Progress report for October - December 1950

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RADIO AND ELECTRICAL ENGINEERING DIVISION

PROGRESS REPORT

FOR

OCTOBER - DECEMBER 1950

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National Research Council of Canada

Radio and Electrical Engineering Division

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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

RADIO FREQUENCY MASS SPECTROMETER

(a) Linear Type

A new type of mass spectrometer has been developed which separates ions of differing mass by virtue of the different energies these ions acquire in passing through suitable radio-frequency fields. The main advantages of this device are its simplicity, the absence of any magnet, and the high useful ion current. Ion currents as high as 10^{-7} amperes are available at the collector.

Preliminary measurements indicate that a mass resolution of about one per cent in the range from mass unity to mass eighty is obtainable. Details of this tube will be reported in full elsewhere.

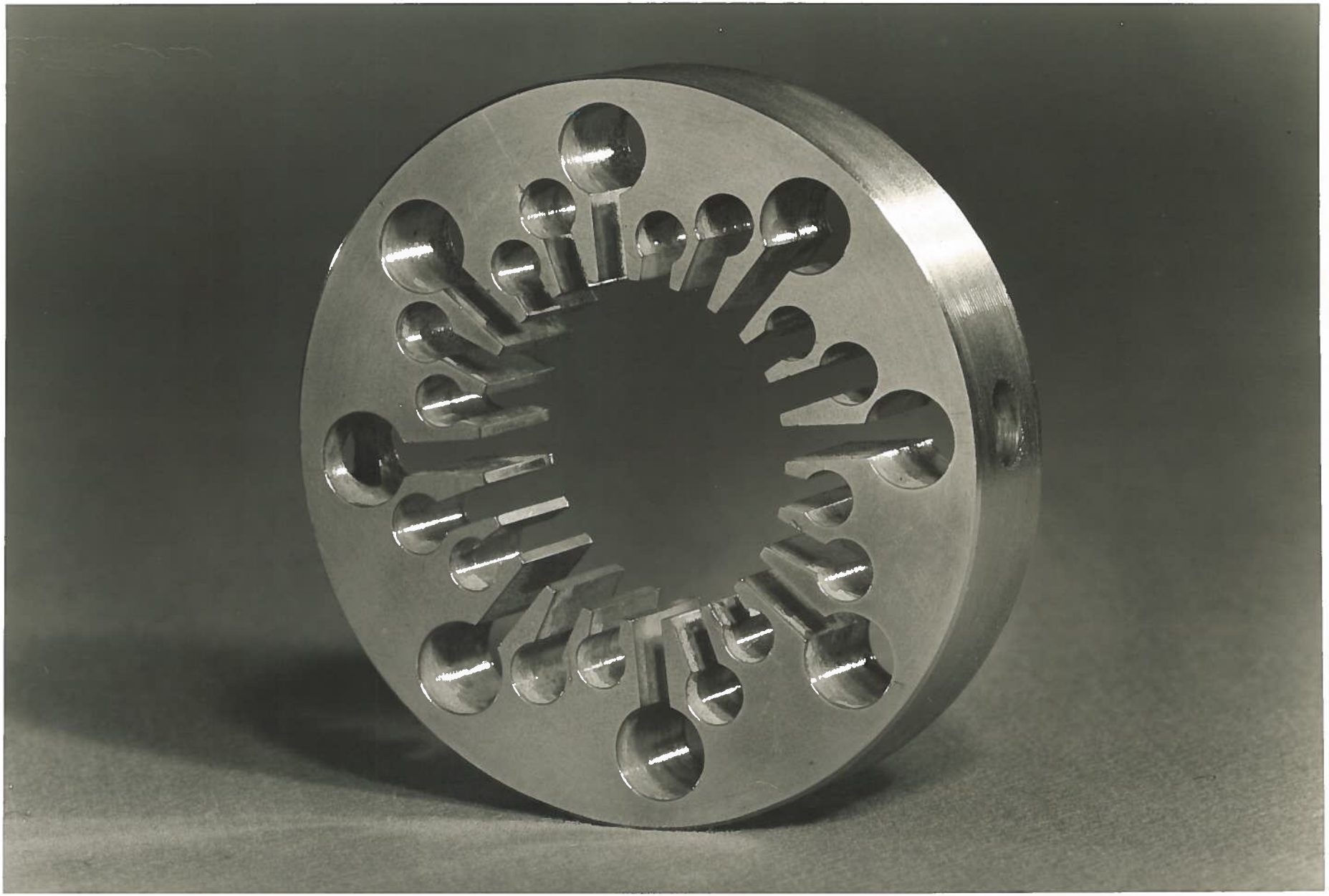
A model suitable for manufacture has been designed.

(b) Resonance Type

Investigations have started on another, simpler, type of radio-frequency mass spectrometer in which the ions perform isochronous oscillations in an electric field. It is hoped that greater resolution will be obtained than with the linear type.

MAGNETRON RESEARCH

Measurements of the mode spectrum of a triple-resonator magnetron anode have been completed. One of the dummy anode blocks used for test purposes appears in the accompanying photograph. This anode has the useful property of having no zero-order mode contamination of the π mode. A paper on this work has been submitted for publication.



TRIPLE RESONATOR MAGNETRON ANODE

FOR OPERATION ON A WAVELENGTH OF APPROXIMATELY 10 CENTIMETERS

SHOOTING-STAR RADAR

Summary

A program of observation of meteors is being carried on under the joint auspices of the Dominion Observatory and the National Research Council of Canada, with the objective of adding to the existing knowledge of meteors and of the upper atmosphere. The paths, positions, and velocities of the meteors are determined by triangulation from three radar stations. A continuous-wave system installed at Ottawa enables the Doppler whistles of the meteors to be photographically recorded. Automatic cameras have been built for direct photography of meteors. Photoelectric detection of meteors has been investigated experimentally.

