WAVE-GUIDE ARRAYS AND THEIR SUPPRESSION

In the design of slotted wave-guide arrays for high-gain antennas it is customary to use the theory of linear arrays to predict radiation patterns. For certain wave-guide arrays this is not quite justified.

Consider, for instance, an array consisting of longitudinal slots in the broad face of a rectangular wave guide. The slots will radiate only if they are displaced from the center line of the guide face. The amount of radiation depends on the distance from the center line. A broadside array can be obtained by spacing the slots about a guide wavelength apart on one side of the center line because they will then be excited approximately in phase. Such an array would have large second-order diffraction beams which would make it unsuitable for most purposes. The second-order beams come about because the slot spacing is greater than the free-space wavelength. It is generally argued that this defect can be eliminated and, at the same time, the broadside feature of the array retained, by spacing the slots approximately half a guide wavelength apart and reversing the phase of alternate slots by staggering them about the center line.

The above reasoning is based on the theory of linear arrays and tacitly assumes that the small displacement of the slot radiators from a straight line has negligible effect on the radiation pattern. It can be shown that such an assumption is, in general, not justified. The above array of longitudinal slots staggered about the center line actually has second-order beams even for slot spacings of half a wavelength. These beams, however, are not to be found in the plane containing the guide axis and the main beam, but closer to the plane of the slots. Since radiation patterns are usually taken only in the former plane, these second-order beams have until now escaped detection, as far as the writer is aware.

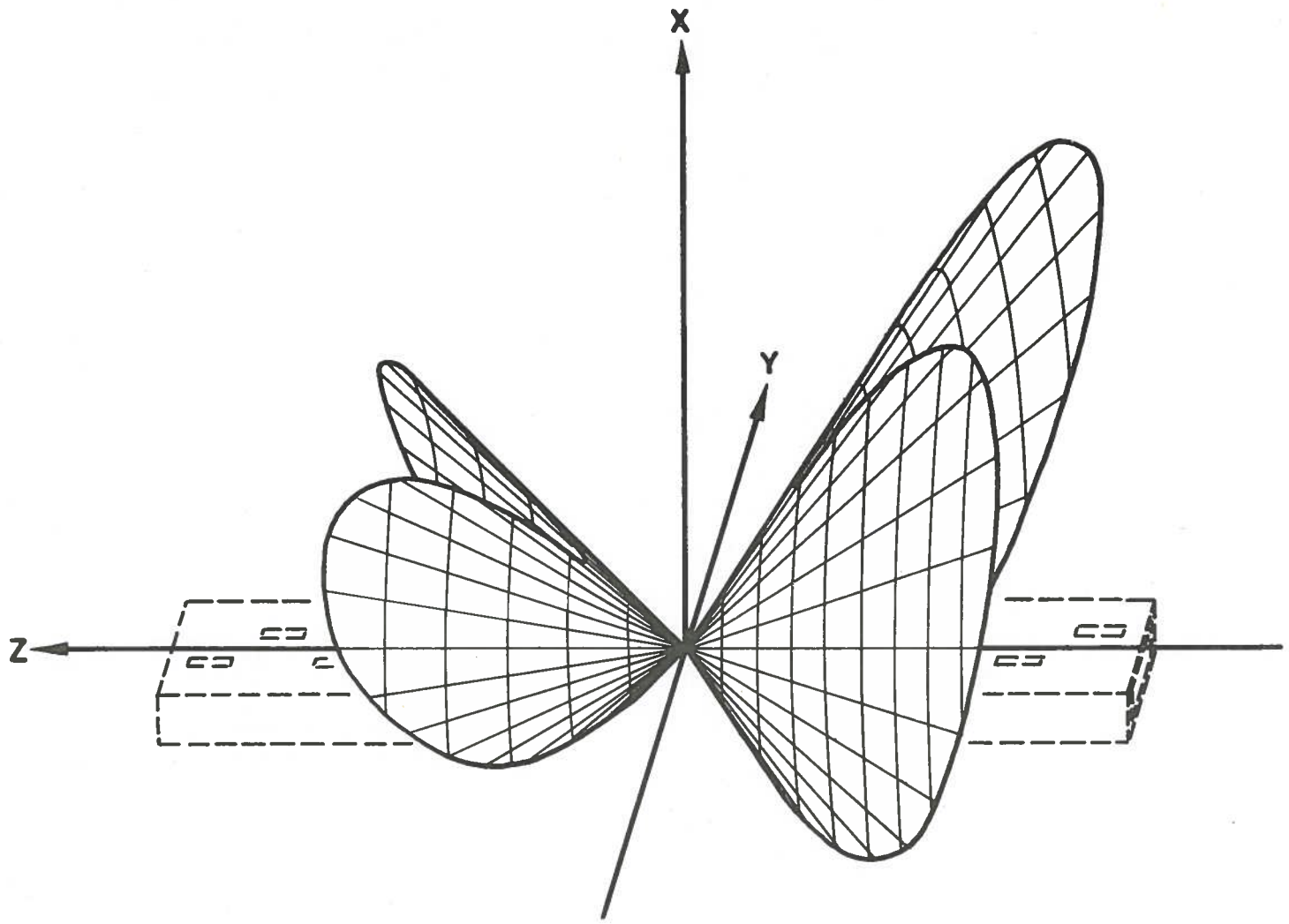
In a properly constructed array the size of second-order beams depends on the magnitude of slot offsets relative to wavelength. For practical arrays they may be ten per cent or more of the main beam in terms of field strength. They will be larger in arrays of comparatively short electrical length because of the necessity of using larger slot conductances and hence larger offsets. In some applications, such as merchant-marine radar for use in narrow waters, where all spurious radiation more than about five degrees from the main beam should be kept down to thirty or forty decibels below the main beam, a knowledge of these side lobes will be of prime importance.

The accompanying three-dimensional sketch shows the second-order beams radiated by a typical conventional wave-guide array, approximately 50 wavelengths long, employing longitudinal shunt slots. These beams are seen to lie on conical surfaces, the generators of which make angles of 45 and 123 degrees with the Z-axis. The beams have minima in the axial plane through the peak of the main beam (X-Z plane), and maxima in the two axial planes, making an angle of 50 degrees with the X-Z plane. This gives the second-order beams a "split" character. The main beam, the peak of which is approximately directed along the X-axis, has been omitted from the sketch for clarity. The maxima of the second-order beams are, respectively, six per cent and nine per cent of the main beam, measured in terms of field strength.

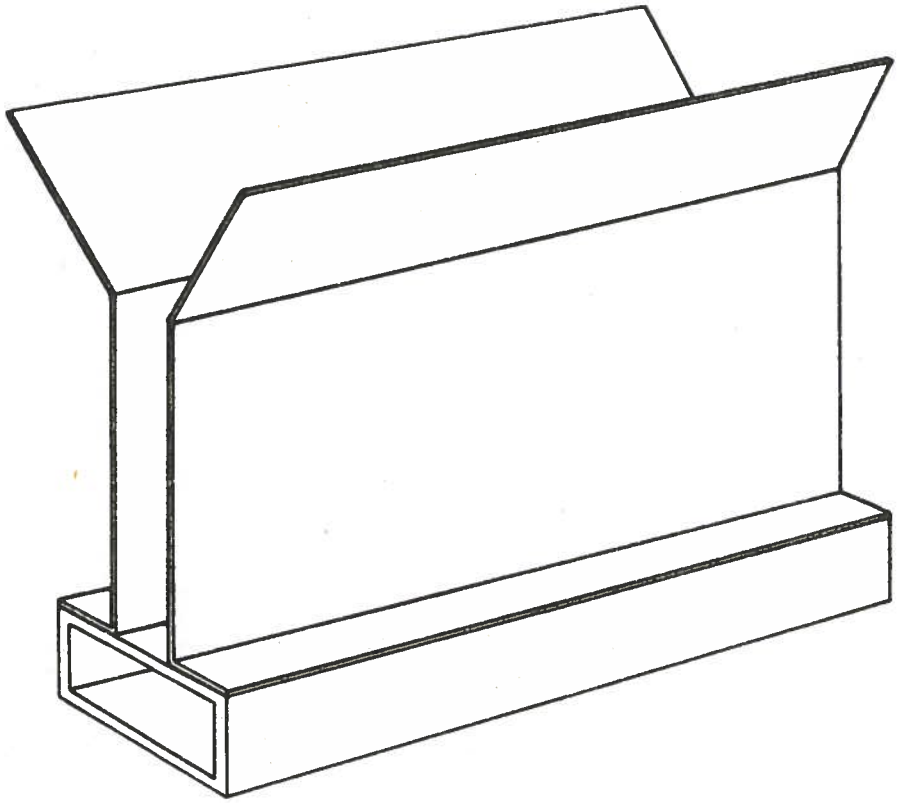
The position, shape, and magnitude of second-order beams can be calculated and good agreement is obtained with experiment. For rough estimates, the size of second-order beams as a fraction of the main beam turns out to be of the order δ/λ, where λ is the free-space wavelength and δ is a "weighted" mean slot offset. This weighted mean will be close to the offset of the slot which is most strongly excited — usually a slot near the center of the array.

Two schemes have been proposed in our laboratories to suppress such second-order beams and both have been successful. One makes use of a conventional wave-guide array fitted with a parallel-plate section and horn; the other employs an array with all slots in line (see illustrations).

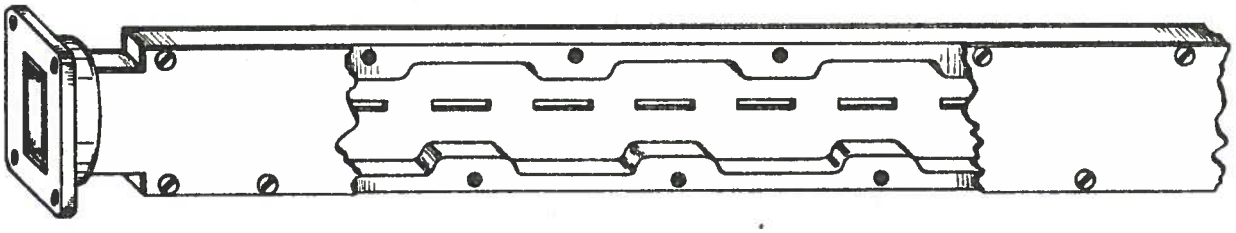
In the first scheme a parallel-plate section is constructed to suppress all but the two lowest modes. The plate spacing is less than half a free-space wavelength and the length of the region is a wavelength or more. With this modification, asymmetries in the field, produced by the slot offset and staggering, do not appear at the mouth of the horn. Thus the main cause of second-order beams, slot offset, is eliminated.