Progress

During this period several runs were carried out in which the power of the SSR transmitter was varied periodically and meteor echo counts were made for high and low power periods. Separate transmitters were used to obtain a power ratio of 1000 to 1. During non-shower periods the echo rates were proportional to the square root of the power. However, during a strong shower the low-power system detected more than twice the expected number of echoes that would have been predicted by the square root relation from the simultaneous performance of the high-power system. The conclusions are that the size-magnitude distribution law for the normal background meteors holds up to at least the ninth or tenth magnitude, which is calculated to be the limiting magnitude of the high-power system, but that the shower meteors follow a different law. The low-power system had a limit of about the third magnitude; hence the size-magnitude distribution law for shower meteors must fall off significantly between the third and ninth magnitude; i.e., there are few faint meteors in the well-established showers.

The Geminid shower was observed for three nights by visual, photographic, photoelectric, three-station radar, and Doppler methods, although the visual methods were severely hampered by clouds. Some modifications were made to the photoelectric system; in particular, the photocell apertures were narrowed, but the expected improvement in performance was lacking, probably because the duration of the meteor signal in any photocell then appeared to be of the same order as the random noise pulses.

Equipment

SSR

A two-megawatt-output pulse transmitter is in the design stage, but construction will be deferred pending arrival of materials. The Ottawa SSR transmitter, using four type-WL530 air-cooled tubes, has been converted to accommodate type-WL530 liquid-cooled tubes, as the supply of air-cooled tubes is exhausted. Redesign of the oscillator stage is under way in an effort to increase the power output of the present oscillator.

For some of the high-low power tests described above, the power supply voltage was varied over as wide a range as the spark-gap or thyratron modulators would permit, but the greatest variation in power that could be obtained by this method was about 15 to 1. To get a greater range of power a small radar transmitter was built, using receiving tubes, which had a peak output up to 100 watts, compared with the high-power transmitter output of 200 kw.

SCR-270D Radar

The modified SCR-270D convoy was delivered in November.

Doppler System

Several experimental runs were made on the Doppler system in conjunction with the observing programs described above.

A graphical Cornu-spiral presentation of meteor echoes is being investigated in which both the instantaneous amplitude and phase of the echo will be displayed together. Bench tests of the circuits are now under way.

Other equipment for use in the SSR-Doppler projects includes a photoelectric exposure meter for setting up oscilloscope intensities for consistent photographic results, a three-channel electronic switch of high switching rate for simultaneous examination of three transient signals (amplitude-time records of meteors), and a well shielded high-speed oscillograph for examining high-power pulses.

The ten-kilowatt c-w Doppler transmitter is now in the mock-up stage.

Precision 60-cycle Power Supply

Two amplifier units have been designed and constructed for the provision of precise 60-cycle power, using temperature-controlled

tuning forks as sources. These units are intended to drive small synchronous motors, up to 1/12 h.p., for the operation of the two Super-Schmidt meteor cameras which will be used by the Dominion Observatory in isolated areas. Since the amplifier portion of the equipment provides 100 watts output at 115 volts, with inherently good voltage regulation, using type-6L6 tubes, the unit may be of general interest, and a short paper on the design is being prepared for publication.

SOLAR NOISE OBSERVATIONS

Daily observations of the intensity of 10.7-centimeter solar radiation have been continued. The steady decline in the intensity of the emissions continues. An automatic return drive for the four-foot paraboloidal reflector has been installed in preparation for continuous tracking of the sun from sunrise to sunset. The starting cams remain to be installed. The automatic rapid scanning for circularly polarized radiation has been discontinued for the winter months and for lack of solar activity.

Daily observations of 10.7-centimeter solar radio noise for the period April-June, 1949, have been published in the "Quarterly Bulletin of Solar Activity" of the International Astronomical Union.

Further work has been done to improve the efficiency of the radiometer system. A detailed analysis of the circuit for d-c stabilization of the i-f transconductance of the type-6AK5 tubes in the 30-mc amplifier, for heater voltage variation, has been completed. The circuit constants can now be adjusted so that over-compensation and under-compensation are obtained. A 10-stage i-f amplifier with circuit parameters adjusted according to the analysis has been constructed. This amplifier shows less than ± 1/50 of one per cent gain variation when the heater voltage changes from 6.2 to 6.4 volts. An uncompensated amplifier shows a gain variation of ± 6.0 per cent for a similar change in heater voltage.

The compensated i-f amplifier, when used in the chopper-less or d-c radiometer, almost doubles the sensitivity of the radiometer. This increase arises since the d-c radiometer uses all the incident energy while the chopper-type uses only half of it. The long-term stability of the d-c radiometer may be improved. This type of radiometer will be considered in the redesign of the wide-band radiometer in which the construction of a suitable chopper is difficult.

The wide-band radiometer has been dismantled for the winter and will be redesigned. In the newer design it is hoped to incorporate a complete ridge wave-guide system.

Experiments on various types of radiometers, to improve the sensitivity and stability, have been made. An electronic circuit for chopping the antenna noise has been successful. No difference in sensitivity was found when the chopping speed was increased from 30 to 3000 cps. The electronic system appeared to be about as sensitive as the mechanical choppers now in use, but has the disadvantage that it is not as easy to operate.

Preparations are being made for the erection of the 150-foot linear array described in the previous report. The Geodetic Survey Branch co-operated in establishing permanent concrete monuments on an accurate east-west line. As bedrock lies only two feet below the mean surface level the concrete pier will be set on bedrock. The shop work on the mounting and rocking system is about half completed. Most of the wave guide for the array has been slotted, but no work has been done on the array itself.

OXIDE CATHODE PHENOMENA

(a) Interface Measurements

The "sleeping sickness" phenomena encountered in electronic digital computers is due to a high-resistance layer, or interface, which forms between the nickel core and the oxide coating of the cathode when tubes are operated under cut-off conditions for extended periods of time. The interface may be activated by drawing current from the cathode. Its conductivity is also strongly temperature-dependent.

The interface may be represented by a parallel C-R combination in series with the cathode. The capacitance varies from zero to about 0.001 microfarad, and the resistance varies from zero to several thousand ohms.

A pulse method of measuring this phenomena under a variety of conditions has been developed. A square-wave pulse is applied to the tube under test (connected as a diode) from a high impedance source. The waveforms at the anode, and also across a small resistance in the cathode circuit, are observed simultaneously on an oscilloscope.

The anode voltage waveform will have an exponential C-R charging curve superimposed on the square wave. The amplitude of this charging curve is equal to the voltage drop across the interface resistance. The current through the tube may be obtained from the amplitude of the voltage waveform across the cathode resistor. From this information the value of the interface impedance may be obtained.

The activation energy of the interface of a test diode, type-ED1, has been measured under the following conditions of current flow through the tube:

No d.c. — 2.0 e.v.
1.5 ma — 1.2 e.v.
3.0 ma — 0.93 e.v.

Further measurements of the activation of the interface are continuing.

(b) Work Function Measurement

The thermionic work function (ϕ_{th}) of an oxide cathode has been measured in the region 400°-700°K by use of the Richardson equation. The photoelectric work function ($\phi_{p.e.}$) has been calculated by Fowler plots of the photoelectric current, a method justified for semiconductors by Brown and Mahlman. The photoelectric work function decreases as the temperature of the cathode is increased from room temperature to about 550°K. At higher temperatures the photocurrent drops off sharply. At present ϕ_{th} appears to be slightly lower than $\phi_{p.e.}$ when the latter is measured at room temperature, but higher than $\phi_{p.e.}$ at 400°-550°K. However, the method of calculation used by Nisibori and others gives a higher value of $\phi_{p.e.}$. Both work functions become more stable with prolonged operation of the tube at 1000°K. Cathode temperature is measured by a tungsten-nickel thermocouple inside the nickel sleeve.

So far the work function of the tungsten anode has been reduced by evaporation from the cathode and other impurities. Precautions will be taken in the next design to have a clean anode for reference during contact potential measurements.

(c) The Richardson Temperature Bridge

This bridge has been developed to measure the temperature, T, of oxide-coated cathodes, as defined by the retarding field equation

$$I_R = I_s^o \exp \left\{ -e \frac{(V + \phi_c)}{kT} \right\}.$$

The instrument measures the dynamic anode resistance and the anode current with the anode slightly negative with respect to the cathode. The Richardson temperature, T, is then read directly from a calibrated galvanometer.

This instrument is very useful in the measurement of 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.

(d) Emission Decay

A paper on the preliminary results of this investigation has been prepared for publication.

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 the accelerator has been operated with the high-power radio-frequency system, using BM-735 magnetrons. Sparking in the magnetrons and in the bellows of the phase shifter has prevented the use of peak power greater than about 1.5 megawatts, at which level as much as 600 kilowatts was dissipated in the cavity. These powers are roughly fifty per cent greater than previously available, and operation of the machine is consequently facilitated.

The peak circulating current in the accelerator is still little more than a milliampere, and the shift to higher power has done nothing to improve this matter. The higher power was expected to allow higher currents before electronic loading of the cavity became serious, but was not in itself expected to increase the current. Plans to include controlled emission from a filament are proceeding.

While the machine was being operated, it became clear that the radio-frequency system described in the last report was too cumbersome in adjustment, and designs for systems more complicated mechanically but more readily adjustable have been started. With the present system, wear on the cavity tuning system is rapid and the resulting narrowness of tuning range leads to critical adjustments in the phase-shifter, and, in turn, to a sparking at high power levels. It is hoped that these difficulties will be alleviated in the new designs.

LARGE BARKHAUSEN DISCONTINUITIES

The measurements of the change of longitudinal magnetization of the nickel-iron wire, as a function of the current through the wire, have now been completed.

Some preliminary measurements have been done on the second part of the program — the dynamic characteristics of the Wiedemann effect. The pulses from the torqued wire are observed on an oscilloscope, together with the driving alternating-current magnetic field. For supersonic frequencies up to 0.5 megacycles per second, a high-speed oscilloscope is used. The Wiedemann effect could be observed very clearly up to 0.5 megacycles per second.

II

RADAR

STUDIES OF ANOMALOUS PROPAGATION OVER WATER

Statistical studies of anomalous propagation over water, made in a definite area, will provide data on the correlation of weather conditions and tropospheric trapping in that area. It is believed that such information may prove valuable in the siting of radar shore beacons, and also may assist mariners in obtaining maximum performance from their radar navigational equipment. The initial program will be carried out with a modified Type-268 Radar operating in the three-centimeter band.

The cliffs at the Scarboro Field Station provide an excellent site for such tests. Some means of raising and lowering the experimental radar equipment on the cliffs is required. Unfortunately, the character of the terrain is such that a trackway was considered impracticable. During the past year a 400-foot cableway (see photograph) was constructed to overcome this difficulty. A sloping A-frame composed of two 75-foot booms extending outwards from the edge of the cliff at the 200-foot level supports the cableway at its mid-point. The cableway is inclined at an angle of about 60 degrees to the horizontal and extends down to a lever counterweight system at the lake level. It is now in operation with manual control. An automatic reversing mechanism and safety limit switches are being added.

CABLEWAY FOR RADAR CARRIER TO BE USED IN STUDIES
OF ANOMALOUS PROPAGATION OVER WATER
CARRIER SHOWN NEAR MIDDLE OF 400-FOOT SPAN

MERCHANT MARINE RADAR

(a) Short-range (High-speed) PPI Sweep

Design of a console-type radar using the new high-speed PPI display is under way. This set is to be designated the "Navigational and Docking Radar", and will be designed along lines indicated by the summer trials of the experimental equipment.

Several hundred enlarged prints of the photographic records taken during the summer have been edited and analyzed.

(b) Echo Sounding

After extensive tests during the summer the electronic depth recorder was removed from the M.V. "Radel II", and some redesign of the circuitry has been completed, which improved the stability of the presentation.

The experimental photographic depth display unit has been rebuilt. A new three-inch cathode-ray tube has been installed, and a new front panel has been constructed which incorporates a Veeder-Root type of counter for numbering the film records.