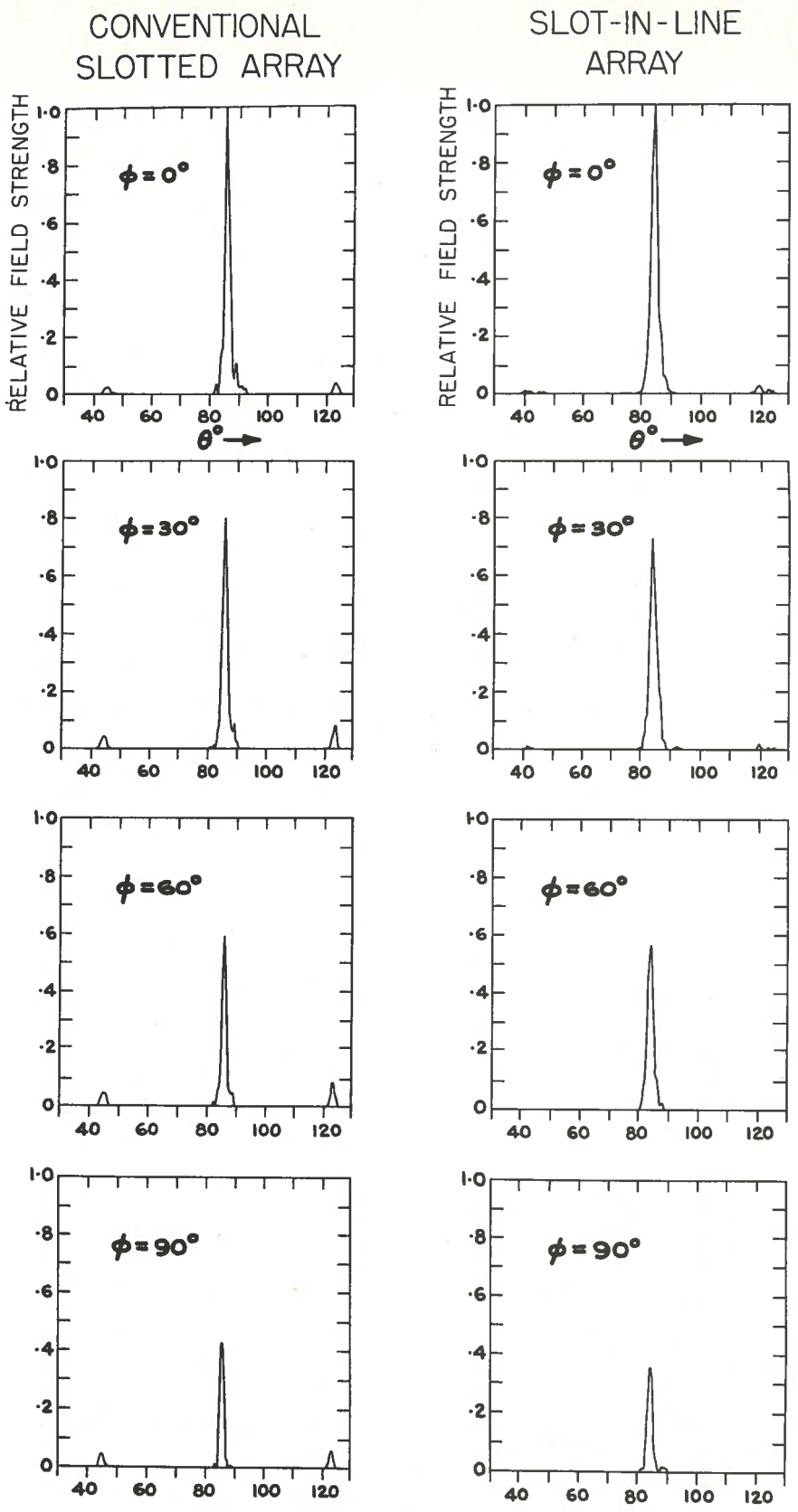
THREE-DIMENSIONAL SKETCH OF SECOND-ORDER BEAMS
RADIATED BY A CONVENTIONAL WAVE-GUIDE ARRAY



CONVENTIONAL WAVE-GUIDE ARRAY WITH PARALLEL-PLATE SECTION AND HORN
FOR THE SUPPRESSION OF SECOND-ORDER BEAMS



SLOT-IN-LINE CORRUGATED-WALL WAVE-GUIDE ARRAY
FOR THE SUPPRESSION OF SECOND-ORDER BEAMS
(BACK CUT AWAY TO SHOW SLOTS AND CORRUGATIONS)



RADIATION PATTERNS OF CONVENTIONAL AND SLOT-IN-LINE WAVE-GUIDE ARRAYS

In the second scheme, means must be provided to excite the slots, since they will not radiate when placed on the center line of a standard wave guide. This can be done by using probes or by offsetting the side walls of the guide.

In both schemes, only the main cause of second-order beams is eliminated — the effect of slot offset. There are normally some residual beams due to mechanical imperfections in the array. These beams are not split and have their maximum in the X-Z plane, the same axial plane that contains the peak of the main beam. Their size can be minimized by proper design and close mechanical tolerances. Radiation patterns of conventional and slot-in-line arrays (see illustrations) show the extent to which second-order beams can be reduced with reasonable tolerances. The patterns are all taken in planes through the axis of the arrays with various angles of tilt (ϕ) with respect to the X-Z plane. It will be seen that second-order beams are suppressed to 30 decibels below the main beam.

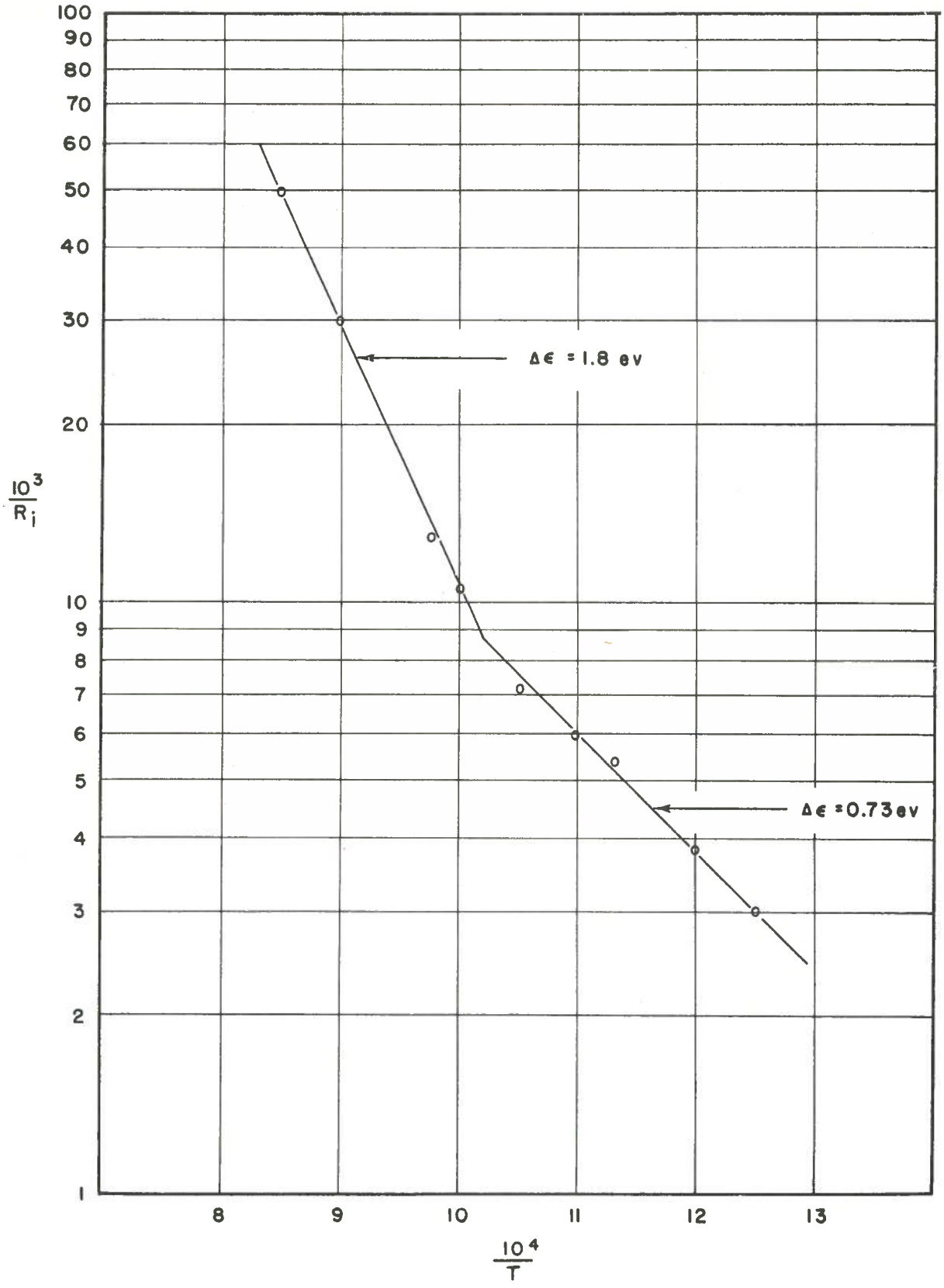
With proper design and careful construction it was possible to obtain an array of 52-inch aperture for use on merchant-marine radar with the following characteristics at a wavelength of 3.2 centimeters:

(a) half-power beam width . . .	1.5 degrees,
(b) half-voltage beam width . .	2.2 degrees,
(c) first side-lobe	approximately 30 decibels down from main beam,
(d) second-order beams	about 40 decibels down,
(e) all other spurious radiation more than five degrees from the main beam	negligible.