(c) Chart-PPI Superposition Unit

This equipment is being modified so that it can be used with the Short-range (High-speed) Sweep Radar. This involves (a) modification of the video amplifier so as to broaden its bandwidth, and (b) making room for the i-f post-amplifier section of the receiver. All circuits will be located under a separate cover on the back of the unit as before.

The design of an improved mirror and mount is under consideration.

(d) Azimuth Stabilization of PPI Display

The servo components used in the experimental antenna-follow unit are being incorporated in a proper mechanical design which will provide an operational unit for use on the M.V. "Radel II". The components forming the mechanical drive are being made as one sub-assembly and the servo amplifier as another, while the two sub-assemblies are being mounted together to form a complete unit.

The chief reasons for the construction of the antenna-follow system are:

1. It provides a convenient means of feeding azimuth information into the PPI deflection system drive, for stabilization from a gyro or magnetic transmitting compass.

2. Experiments with various synchro-type deflection systems (selsyns, magslips, etc.) can be conducted with a minimum of mechanical adaptation, and without modification to the antenna drive mechanism.

3. It allows much shorter electrical leads in the deflection system, which aids in reducing the problem of securing very fast, linear sweeps with automatic centering.

* * * *

A 24-28 volt d-c, 50-ampere, portable, laboratory power supply has been designed to facilitate development and testing of equipment, such as the above, which must operate from the battery supply of the M.V. "Radel II".

(e) Radar Reflectors

Some work has been done on the development of an improved type of radar reflector for use with life rafts. Trials conducted with the first experimental reflector were not entirely successful, due mainly to the characteristics of the material used in its construction. A new design is being considered, using improved materials.

The radar reflector designed and built for the Halifax Pilot Vessel "General Page" has been installed and is giving satisfactory service.

MICROWAVE LIGHTHOUSE

At the request of the Department of Transport an investigation is being made of the possibility of providing shipping, especially those 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 radiation pattern of the transmitting antenna is such as to provide an aural "on-course" indication, 1/4° in minimum width, and also a left-or-right aural indication covering a sector of 90° on either side of the "on-course" indication.

The coverage of the transmitter is a semicircle having a minimum radius of ten miles. Various modifications are possible to provide all-round coverage, multiple tracks, intersecting tracks, indication of dangerous areas, and position fixing.

In cooperation with the Department of Transport, a full-scale trial of the system will be made at Halifax during the coming summer. The proposed system will consist of two transmitters ashore — one located on George Island, with "on-course" signal coincident with the Dartmouth - George Island Range, and the other located at the Chebucto Lighthouse with the "on-course" signal coincident with the Macnab Island Range. These two courses provide a safe entry to the inner harbour for both northbound and westbound vessels. Equipment is now being designed and constructed for these trials.

A revised antenna system for the receiver has been designed and tested in the laboratory. This antenna consists of a six-slot wave-guide array illuminating a section of a cylindrical parabola. The new design is considerably less expensive to manufacture than the existing antenna which is a section of a paraboloid fed by a double dipole array. The pattern of the wave-guide array and cylindrical parabolic section is also superior to that of a dipole-fed paraboloid of the same aperture.

A new video amplifier has also been designed and tested. This receiver, which has the same minimum sensitivity as the one it replaces, has 30 per cent fewer components, is more stable, and is somewhat smaller than its predecessor.

Tests have been made with the old receiver to determine the cause of some anomalies observed during the summer trials at Scarboro. It was noted at that time that the twilight zone of the radiation pattern of the transmitter appeared to subtend a smaller angle at long ranges than at ranges of about a mile. It has now been established that this was caused by a change in the response of the crystal at high and low intensity signals. At low signal levels (below 10 microwatts) the response of the crystal follows essentially a square law. At levels higher than this the response approaches linearity. In addition, the method of gain control used in the video amplifier contributes to a non-linear response of the amplifier. The new receiver will be free from these defects where practicable.

Considerable effort has been made to ensure reliable long-term operation of the shore equipment. To achieve this, extensive life-testing of the equipment has been undertaken. Particular attention has been paid to the operation of the rotary spark gap, and to the magnetron. The modulator now under test has operated satisfactorily for 1600 hours, without adjustment or maintenance of the spark gap or magnetron.

RADAR AID AT HARBOUR ENTRANCES

Supervision of the shore-based radar surveillance stations at Halifax and Vancouver has been discontinued by the National Research Council. The National Harbours Board will, in future, supervise the Vancouver station, and the Department of Transport will supervise the Halifax station. However, equipment is being prepared by the NRC Laboratories to facilitate remote-control operation of the Halifax station.

UNDERWATER TELEVISOR

A wired television system is under development which, when mounted in a submersible head for viewing underwater objects, provides a type of remote "eye" which may be controlled and manoeuvered by an operator aboard a surface vessel. It should be possible to use this device for much longer periods and at greater depths than a human diver could withstand. The equipment appears to have many possible applications -- such as for the study of marine animal and plant life, or for the examination of damage to wharves, hulls of sunken ships, etc.

The equipment consists of three main units. The camera head has been designed as compactly as possible while employing a sensitive image orthicon tube. Only such circuits and tubes as are absolutely necessary are included in this unit. All the control wiring for the operation of the tube, of the lenses, and for steering the submerged head are contained in one cable, and are brought to a remote panel on the auxiliary control unit, the second unit of the system. This unit contains all the necessary timing, sweeps, and power supply circuits for operation of the television system. The third, or display unit, is connected to the auxiliary control unit by several feet of cable and can be placed in any convenient position near the operator. Its function is to reproduce a televised image of the objects viewed by the lens and image orthicon tube in the pickup head. The type of cathode-ray tube used at present is the 10FP4. A small auxiliary box has also been considered for those controls which steer the submersible head. This would be necessary if the equipment required more than one operator.

The television equipment has been in operation in an experimental setup for approximately six months. Although the first pictures were poor, the quality has been consistently improved, and at present is comparable with that of commercial equipment. The various units have been modified and incorporated into the three units already mentioned.

NEW CONTROL PANEL USED TO OPERATE THE STRAIGHT-LINE FLIGHT COMPUTER
WHICH GUIDES THE AIRCRAFT ALONG PREDETERMINED FLIGHT LINES
DURING SHORAN TOPOGRAPHIC SURVEY OPERATIONS

A submersible container for the pickup head has been proposed and is in the drawing stage. This unit will be designed for submersion to a depth of approximately one hundred feet.

SHORAN AIDS TO AERIAL SURVEY

A new control panel has been designed for use in Shoran topographic survey operations. This panel (see photograph) is that provided at the position, in the rear of the aircraft, from which the navigator controls the over-all operation of a survey flight. It includes the components necessary for synchronizing and adjusting the Straight-line Flight Computer (see ERA-151), and duplicates those on the Navigator's Control Panel (mounted forward) which is used during geodetic operations.

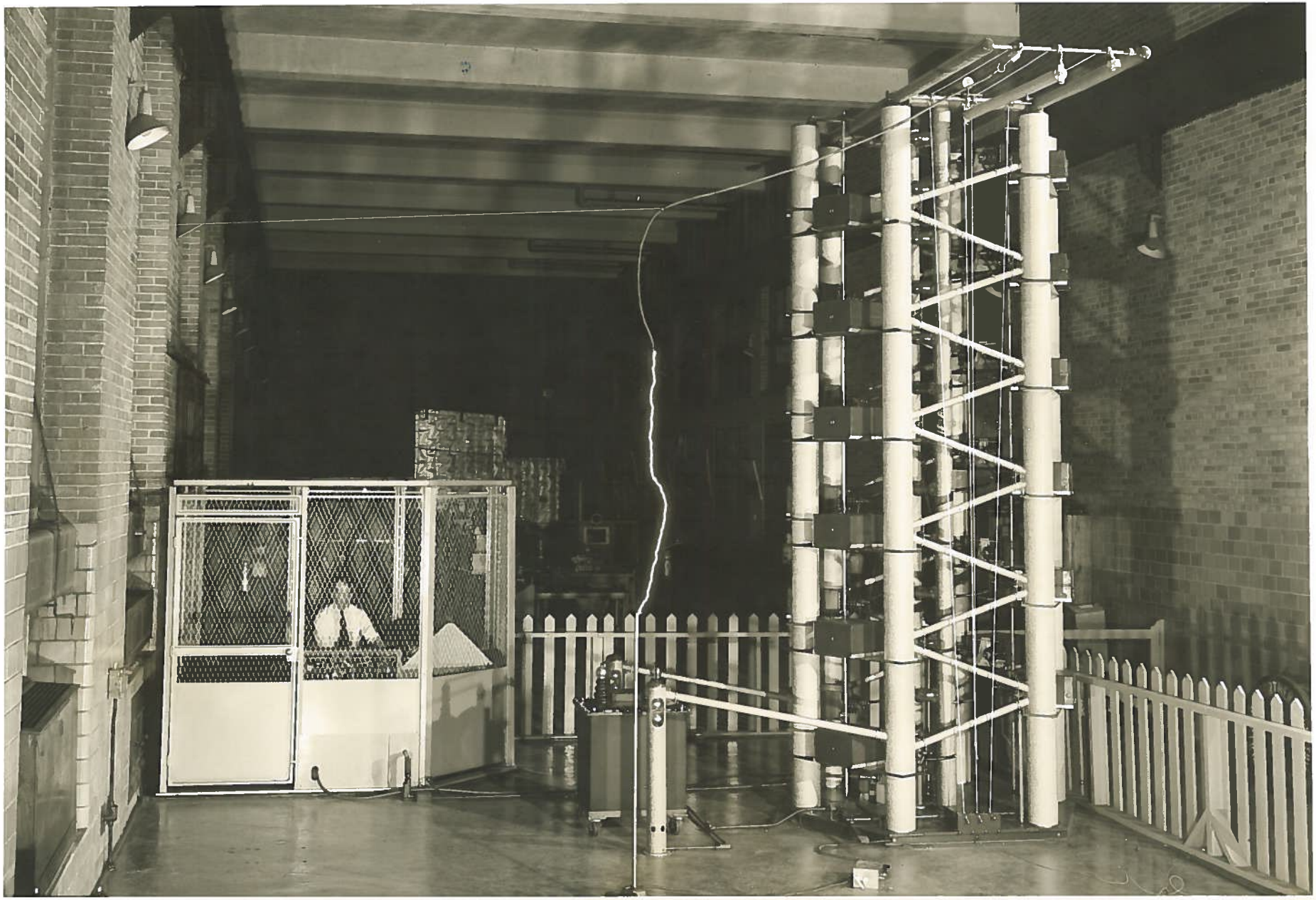
The switches and Veeder-Root counters at the upper left-hand and right-hand sides deal with the distance information transmitted from the Shoran Recorder-Controller by selsyn links, the counters indicating the two Shoran distances, and the switches providing a means of driving them to the proper values each time the whole apparatus is set up. Through the covered access holes below, adjustments may be made to the two servo-amplifiers mounted behind the panel. These amplifiers drive the lead screws of the arms of the Straight-line Flight Computer by following the autosyns in the Recorder-Controller. By means of the switches below, the amplifiers may be connected to fixed voltages to drive the arms at a constant speed to any position when setting up the equipment.

The center-zero meter is the detector of the resistor bridge circuit involving the card-resistor unit on the Flight Computer table. Thus, in effect, it is a tracking error indicator. The knob below the meter controls the sensitivity of the bridge. The switches beneath the sensitivity control "connect in" this local meter and the remote pilot's indicator, as required.

The "Orientation" control, and the "Run No." counter are used to set up the proper indications on the panel of the Recorder-Controller for the photographic record, the "Picture No." counter being operated by the recording camera. The remaining switches and lights supply information to the navigator, allow him to pass signals to other members of the crew, and control the camera operation.