OXIDE CATHODE PHENOMENA

(a) Interface Measurements

A change of slope in the conductivity versus 1/T curve has been observed in measurements of the oxide-coated cathode interface. This break occurs at about 1,000°K. The activation



INTERFACE CONDUCTIVITY VERSUS RECIPROCAL TEMPERATURE
FOR AN EXPERIMENTAL DIODE

energy of the interface below 1,000°K for a typical tube may be 0.8 electron volts, and 2 electron volts above 1,000°K. This effect, as measured on an experimental diode, is shown in the accompanying figure. It is analogous to the change in activation energy observed in barium oxide coatings.

Measurements of the interface impedance of a type-6AK5 miniature tube have shown that the interface resistance may reach values as high as 100,000 ohms at a cathode temperature of 800°K. When the cathode is operated at 1050°K the interface resistance is reduced to about 500 ohms for this particular tube. The interface capacitance remained fairly constant at about 0.003 microfarad throughout the above range of temperature.

Similar measurements on a type-6AC7 tube yielded a range of interface resistance from about 1500 ohms at a cathode temperature of 800°K to 20 ohms at a cathode temperature of 1100°K, with a value of 0.4 microfarad for the interface capacitance.

(b) Work Function Measurement

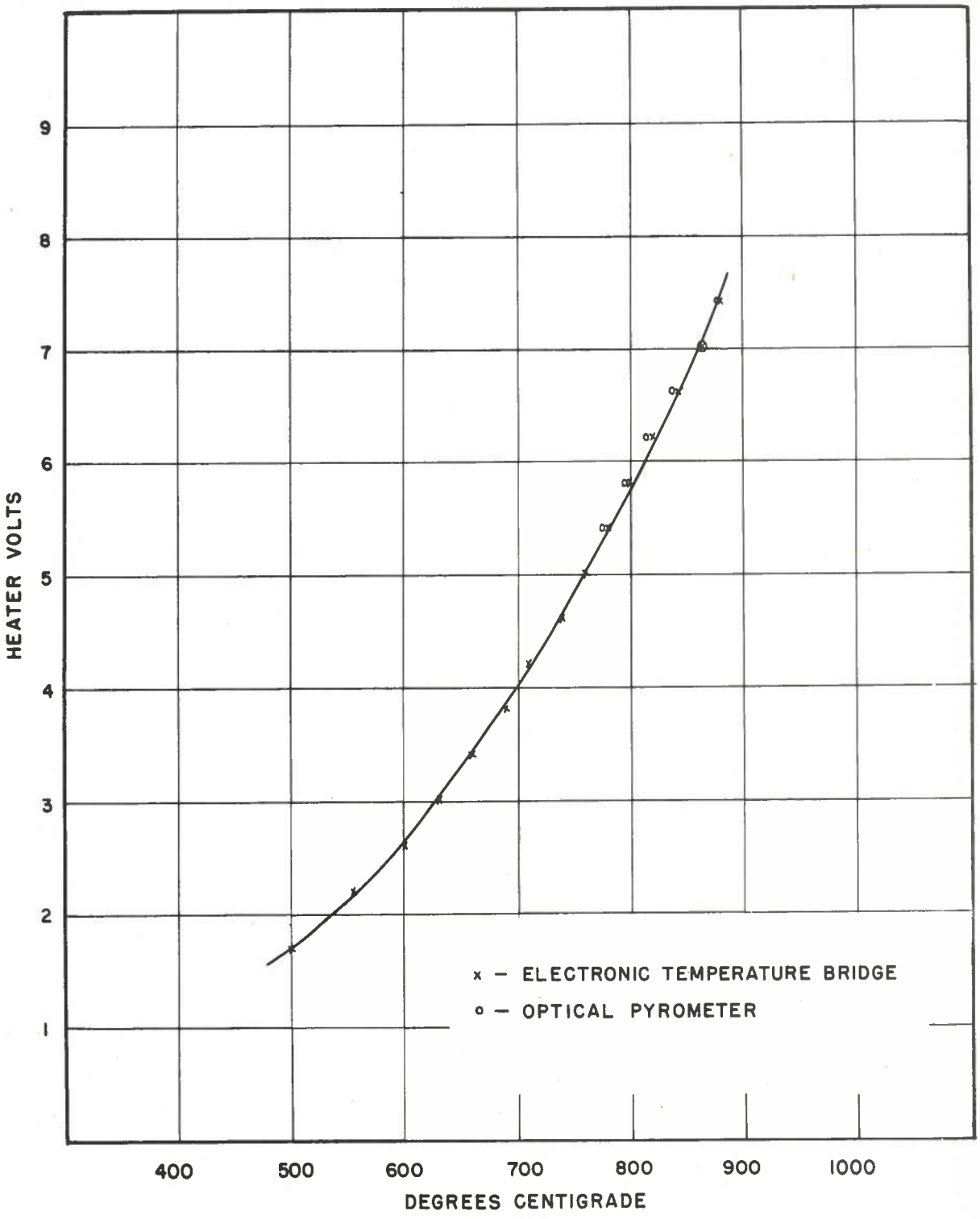
Photoelectric work functions have been measured both by the universal Fowler curve, which is accurate for pure metals, and by rough extrapolation to zero current of the curve of photoelectric current versus wavelength. The values of photoelectric work function obtained for oxide cathodes differ by as much as 15 per cent with these two commonly used methods.

In addition to the true, instantaneous, photoelectric current, the radiation striking the oxide cathode appears to cause an enhanced thermionic emission which rises slowly when the cathode is illuminated, and decays slowly after the light is removed. This enhanced thermionic emission may be analogous to the bombardment-enhanced emission which has been attributed by J.B. Johnson to thermal electrons arising from an increase in the electron density in the conduction band. In this case the increase in the density of conduction electrons is attributed to photo-excitation of electrons into the conduction band.

(c) The Electronic Temperature Bridge

In previous reports this instrument (see photograph) has been designated the "Richardson Temperature Bridge". It

BRIDGE FOR THE ELECTRONIC MEASUREMENT OF CATHODE TEMPERATURE



CORRELATION BETWEEN ELECTRONIC TEMPERATURE MEASURED BY THE BRIDGE AND CATHODE TEMPERATURE MEASURED WITH AN OPTICAL PYROMETER

measures the differential anode resistance and the anode current in the presence of a retarding field. The "electronic" temperature is then read directly from the calibrated galvanometer. A criterion has been established which limits the validity of measurements to tubes with a ratio of effective anode-to-cathode radii not greater than 3.5.

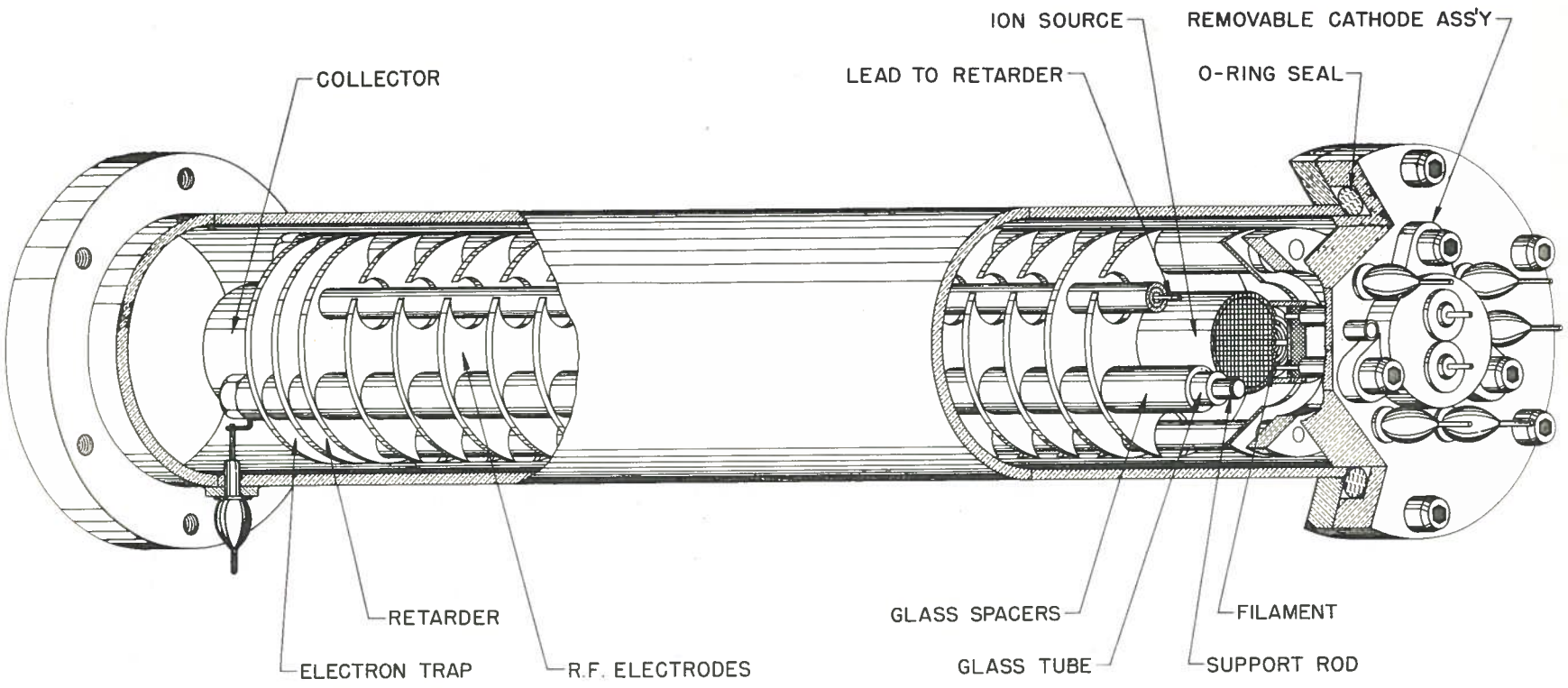
The correlation between electronic temperature measured by the bridge and cathode temperature measured by an optical pyrometer is shown in the figure following the photograph. The bridge is very useful for measurements related to interface phenomena and will undoubtedly find many other uses, such as the investigation of electron-tube noise. A full description of the device has been prepared for publication.