PRECISION POLAR COORDINATE RECORDER

This instrument was designed originally for recording in polar coordinates the angular accuracy of goniometers, but it was later decided to extend its usefulness by adding range gear box



NRC 1.2-MILLION-VOLT SURGE GENERATOR

SHIELDED ROOM FOR CONTROL AND RECORDING EQUIPMENT AT LEFT

facilities. With this in mind, a drive was provided for two precision potentiometers, and a counter was added so that the equipment could be used in the development of radar ranging circuits.

As it now stands, the instrument comprises a motor-driven 16-inch turntable, mountings for three goniometers (one standard unit and two test units), mountings for the two precision potentiometers, main and vernier dials, a range counter, and a servo-driven pen.

III

ELECTRICAL ENGINEERING

1.2-MILLION-VOLT SURGE GENERATOR

The surge generator which has been under construction in the Electrical Engineering Laboratory has now been completed (see photograph). Work done during the last quarter of 1950 consisted of the completion of the surge oscillograph, and the construction of the shunt resistors and a screened cage. The cage houses the control console and oscillograph and also provides a safe area for the operator.

Up to the present, capacitors with a relatively low voltage rating, which were available in the Laboratory, have been used to control the wave shape. This has limited the controllable range to 300 kilovolts. A set of capacitors with higher voltage rating has been on order from a manufacturer for several months but has not yet been delivered. When it is received, the maximum rated output voltage from the generator will be 1200 kilovolts, and the maximum energy per surge will be 15 kilowatt-seconds.

The generator has been designed so that any number of the capacitors may be discharged in parallel. When all are discharged in parallel the output is a high current surge with a maximum voltage of 100 kilovolts.

The oscillograph has two channels, each having a sealed cathode-ray tube, and each being completely independent of the other. This permits any two simultaneous phenomena associated with an impulse to be viewed and photographed.

Most of the tests carried out to date have been for the purpose of checking the performance of the oscillograph and other components. However, preparations are being made to conduct surge tests on some electrical equipment for Canadian manufacturers.

ION SOURCE DEVELOPMENT

A survey of the literature has shown that ion sources, employing the type of gas discharge which occurs in the Philips vacuum gauge, have had only limited application to Van de Graaff particle accelerators. Since these ion sources are free from troublesome externally-heated cathodes and seem to have suitable characteristics in regard to power consumption, gas flow, and efficiency, a further evaluation of their usefulness is being made in the present project.

Apparatus has been constructed for comparing the performance of various cathode materials in the ion source; for measuring the effect of varying the physical dimensions of the discharge chamber; and for studying the use of gas mixtures. The criteria, on which performance under each condition is judged, are: total ion output, proton percentage, energy spread, and input power requirement.

The necessary high-pumping-speed vacuum system has been designed and constructed. Suitable vacuum-measuring devices have been procured. Power supplies for the gas discharge and for particle acceleration have been arranged. A palladium heater has been installed to admit pure hydrogen to the system, and a needle valve leak is being used to admit oxygen or tank hydrogen when required. A simple mass analyzer made up of a permanent magnet and a series of collecting electrodes is being used to measure the components of the ion beam and to estimate energy spread.

Preliminary measurements with the apparatus indicate that pure magnesium is the most satisfactory cathode material of those tested so far. Other comparative tests are now being carried out.

A-C VOLTAGE SENSITIVE BRIDGE

In order to test the accuracy and response time of an a-c line voltage regulator, it is necessary to have some means of detecting variations in line voltage of the order of 0.1 per cent, which has a fast response to sudden fluctuations in voltage. When an oscillograph or quick-acting recording instrument is used to make observations with such a detector, ripple voltage can make the results difficult to interpret. The problem then is to filter the output of the detector and still obtain a fast speed of response.

The detector used is an emission-limited diode in a d-c bridge circuit. Since the filament operates from 60-cycle power, the output of the detector bridge has a large 120-cycle ripple, as well as a component at 240 cycles. In the amplifier stage, the 120-cycle ripple is large enough to cause saturation. Two methods were tried to obtain filtering. The first method was to use parallel-T filters, one for 120 cycles and the other for 240 cycles, separated by cathode followers. The other method was to use a suppressor circuit in which the ripple is filtered to pass the higher frequencies, amplified, and added in series with the output. This method gives a better speed of response than the parallel-T filter method, but has the drawback of being critical in gain adjustment. A condenser-coupled suppressor circuit was treated theoretically to find the limitations in the response, but a transformer-coupled design gave the most practical circuit.

When a lead network is included in the circuit to reduce the time constant of the detector tube by a factor of 10, the effective time constant of the instrument for a step variation is 0.006 seconds for the suppressor circuit and 0.008 seconds for the parallel-T filters. The instrument includes a panel meter with suitable sensitivity settings. Calibration of the meter is in per cent variation of line voltage.

MAGNETIC AMPLIFIERS

Work has been done to develop direct methods for the design of magnetic amplifiers to fulfill specified requirements. An attempt has been made to correlate the slope of the transfer characteristic and the rectifier leakage, expressed as a normalized resistance, for full-wave circuits using various Deltamax toroidal cores. However, the results obtained have not been completely consistent, probably due to the lack of sufficient suitable rectifiers.

Tests made to compare the effect of rectifiers on various circuits indicate that the full-wave circuit, on which most of the recent work in this laboratory has been based, is more affected by rectifier characteristics than is the doubler circuit. With good rectifiers the gain of the doubler circuit is greater than that of the full-wave circuit using the same components. Poor rectifiers reduce the gain of the full-wave circuit more than that of the doubler circuit.

It has been noted that the amount of power which can be obtained from magnetic amplifiers made with the same cores depends on the amount of winding which is placed on the core, and, in general, increases with the amount of winding used. Tests were made to

determine the type of winding which would give the maximum output power from a given size of toroidal core. In the case of the smallest cores available, whose output is of the order of a fraction of a watt, the current is limited by the saturation voltage and the circuit resistance to values at which thermal effects are not critical even on short circuit. Thus the maximum output is limited by the amount of winding which can be placed on the core. With the larger cores, the heating effect is greater, and this limits the allowable current density, and the maximum output. The heating effect with toroids, where all heat must be lost through the windings, is much greater than it would be if the core were not all enclosed, so that some heat could be dissipated by the core.

Amplifiers using identical cores, and using the same amount of power windings, theoretically should deliver the same power, irrespective of the number of turns and size of wire used. Experiments designed to prove this theory have shown that if no rectifiers are used in the circuit, the output power varies slightly with the wire size, apparently due to differences in the space factor of the windings. With rectifiers used for self-feedback in the circuit, the output power depends to a considerable extent on the type of winding used. This appears to be due mainly to the characteristics of the rectifiers. Increasing the number of turns in the power winding by a factor of n, increases the load impedance at which the maximum output is obtained by approximately n^2. The resistance of the rectifiers would not normally increase to this extent, so that the load power becomes a greater percentage of the total circuit power, and the output is increased. However, the increase in power is usually accompanied by a decrease in the slope of the characteristic and a decrease in the over-all power gain.

SPEED REGULATOR FOR 9-KVA MOTOR-GENERATOR SET

This regulator is to operate in the field circuit of a 12-hp 220-volt 1800-rpm d-c shunt motor driving a 9-kva 115-volt single-phase 60-cycle alternator. Since it is for use on shipboard, it is intended to use magnetic amplifiers and other components of similar ruggedness throughout.

The time constant of each stage of the magnetic amplifier has been determined by frequency response methods. The time constant of the first stage was found to be about 1/4 second, while that of the power stage is about 1/2 second. The over-all time delay is somewhat increased, however, due to inductive coupling between the two control windings in the power stage, which are used to obtain push-pull output magnetically. Resistive coupling of the push-pull stage is therefore being tried, even though this results in considerable loss of power and gain.

Some difficulty is being experienced in obtaining four wound cores of more or less identical characteristics for the push-pull stage.

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 the 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 a slight moisture film on them. By some it is felt that the carbon dioxide normally present in the room is a necessary adjunct (dissolving in the film to form an electrolyte) and that it must not be removed by the air conditioning process.

Continued tests run at this laboratory have shown carbon dioxide to have no appreciable effect on the surface conductivity of carefully cleaned fuzed quartz. (Several cleaning methods were tried; best results were obtained by using a steam jet.) However, it is reported that in 1939 it was conclusively shown that the presence of carbon dioxide had a great effect on the production of static sparks at various relative humidities. A possible theory has been advanced for the apparent contradiction.

The carbon-dioxide-water combination may have a surface effect which hampers the production of static charges, but which does not appreciably change the surface conductivity. If this is the case, then there is a definite need for carbon-dioxide to be present to prevent the creation of charges, as such charges may easily discharge almost immediately, (i.e., with separation of the charged bodies). Any tendency for charges to build up gradually will be countered by the conductive moisture film, which will still have a general levelling effect.

A bibliography of over 200 references on the subject of operating room explosions is nearing completion.

500-KV ELECTROSTATIC GENERATOR

A generator of the Van de Graaff type for electron acceleration is being constructed for the Division of Chemistry, where it will be used for the study of reactions between ionized gases.

Preparations were made during the period under review to obtain a beam of electrons through the accelerating tube. Vacuum

system components were fabricated or procured for this purpose. The tube made at NRC was used since the Machlett tube was broken beyond repair.

A three-stage, 4-inch-diameter line, oil diffusion pump was obtained. After a liquid air trap was installed, a vacuum of 5×10^{-6} mm at atmospheric external pressure was indicated. An automatic arrangement for replenishing the level of the trap was also set up to allow extended periods of pumping without attention, such as overnight operation.

A modified design of the variable-shunt filament transformer was made to eliminate backlash. Its characteristics were taken and adjusted to match the emission range of the filament.

During the period under review, the pressure vessel was sent to the original fabricator for the addition of another wall opening. The absence of pressurization allowed only the low voltages available at atmospheric pressure to be applied to the tube. Some current was registered at the anode end of the tube, but no current penetrated through the aluminum window. A fluorescent screen was installed in place of the aluminum window and the fluorescence showed the beam striking the window area. However, the beam was not too well defined.

DIELECTRIC RESEARCH

Dielectric breakdown tests using short rectangular pulses have not been commenced because of delays in the delivery of equipment associated with the gap-measuring microscope. In the interim, additions and improvements to the electronic equipment have been made. A circuit for the production of 20-kv linearly rising pulses has also been built. Pulses obtained from this circuit will be used to investigate the conductivity and breakdown characteristic of glass.

Investigations of the breakdown strength of transformer oil using linearly rising pulses (200 kv in 0.002 seconds) have given rather erratic results. The scatter is apparently due either to foreign particles or roughness of electrode surfaces, or both. As a first step towards ascertaining the relative importance of these two effects, methods of improving the electrode polish have been investigated. It has been found that, by a combination of careful mechanical buffing and electrolytic polishing, very smooth surfaces on copper, brass, and stainless steel can be obtained. Tests on filtered oil, using stainless steel as electrode material, are about to be made.

Two papers on dielectric subjects (see page 23) were presented at the Annual Conference on Insulation of the National Research Council (U.S.A.).

CSA-APPROVAL TESTS

During the period under review, seven revised samples and electric component parts of previously unacceptable oil burners were examined and tested. On the basis of such examinations and tests, interim reports, and reports leading to tentative CSA listing, were issued.

Eleven final reports were issued and the respective laboratory orders were closed out.