RADIO-FREQUENCY MASS SPECTROMETER

(a) Linear Type

A brief description of this instrument was given in the last progress report. The construction of a twenty-stage tube is shown in the diagram. Ions are produced by electron collision in a field-free cylinder having both ends covered with a fine mesh. Ions are drawn out of this cylinder by a direct-current extracting field and accelerated through the stack of electrodes excited at radio frequencies. These electrodes have a 5/8-inch central hole covered by a mesh of 95 per cent transparency. The ion which crosses the gap between two radio-frequency electrodes in 180 electrical degrees will gain most energy from the radio-frequency field. By setting the direct-current potential of the retarder grid at a suitable level, only those ions which have gained the maximum energy can reach the collector cup. Thus, by knowing the initial direct-current accelerating voltage, the frequency of the r-f voltage, and the gap spacing, the charge-mass ratio of the ion may be determined.

The mass spectrum is presented on a long-persistence cathode-ray tube by slowly varying the initial direct-current accelerating voltage. Resolution of one per cent may be obtained in the range of mass unity to mass 100.



TWENTY-GAP LINEAR R-F MASS SPECTROMETER

CUTAWAY DIAGRAM

The collector characteristics are being improved to obtain a higher resolution.

A paper on this instrument is being prepared for publication.

(b) Resonance Type

Precession of the oscillating ions in the present tube has presented a serious difficulty. An analysis of the ion motion is being undertaken to determine whether a field distribution can be achieved to prevent this precession.

ELECTRON BALLISTICS

A device for automatically plotting electron trajectories from information extracted from an electrolytic tank has been designed. A novel form of carriage control and support is used. Work on the electromechanical computer is almost complete.

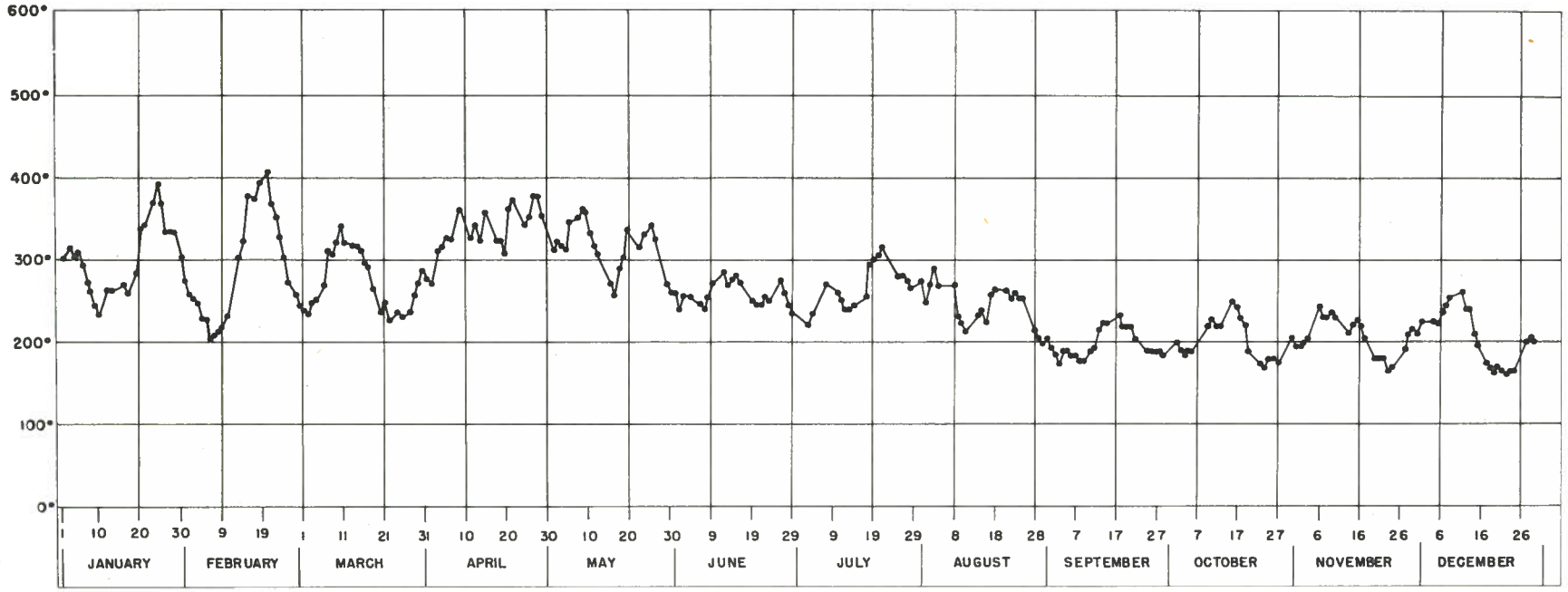
A resistance network for the solution of Laplace's equation has been designed and is under construction.

SOLAR NOISE OBSERVATIONS

Daily observations of the intensity of 10.7-centimeter solar noise have been continued, and the results for the past quarter have been submitted for publication in the "Quarterly Bulletin of Solar Activity" of the International Astronomical Union. Daily values for the past year, 1950 (see figure), show a gradual decline in intensity that can be associated with declining sunspot activity.

Preparation for retiring Radiometer No.1 has been started at the Goth Hill Observatory. It is planned to have two radiometers; one will be connected to the four-foot radiotelescope, while the other will be used as a standby unit and can be connected quickly to the radiotelescope when operational troubles are being experienced with the radiometer in use.

Further experiments on various types of radiometers are awaiting the completion of an experimental rack to hold equipment.



DAILY OBSERVATIONS OF 10.7-CENTIMETER SOLAR NOISE FOR 1950

The first experiments will be a repetition of previous work in order to verify the conclusions that have been reached. (Later experiments will use an asymmetrical wave-guide chopper which should utilize some of the advantages of the Dicke system and of the d-c radiometer.)

A laboratory model of the ten-centimeter crystal conversion-loss tester has been made and put into operation. A compensated intermediate-frequency 30-megacycle amplifier has been constructed and will be used to find the equivalent noise temperature of crystals.

Work has gone forward in the shops on mechanical details of both the 150-foot array and the 10-foot paraboloidal reflector. Castings have been coming in for both projects and have been machined as opportunity offered. By the end of March the site for the 150-foot array was sufficiently clear of snow for a preliminary inspection preparatory to work on the concrete footing.

ELECTRON ACCELERATOR

A new type of electron accelerator has been constructed and a detailed investigation of its performance is proceeding. This accelerator operates with a constant magnetic field and an accelerating potential of at least 500 kilovolts developed across a resonant cavity. The accelerating power is derived from a ten-centimeter magnetron. Final energies greater than four million electron volts are obtained.

During the period under review little direct progress was made, as the group's time was fully occupied testing magnetrons and wave-guide components at high power levels, both for use in the accelerator and for other projects.

A proton resonance magnetometer was built for checking the permanent magnets used with the high-power magnetrons and for calibrating the rotating coil fluxmeter used in the accelerator itself. Consideration was given to the use of this magnetometer in hour-to-hour measurements of the magnetic field of the accelerator, but on account of the limited space available this will require a specially shaped radio-frequency head. Work is continuing on this problem as time permits.

II

ELECTRICAL ENGINEERING

A-C LINE FREQUENCY STABILIZER

An a-c line frequency stabilizer is being developed to deliver several kilowatts of power at precisely 60 cycles. The stabilizer consists of a three-phase wound rotor induction motor used as a transformer. The stator is supplied with three-phase power from the a-c line, while the output is drawn from the rotor. A motor turns the rotor slowly in either direction as required, thereby adding to, or subtracting from, the line frequency to maintain the output of the stabilizer in synchronism with a crystal-controlled oscillator.

The first design used a two-phase a-c driving motor controlled by a magnetic amplifier. However, the magnetic core material which was on hand was not suitable for this application, and considerable delay in obtaining suitable cores held up further work on this control circuit.

A second design using a thyratron-controlled d-c motor drive has been adopted. The unit is capable of correcting line frequency variations of about ±0.5 per cent. It has an output capacity of 3 kva and is very stable. Sudden load variations up to the full output capacity of the stabilizer can be handled without loss of synchronism. The maximum phase-angle shift between the output of the stabilizer and the crystal-controlled oscillator is about ±60° within the operating range. This maximum shift can be reduced considerably, if desired.

Transient analysis of the operation of the stabilizer is being continued.

A-C LINE VOLTAGE STABILIZER

An electromechanical a-c line voltage stabilizer has been developed, the chief feature of which is its fast response. This is achieved mainly by the adaptation of a d'Arsonval-type of meter movement to the power drive for a Variac.

A request for one of these stabilizers for a 200-kv X-ray machine operating from the 220-volt line resulted in a redesign for

this application. The design of the driving unit was revised and the control circuit simplified. Further improvements in the speed of response of the stabilizer were made by operating the armature of the driving unit at a higher current density and improving the filter circuits. The recovery time is now 4 to 6 cycles, instead of the previous 8 to 10 cycles, on a 60-cycle calibration.

The increased current density in the armature of the driving unit was obtained by reducing the cross section of the armature coil without changing the resistance. This permits the use of a reduced air gap, and hence less field winding. Further reduction in the over-all size can be obtained by using a high magnetic saturation iron. A design incorporating these features is under way.

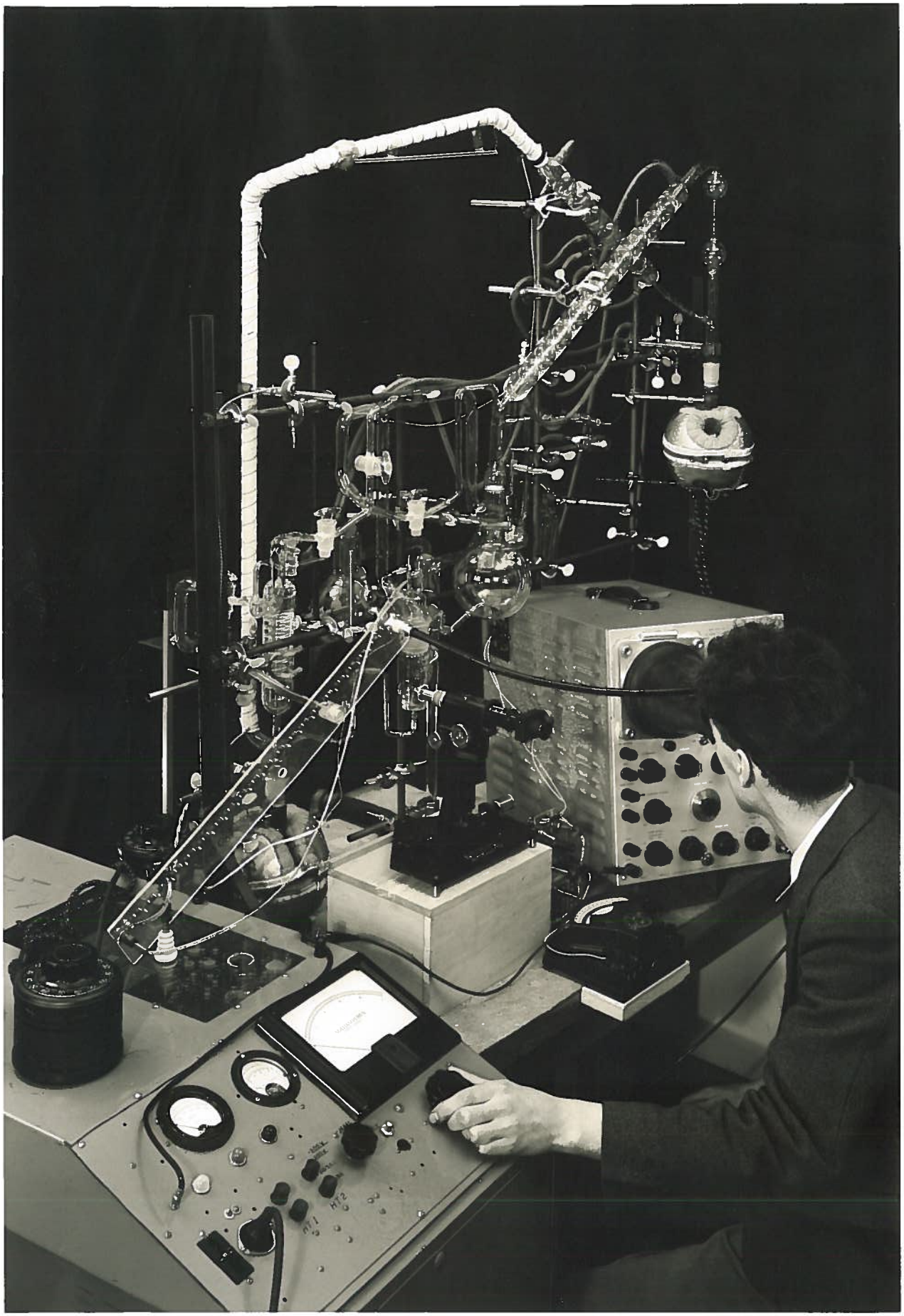
DIELECTRIC RESEARCH

Studies are in progress on the dielectric strength of pure organic liquids and transformer insulating oils. Research on the former is a fundamental investigation of the time delay in the breakdown process, involving the application of pulses less than one microsecond in duration. The aim of the latter study is to develop more suitable test methods for commercially important liquid dielectrics.

Delays in delivery of gap-measuring equipment prevented application of the rectangular pulse generator until late in the period. Various auxiliary pieces of equipment were built and calibrated during this time. These included an automatic shut-off circuit to minimize damage to the electrodes by the arc, and circuits for the measurement of pulse length and pulse magnitude.

A few dielectric strength measurements on pure benzene were possible. These showed considerable scatter, due, apparently, to variations in gap length and to products of breakdown adhering to the electrodes. These effects are now being investigated.

Tests on filtered transformer oil, using linearly rising pulses and electrolytically polished stainless steel electrodes, indicated that the presence of particles in the gap is still the chief cause of scatter. Attempts to remove these by electrical means, using auxiliary electrodes, have been fairly successful. However, repeated discharges in the main gap apparently disturb foreign material clinging to the walls of the vessel, and, in order



APPARATUS FOR THE DETERMINATION OF THE DIELECTRIC STRENGTH OF PURE LIQUIDS

to remove these rapidly, a new design of the oil filtering circuit is necessary. This is now in progress.

An attempt is being made to interpret theoretically a process of heat treatment of thermistors used by a Canadian electrical manufacturer. Preliminary work has indicated two possible interpretations which are being investigated experimentally by the manufacturer.

ION SOURCE DEVELOPMENT

A study of the Philips-Ionization-Gauge ion source is being continued. This type of source has several characteristics which make it appear particularly suitable for application as a constant-voltage source, as well as a pulsed source, in Van de Graaff particle accelerators. The literature on the subject indicates these characteristics to be, (a) absence of externally heated cathode, (b) low power consumption, (c) small gas flow, and (d) high efficiency. Such characteristics are being further investigated in an attempt to increase the usefulness of the device as a constant-voltage source.

During this period a study was made of proton percentage when using hydrogen gas under various operating conditions. Mass analyses have been made by means of a simple, permanent-magnet analyzer. Cathodes of magnesium, aluminum, and copper were studied. Gas supplies consisting of pure hydrogen, and mixtures in various proportions of hydrogen, oxygen, and water vapour were used. All experiments were carried out in a discharge chamber of fixed dimensions. The effect of chamber shape and size remains to be investigated.

When magnesium or aluminum electrodes were used, the proton percentage of the total ion beam (including heavy ions other than hydrogen) departed little from 10 per cent under any circumstances. The proton percentage of the hydrogen ion beam rose to 40 or 50 per cent when oxygen and water vapour were present in the gas. However, in this case, the percentage of heavy ions in the total beam also increased.

When thin copper cathodes and a thin copper anode were used with a pure hydrogen gas supply, a condition was recorded where the proton percentage in the total beam was 37 per cent. This was the best percentage so far found, but sputtering of the copper electrode renders the system, in its present form, unsatisfactory.

500-KV ELECTROSTATIC GENERATOR

A generator of the Van de Graaff type for electron acceleration is being constructed for the experimental study of reactions between ionized gases.

During the period under review the method of attaching the dome to the equipotential column was improved. With precautions taken to keep the interior free of lint particles, substantial voltages were obtained without incurring high charge-loading of the belt due to corona losses from the high potential parts to the tank wall. A steady voltage of 980 kilovolts was reached without difficulty (this was without the accelerating tube in place). This voltage was still below the limiting voltage set by longitudinal breakdown of the particular belt used. The output voltage of the generator is now controllable, and the performance is predictable. The high-voltage operation is therefore considered quite satisfactory.

Progress toward extraction of a useful beam current from the generator was held up owing to difficulty in getting the accelerating tube vacuum tight. A small leak in a cracked glass section of the tube was evident when the tube was surrounded by external gas pressure. Another application of vinyl-acetate resin over the glass section failed to close the leak permanently. It was therefore decided to rebuild the tube.

Electron emission and beam focus were not satisfactory under the poor vacuum conditions.

STATIC ELECTRICITY HAZARDS IN OPERATING ROOMS

Many explosions of anaesthetic mixtures in hospital operating rooms have been attributed to static electricity. A study is being made of possibilities of eliminating this hazard. One possibility is the maintenance of the operating room at a high relative humidity, thus making all surfaces conductive, due to the presence of a thin film of moisture. By some it is felt that the carbon dioxide normally present in the room (dissolving in the film to form an electrolyte) is a necessary condition and must not be removed by the air-conditioning process.

For the present, no further experimental investigation is being made of this carbon-dioxide relative-humidity problem, pending more detailed information of tests run by others. In the

meantime, a more extensive study is proceeding of literature dealing with the effect of adsorbed gases on solids, particularly with respect to static electricity.

Visits to two hospitals were made with a view to becoming familiar with the types of operating-room equipment in use and with the methods of use, and also to advise the authority concerned of the existing, possible, explosion hazards (due to all causes, including static electricity).

THYRATRON MOTOR CONTROL

A simple, variable-speed thyratron motor control for small motors has been developed. It is relatively inexpensive and should have many laboratory applications. A report outlining the design features will be prepared at a later date.

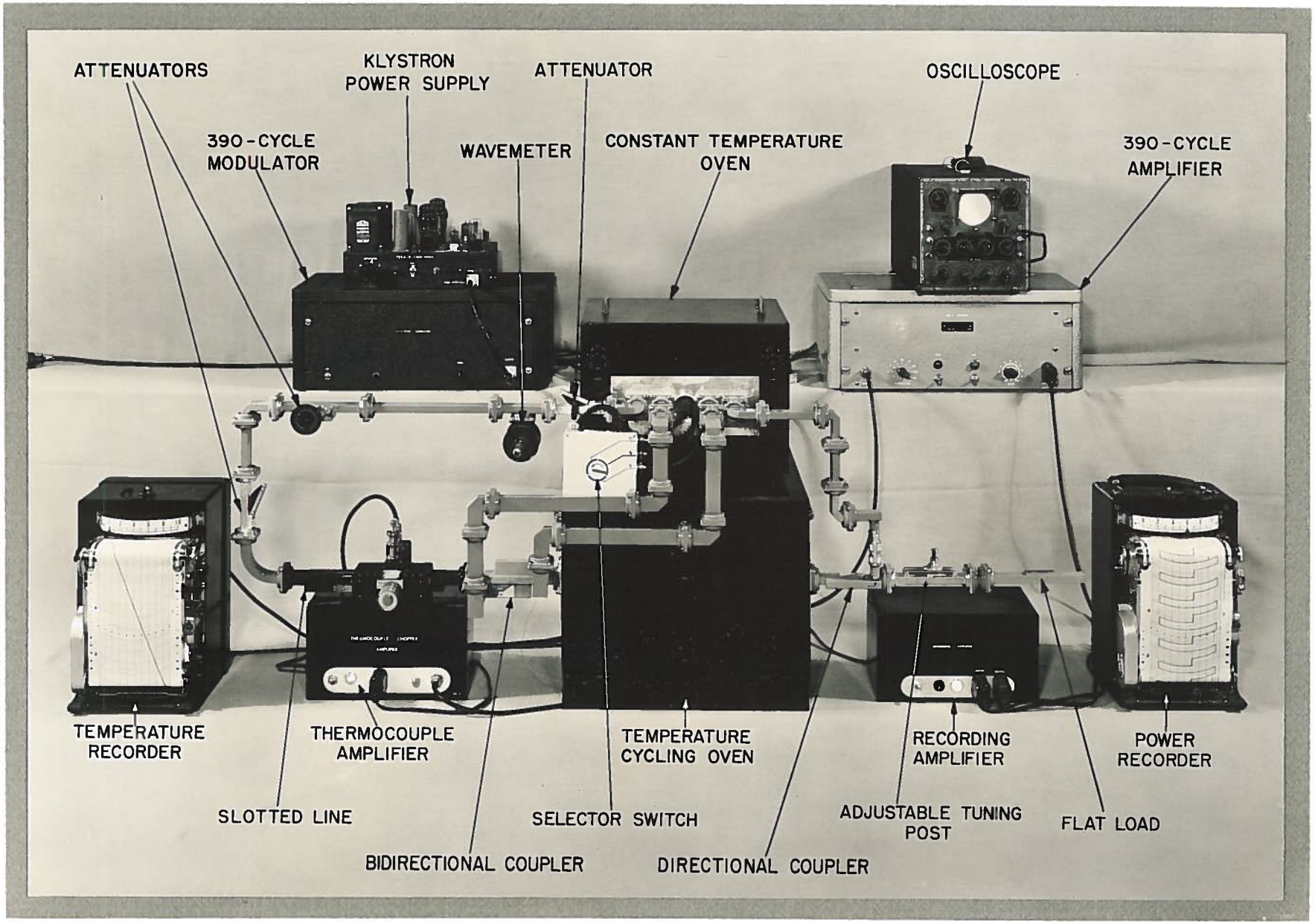
SURGE TESTS

Canadian manufacturers of electric equipment submitted nine small distribution transformers for surge testing during the first quarter of 1951. All nine were given ASA surge tests and several were tested to destruction.

CSA-APPROVAL TESTS

During the period under review, emphasis was laid on concluding the work on hand. Eleven final reports were issued and the respective laboratory orders were closed out.

As the Canadian Standards Association has now established its own laboratories in Toronto, examination of domestic oil-burning equipment with respect to its electrical safety features will, in future, be carried out by the Association itself.



AUTOMATIC EQUIPMENT FOR THE MEASUREMENT OF DIELECTRIC LOSS IN SNOW AND ICE AT THREE-CENTIMETER WAVELENGTHS

III

ELECTRONICS

REFLECTION COEFFICIENTS OVER SNOW AT THREE CENTIMETERS

Summary

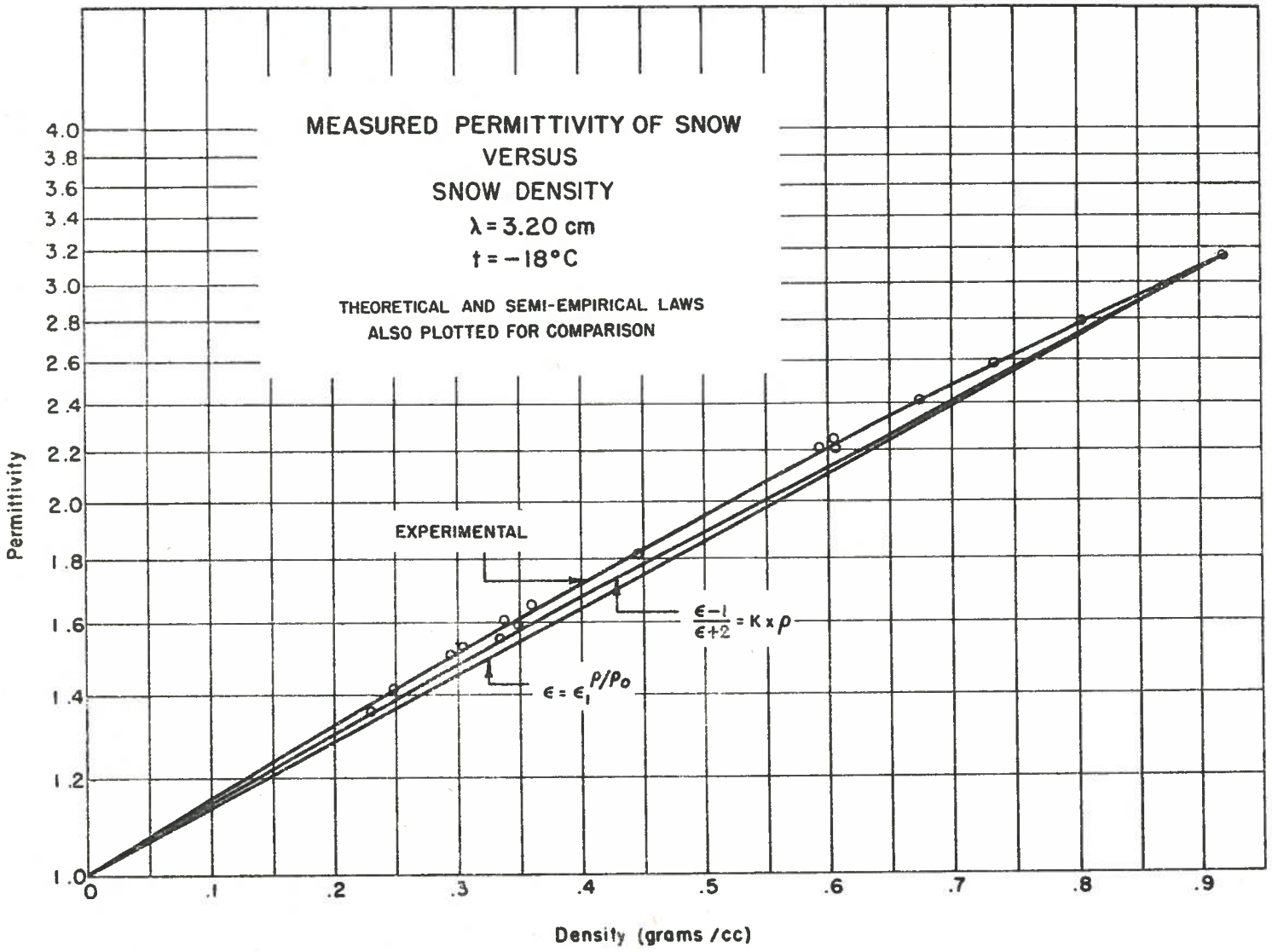
The absorption and reflection of radar signals caused by a loose covering of snow on radar targets is being studied. Two experimental setups are being used. The first is an outdoor range on which the reflection coefficient of a snow-covered surface is measured directly. The second is a cold chamber setup employing wave-guide techniques in which the permittivity and loss tangent of snow and ice are measured as functions of temperature. The loss tangent measurements are made automatically as the temperature of the sample is varied.

Measurement of Permittivity

Measurements of the permittivity (i.e., the real part of the dielectric constant) of ice and snow have been completed. A value of 3.15 has been obtained for the permittivity of ice at a wavelength of 3.2 centimeters, this value being independent of temperature over the range 0° to -20°C. Previous values obtained by other workers are 3.05 measured by Lamb at Manchester, and 3.17 obtained at the MIT Dielectrics Laboratory.

The permittivity of snow was measured as a function of snow density and the results of these measurements are shown graphically in the figure on the following page. As can be seen, the maximum deviation of the measured points from a "best-fit" curve is of the order of 1.5 per cent. It is interesting to compare this curve with one obtained by plotting the Clausius-Mosotti relation ($\frac{\epsilon-1}{\epsilon+2}$ = K x density) with the permittivity of ice taken as 3.15. The agreement between the two curves is surprising, since the Clausius-Mosotti expression assumes no interaction of the molecules and hence is valid only for gases or dilute solutions of polar liquids in non-polar solvents.

A third curve is also plotted for comparison. It is a relation often used to give an approximate value of the permittivity of a mixture of a dielectric and air, and is given by $\epsilon = \epsilon_1^{\rho/\rho_0}$,


MEASURED PERMITTIVITY OF SNOW
VERSUS
SNOW DENSITY
λ = 3.20 cm
t = −18°C
THEORETICAL AND SEMI-EMPIRICAL LAWS
ALSO PLOTTED FOR COMPARISON
EXPERIMENTAL
$\frac{\epsilon-1}{\epsilon+2} = K \times \rho$
$\epsilon = \epsilon_1^{\,P/P_0}$
Permittivity
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
Density (grams /cc)

where ϵ_1 is the permittivity of the dielectric, ρ_o its density, ρ the density of the mixture, and ϵ the permittivity of the mixture.

The values discussed above were measured using wave-guide techniques. A slotted wave-guide section was filled with the material under test and the field in the sample probed to measure the guide wavelength, from which the permittivity was calculated. As the slotted section was several half-wavelengths long, the errors due to non-homogeneity of the samples were minimized.

Measurement of Loss Tangent

The apparatus currently being used to measure the loss tangent (i.e., the tangent of the phase angle of the complex dielectric constant) of ice and also of snow is shown in the photograph. A 3.2-centimeter klystron mounted in a temperature-controlled oven provides the radio-frequency energy used. Between the oscillator and the wave-guide section containing the sample are several padding attenuators, a wavemeter, a slotted section, and a bidirectional coupler. After passing through the sample to be tested, the energy is again monitored by a directional coupler and is dissipated in a flat load.

The three basic measurements made in the tests are the outputs of the directional couplers, which measure incident, reflected, and transmitted field strengths. Hence, the apparatus measures the loss through the sample. The crystal detectors associated with the couplers are mounted in the temperature-controlled oven and are connected to the couplers by wave guide. The audio signals obtained from the detectors are fed through a rotating switch to an amplifier and a recording meter. The switch operates at a speed such that the output of each coupler is recorded for a period of forty seconds, giving a trace such as is shown on the recorder. This method of switching requires only one amplifier and gives more reliable results than would be obtained with a separate amplifier for each coupler.

The sample under test is mounted in an oven whose temperature can be cycled automatically between the limits 0°C and -20°C. Thus a continuous plot of loss as a function of temperature can be obtained. From these data, together with the information on permittivity previously obtained, the loss tangent of the sample can be calculated. The temperature of the sample is measured by thermocouples located in a piece of snow-filled or ice-filled guide mounted beside the sample holder.

The errors inherent in the directional couplers can be minimized by making the length of the sample an integral number of half-wavelengths, thus reducing the reflected wave to a minimum. This, however, is necessary only with samples of large dielectric constant.

In order to check the accuracy of measurement, the apparatus has been used to determine the loss tangents of several samples of silicone fluids, and has given results consistent with known results. Steps are therefore being taken to proceed with the measurements on snow and ice in the cold chamber.

ELECTROMEDICAL RESEARCH

(a) Radio-frequency Rewarming

Development of radio-frequency rewarming techniques was continued in cooperation with the Department of Surgery, University of Toronto. Results of animal rewarming tests conducted during the past year suggest that the same procedure might be applied to the resuscitation of humans who have suffered lowered body temperatures brought about by immersion in cold water or exposure to cold air.

Tests conducted during the period under review indicate that radio-frequency powers of 200 to 300 watts may be necessary for adequate human rewarming rates. Present techniques for inducing fever by diathermy employ from 125 to 150 watts. It is likely that the higher power and faster warming rate can be tolerated when warming from a lowered temperature to the normal state, since the thermal-regulating mechanism of the body will be assisting in the return. Blanket-type heating coils have been made up to facilitate the rewarming procedure,and satisfactory heating rates have been obtained when using them on animals. Modification of the coil arrangement will be required for use on humans.

A request has been received from the Defence Research Board for a portable radio-frequency rewarming unit for field use by the Armed Services. Design of the unit is under way.

An experiment was conducted to investigate the effects of ultrasonic heating, but results were inconclusive. An ultrasonic therapy unit built by the Division of Physics was used, the application being made to the thorax of a dog in a state of lowered body temperature. No general rise in temperature nor increase in pulse rate was observed, although there was some local heating of the thorax. Diathermy was used to complete the restoration to normal body temperature.

(b) Cardiac Pacemaker Stimulation

An investigation by Dr. W.G. Bigelow and Dr. J.C. Callaghan of the Department of Surgery, University of Toronto, has led to a new method of controlling the rate of beating of the heart by electric stimulation of the sino-auricular node of the heart, the seat of natural excitation of the heart's auricular muscles. An electronic stimulator was designed by this Division for this specific purpose and was used successfully. Recent tests have resulted in modifications to the unit to reduce the output, and to provide a rate control calibrated in heartbeats per minute and a single impulse switch for checking the location and functioning of the cardiac electrodes.

A pilot model of the stimulator, constructed by a Canadian firm, and based on this design, has been produced and in tests was found to compare favourably with the experimental stimulator.

(c) Cardiac Catheter Manometer

A model of the manometer was completed and tested at the Banting Institute. The venous and arterial blood pressure of a dog was measured using a 2.7-millimeter catheter. Satisfactory readings and electrocardiograph traces of the arterial pressure were obtained, but only fair success was achieved in the measurement of venous pressure because of difficulty in positioning the probe and the very low values of the venous pressure (1 to 2 millimeters of mercury).

The manometer is now being modified in line with these tests. The power-supply regulation is being improved and the amplifier gain increased to provide sufficient sensitivity for the measurement of very low values of blood pressure. Some changes have been made in the design of the probe to facilitate its construction.

GENERAL-PURPOSE REGULATED D-C SUPPLIES (TYPE ERA-156A)

A modification was developed whereby a second range, in addition to the original 250-325 volt range, may be added to the Type ERA-156A supply. The new range may be 100-175 volts, or 145-220 volts, depending upon the type of voltage regulator tube used and the position of the internal links. Should a 75-volt miniature regulator tube become available, provision has been made in the design for a third option of 175-250 volts for the second range. The full-load rating remains at 400 milliamperes for all ranges and regulation is comparable with that of the original design.

INFRARED DETECTOR

This instrument, to be used for locating faulty joints on power transmission lines, was radically redesigned during the past year. By using subminiature components and techniques in the new design, weight will be considerably reduced, with no deterioration in performance. The mechanical construction of the new design has been completed. Wiring and testing will be finished as soon as the pressure of other work permits.

PRECISION POLAR COORDINATE RECORDER

This instrument was designed originally for recording the angular accuracy of goniometers in polar coordinates, but it was later decided to extend its usefulness by adding range gear box facilities so that it could be used in the development of radar ranging circuits. Design and detailing of this equipment has been completed.

IV

AIDS TO NAVIGATION

NAVIGATIONAL AND DOCKING RADAR

The Navigational and Docking (NAD) Radar is intended to facilitate navigation in restricted waters. The shortest range on the continuously variable scale is now 400 yards, representing an expansion in the scale of the display of approximately eight times over that provided in the previous Merchant Marine Radar equipment (MMR-B). This expanded scale, together with the use of separate transmitting and receiving antennas and an extremely short minimum detection range (10 yards), results in excellent definition in the radar display.

(a) Experimental Model

The experimental model was redesigned to extend the maximum range to 15,000 yards, and is now being tested in the laboratory. It will be given further operational trials on the M.V. "Radel II" during the coming summer in conjunction with the Radar and Chart Matching Unit and the Photographic Radar Depth Display Unit.

A considerable amount of time was spent in an attempt to improve the operating characteristics of the receiver. Also, since several of these receivers were required both as operating units and as spares, it was essential to specify the circuit parameters quite carefully. The early experimental receiver employed fixed-tuned coils in five stagger-tuned triples operating at 60 megacycles, with a bandwidth of 25 megacycles, but was found to have insufficient gain for proper operation of the limiting video. Accordingly, an additional triple was added and the bandwidth was reduced to about 22 megacycles. As before, the receiver consists of two chassis joined by a piece of coaxial, low-impedance line, coupling the amplifier at a center-frequency stage. Matching networks are used at both ends, and the line is cut to represent a half wavelength at 60 megacycles. Several units have been completed and are being tested.

(b) Console Model

The console model is being assembled and wired, and all components are on hand. This unit will have three range scales —

one, variable from 400 yards to 15,000 yards, and two fixed scales of 30,000 yards and 60,000 yards. A dual, coaxial, rotating joint and a twin, slotted, wave-guide antenna are being built.

CHART-PPI SUPERPOSITION UNIT

During the past summer, field trials with the experimental unit demonstrated its usefulness in plotting soundings and in navigation. There were, however, many areas, particularly harbours and harbour entrances, where a much shorter PPI range would have been advantageous in obtaining greater accuracy in plotting depth records. The development of the "short-range" or fast-sweep PPI for the Navigational and Docking Radar has made these shorter range scales possible, and the Chart-PPI Superposition Unit is being modified to incorporate this new feature. The modifications consist of the fitting of a new i-f postamplifier and an improved video amplifier, so that the unit can be operated as the display for the experimental Navigational and Docking Radar equipment.

In tests made during the past summer it was found that the aluminized side of the partially transmitting mirror accumulated dust and could not be cleaned by ordinary methods without damage. A new mirror mount has been designed which totally encloses the coated side of the mirror and leaves only glass surfaces exposed. These can be kept clean by ordinary methods.

A chromium-surface mirror has been obtained also, and will be tried during the summer's work on the M.V. "Radel II". This mirror, although less efficient, has a surface which is very hard and which will withstand cleaning.

AZIMUTH STABILIZATION OF PPI DISPLAY

The use of synchros in radar PPI sweep systems has been so common in the past that, in the case of simpler equipments, the antenna drive unit has usually incorporated a selsyn or like device. In order to provide for multiple displays and the incorporation of bearing information for the azimuth stabilization of the display, the synchro in the antenna drive unit can be used as part of a servo link to provide an antenna-follow system which can drive one or more deflection units. The antenna rotational information can be

fed through a differential synchro, the angular position of which can be controlled by a transmitting compass through a second servo link, thus stabilizing the display in azimuth. Such a system has been constructed, using standard components, with the exception of the transmitting compass.

A small gyro, which had been commercially manufactured for a guided-missile application, was modified to provide autosyn transmission of the azimuthal position of the outer cage or ring. It was found that this gyro would maintain its orientation within a small error for periods of an hour or so. It has been mounted in a set of gymbals supported by a pedestal, the base of which houses a motor drive unit which can be used to orient the gymbal mount in initially setting up, or to correct for small errors due to a gradual precession of the gyro after a long period of time.

This system will be installed on the M.V. "Radel II" for use with the Chart-PPI Superposition Unit in which it has been found desirable to have an azimuth-stabilized display.

ECHO SOUNDING

Experimental echo sounding trials on Upper Rideau Lake with a modified, commercially manufactured, paper-type depth recorder showed that this recorder lacked many features to make it versatile enough for the sort of work required. The main disadvantages were: (a) only one depth scale was available, (b) there was no cathode-ray-tube presentation for photographic purposes, (c) the gain was very poor, (d) the accuracy was insufficient at shallow depths, and (e) the mechanical parts of the system were subject to wear.

To overcome these difficulties a completely electronic depth recorder was designed by this Division, having a five-inch CRT monitor display and a remote three-inch CRT display for photographic purposes. Range scales of 50 feet, 100 feet, and 600 feet are available. The gain of the recorder is many times that of the commercially manufactured recorder, and the over-all stability and accuracy are much better. The 50-foot range enables the operator to read depths as shallow as two feet with some degree of accuracy. This is quite impossible with the paper-type recorder.

Both recorders will be installed on the M.V. "Radel II", the electronic recorder being used in conjunction with the NAD

Radar and the Chart Matching Unit, and the paper-type recorder being set up in the lower wheelhouse for navigational purposes.

MICROWAVE LIGHTHOUSE

At the request of the Department of Transport an investigation is being made of the possibility of providing shipping, especially vessels too small to take advantage of radar equipment, with a simple, inexpensive, microwave navigational aid. A direction-finding system has been developed which uses a simple, lightweight and inexpensive, three-centimeter direction-finding receiver aboard ship, and a shore-based transmitter. The coverage of the transmitter is approximately a semicircle having a minimum radius of ten miles. In cooperation with the Department of Transport, a full-scale trial of the system will be made at Halifax in the course of the coming summer.

During the period under review work was restricted to the construction of equipment for the Halifax trials, as outlined below.

Nine complete receiving equipments were made. They are of reduced size and weight, and incorporate a new video receiver strip smaller than the previous design and more economical both as to power requirements and components. Operating convenience has been increased, and construction has been made easier and less expensive.

Three transmitters were completed. They were designed with considerable thought as to reliable and consistent performance, since they are to operate without technical attendance. Life tests of the complete transmitters were made, and trouble-free periods of the order of 1,000 hours, or better, are anticipated. To achieve this, a number of modifications were incorporated. The life of the magnetron was increased by reduction of filament voltage during operation, and also by the use of a network to present a relatively constant load to the pulse line during the pre-oscillation period. Considerable difficulty was experienced with the bearings of the spark-gap motor. This difficulty was overcome by the use of sleeve bearings, and the provision of a capacitive bypass around the bearings for the pulse currents. The keying mechanism was modified to reduce cam wear and to ensure that the keying contacts do not weld.

Two transmitting antennas were constructed. The design in this case aims at ensuring mechanical stability under all weather conditions, and provision was made for de-icing, if required.

UNDERWATER TELEVISOR

A wired television system is being developed for the specific purpose of viewing underwater areas. Possible applications for such equipment include the study of marine animal and plant life, and of the composition of lake, river, and ocean beds, and the examination of damage to wharves, hulls of sunken ships, etc. The pickup camera uses a sensitive image-orthicon tube mounted in a compact "head" and linked by a cable with a remote control unit. Complete operation of the head is possible from this remote position. It is intended to make underwater observations by placing the control and viewing equipment aboard a surface vessel and lowering the camera head overboard in a watertight container.

The equipment has been in operation using 50 feet of interconnecting cable. The cable conductor carrying the horizontal sweep was extended experimentally as much as 200 feet with satisfactory results. A camera unit for making photographic records was designed and is almost completed. A watertight container for the camera head was designed and is now under construction. Circuit diagrams for most of the equipment were completed.

STUDIES OF ANOMALOUS PROPAGATION OVER WATER

The installation of radar equipment at Scarboro Bluffs for the study of anomalous propagation effects has been completed. Trial experiments have been carried out with the equipment under complete automatic control.

Limit switches have been installed in the winch motor leads. These switches are operated by a lead screw driven from the winch drum shaft. A selsyn-driven automatic reversing mechanism is in operation, with the limits adjusted at 6 feet and 250 feet. Under continuous travel the radar carrier takes 13 minutes between limits. The PPI scan of the Type-268 Radar is

photographed every 20 feet of change in vertical height. If more accurate data are required, a second automatic control will stop the car at predetermined levels of 5 or 10 feet for each picture.

A platform and service tower have been constructed at the 150-foot level, and a small handwinch-operated cableway has been installed between the operating hut at the 200-foot level and the service tower. This cableway facilitates the handling of heavy chassis which would otherwise have to be manhandled up the cliff between the operating hut and the radar carrier.

SHORAN AIDS TO AERIAL SURVEY

Preparations were made for the 1951 RCAF Shoran survey operation. Various items of equipment for which the Division was responsible were overhauled. Certain modifications were incorporated, the desirability of which was demonstrated by experience. The calibration and zero-setting methods were studied and changes directed toward greater accuracy were suggested.

It was expected that during the 1951 season the RCAF would combine Shoran geodetic operations with radar altimeter operations, with advantage to both. After some study, informal discussions were arranged to insure that those concerned with operations understood the capabilities and limitations of all the equipment involved and thus would be able to make the most effective use of flying time. However, difficulties in connection with the installation of the K-band narrow beam radar altimeter in the Shoran-equipped aircraft precluded the combined operation this summer.

The war surplus 35-mm single-shot camera purchased for use with the Shoran recorder-controller was checked for reliability. Although essentially superior to the Eyemo units modified for this application, certain specific faults were found. Modifications were made to a prototype and further bench trials will be carried out.

A portion of the error in height determination is caused by insufficient accuracy in the meteorological data recorded at the Shoran ground stations (see Report ERA-183, Appendix B). Equipment and an operating procedure to improve this accuracy have been provided.

V

ELECTRICAL AND ELECTRONIC SYMBOLS

This work has as its objective the elimination, as far as possible, of inconsistencies, ambiguities, and options in the use of electrical and electronic symbols, and the development of a standard suitable for use by all agencies of the Government of Canada.

A draft proposal was submitted to the Electronic Standards Sub-committee of the Joint Telecommunications Committee at their request. The report, consisting of some sixty pages, included, in one self-consistent sequence, symbols for use in both electrical and electronic schematics, instead of separate treatment of the two fields, as has heretofore been the case. Where possible, the symbols were so chosen that a Leroy Electrical Symbol Template could be used in forming them. The symbols were taken from the ASA(CSA) Graphical Standards and JAN-Std-15, with a few exceptions which were, in the main, devised as a compromise.

The report was considered in detail by the sub-committee in conjunction with a report on JAN and British standard symbols. Some changes were recommended and a revised report (ERA-199) was issued by the Radio and Electrical Engineering Division in February. This report has been submitted by Sub-committee C of the Committee on Drawing Practices of the Canadian Government Specifications Board as its recommendation to CGSB.

VI

PAPERS AND PUBLICATIONS

"Research and the Engineer", presented by B.G. Ballard at a joint meeting of the Windsor Branch of the Engineering Institute of Canada and the American Society of Tool Engineers on February 8.

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A receiver seminar was held at the National Research Council at which papers were presented by N.W. Broten, W.M. Cameron, A.C. Hudson, and C.W. McLeish. The seminar was well attended by engineers of the Armed Services and other organizations in Ottawa. Further programs of this nature are planned.

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"Deceleration and Ionizing Efficiency of Radar Meteors", by D.W.R. McKinley, Journal of Applied Physics, vol.22, no.2, pp.202-213, 1951.

Improved instrumentation of the radar system has permitted a more accurate analysis of range-time records of meteor echoes and enabled the meteor deceleration to be determined in a few special cases. Three illustrative examples are described in which the measured mean decelerations were -0.48, -1.1, and -1.5 km sec^{-2}. Velocity data from a continuous-wave Doppler system were also available for these meteors and are compared with the radar data.

Using existing atmospheric density values and Lorell's scattering formula, it is computed that the ionizing efficiency, or the fraction of the kinetic energy of the meteor converted to ionization, is 10^{-6} for a 60-km/sec meteor and 10^{-8} for a 20-km/sec meteor. If lower values of the air density are adopted, the efficiency figures are increased and at the same time the gap is narrowed between the rates of electron production deduced from loss of mass considerations and the rates calculated from the radar data. More statistical data on radar meteors and further information on the ionizing properties of 1000 electron-volt atoms are required before definite conclusions can be drawn.

"Photoelectric Meteor Observations", by Barbara M. McKinley and D.W.R. McKinley, Canadian Journal of Physics, vol.29, no.2, pp.111-121, 1950.

The photoelectric meteor detector consists of 19 type 931-A photomultiplier tubes arranged to cover the entire sky. Signals from the photocells are repeatedly sampled in time sequence and displayed on a cathode-ray tube. Photoelectric meteor signals, radar meteor echoes,

and a marker light operated by visual observers are photographed by a continuous-film camera.

Preliminary tests indicated that the average sensitivity of the photoelectric detector to meteors was about one visual magnitude inferior to that of the human eye. Approximate meteor positions and qualitative light intensities could be obtained from the photoelectric record. Timing comparisons between the photoelectric and the radar records could be made to 0.05 sec. Methods of improving the sensitivity and other operational characteristics are discussed.

"On the Static Dielectric Constant of Dipolar Solids", by J.H. Simpson, Canadian Journal of Physics, vol.29, no.2, pp.163-173, 1950.

An application of Fröhlich's general formula for the static dielectric constant is made to a material having a cubic arrangement of dipolar molecules, each of which has two equilibrium positions 180° apart and ordering forces of the short-range type which tend to make nearest neighbours antiparallel. It is shown that such a model cannot lead to a sharp transition in dielectric constant unless changes in lattice dimensions occur. Qualitative comparison with certain experimental results is made.

"Some Characteristics of 10.7-centimeter Solar Noise (Part I)", by A.E. Covington, Journal of the Royal Astronomical Society of Canada, vol.45, no.1, pp.15-22, 1951.

* * * * *

The following publications have been issued by the Radio and Electrical Engineering Division:

"Tables of Daily Intensity and Outstanding Disturbances of 10.7-cm Solar Radiation, 1946-49" (ERA-192, NRC No.2240), by A.E. Covington.

The daily intensity and outstanding disturbances of 10.7-cm solar radiation, as observed at the Laboratories of the National Research Council in Ottawa, are given in tabular form for the years 1946, 1947, 1948, and 1949.

"Proposed Standard for Electrical and Electronic Symbols" (ERA-199, NRC No.2307), by E.F.V. Robinson, W.J. Purvis, H.E. Parsons.

"Precision 60-cycle Power Supply" (ERB-250), by W.T. Foster.

A General Radio 60-cycle temperature-controlled tuning fork provides a standard frequency (error 0.01%) which is amplified to 100 watts at 110 volts to drive small motors and clocks. Special circuits, using either 4 or 8 type-6L6 tubes, are used to produce this power at high efficiency and low plate voltages. This report describes the circuit details and contains the operating instructions.

"Investigation of the Mode Spectrum of a Triple-Resonator Magnetron Anode" (ERB-251), by P. Lombardini and P.A. Redhead.

The mode spectrum of a magnetron anode, composed of repeated groups of three resonators of different natural frequencies, has been computed by an equivalent circuit method and by field theory. The calculated mode spectrum is compared with experimental measurements. It is shown that the π mode in this type of anode structure is not contaminated by a zero order mode.

"The Preparation of Thoria-on-tungsten Cathodes" (ERB-252, NRC No.2323), by P.A. Redhead and M.G. Armstrong.

Cathodes of thoria coated on a refractory metal base are unaffected by exposure to air. This property makes them useful in demountable apparatus. A simple technique is described for preparing these cathodes.

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