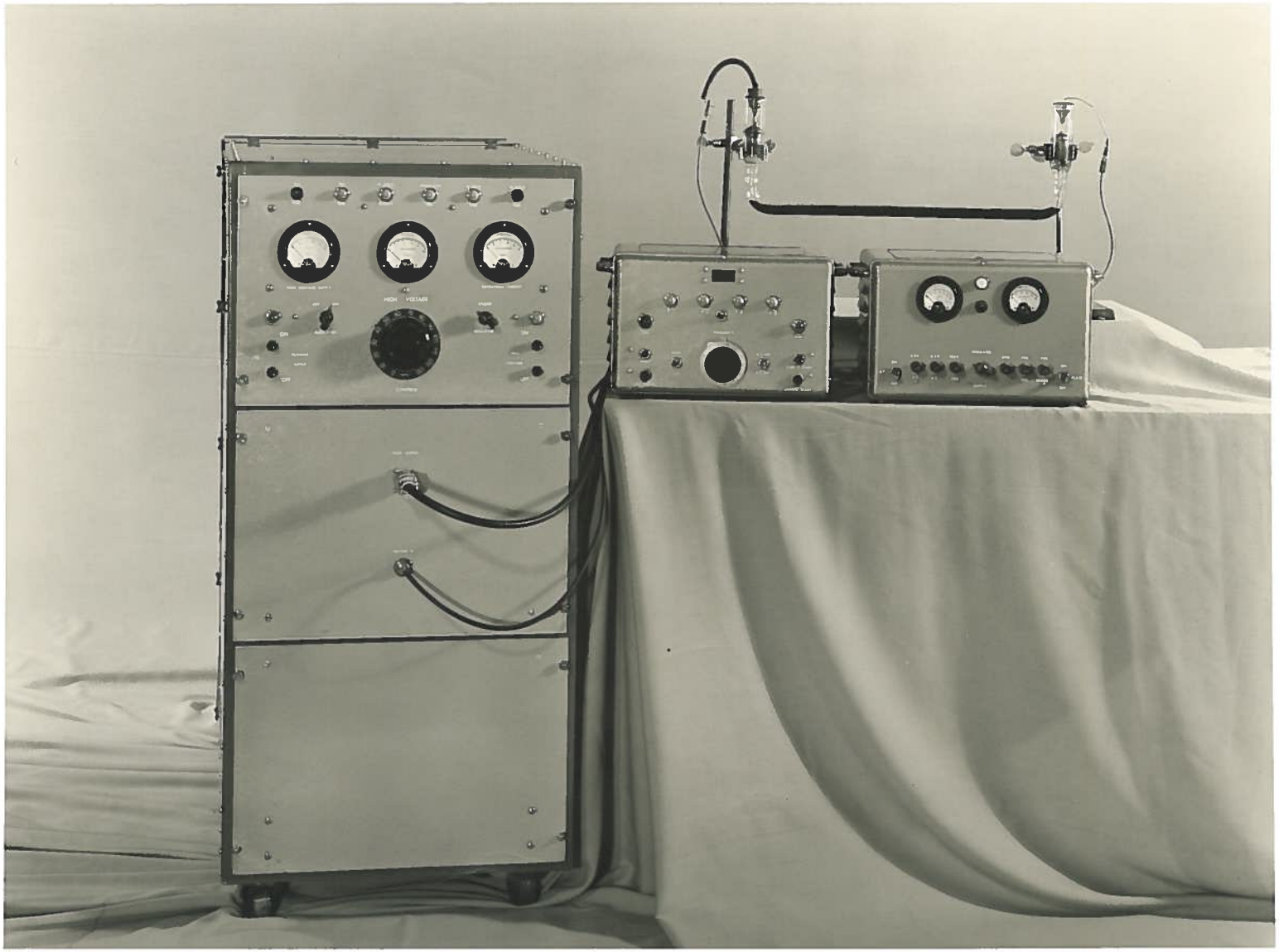
IV

ELECTRONICS

ELECTROMEDICAL RESEARCH

Work has continued on the development of radio-frequency induction heating techniques for resuscitation from cold. It is felt that sufficient progress has now been made in the technique to attempt the rewarming of a human subject, and, in this connection, an arctic sleeping bag has been obtained and suitable induction heating coil pads have been prepared. It is anticipated that the rewarming rate of a human subject below normal temperature may be as high as 6 to 8 degrees F. per hour, because the thermal regulating mechanism of the body will assist a return to normal body state. On the other hand, preliminary tests have shown difficulty in warming a human subject above 98.6 degrees F. at a rate exceeding 4 to 5 degrees F. per hour. The report on radio-frequency rewarming work will be completed when the results of this investigation are at hand.

Further experimental work has been undertaken on heart stimulation. A new pacemaker stimulator, producing pulses variable in duration from two to ten milliseconds, at an amplitude variable from zero to 65 volts, has been delivered to the Department of Surgery (University of Toronto) for possible clinical use at the Toronto General Hospital. The pulses are delivered from ring electrodes mounted at the end of a 2.33-millimeter catheter which is inserted through a vein. Tests on animals have indicated that the equipment provides satisfactory heart control.



PULSE GENERATOR

CONTROL AND COUNTING UNIT

NEON DISCHARGE LAMP POWER SUPPLY

400-KILOWATT FLASH GENERATOR FOR RESEARCH IN PHOTOSYNTHESIS

A report of the pacemaker stimulation investigation which was presented to the American College of Surgeons in Boston by W.G. Bigelow, M.D., and J.C. Callaghan, M.D., of the Banting Institute, evoked several enquiries about technique and equipment. Arrangements have been made for manufacture of the stimulator and catheter electrodes by two Canadian firms.

The 60-cycle heart defibrillator was modified for use on smaller animals, and the pacemaker stimulator circuit was changed to permit application of the defibrillator voltage by means of a catheter electrode instead of by the normal defibrillator electrodes.

The voltage output of the nerve stimulator was found to be inadequate for use on animals in the cold state, due to decreased nerve sensitivity at lowered temperatures. A new stimulator is being designed at the present time for use in electrical stimulation of the phrenic nerve (which controls respiration).

The development of the cardiac catheter manometer, for the measurement of heart blood pressure, continued during the period under review. Early difficulties encountered in building the catheter probe have been overcome, and several probes have been built by the divisional Model Shops — the smallest to fit a No.7 catheter (2.3 millimeters in diameter). Calibration of the manometer against a mercury manometer has been completed and it has a full-scale sensitivity of 100 millimeters of mercury. The unit is now ready for a trial measurement of blood pressure on a live subject, and this will be carried out at the first opportunity.

REFLECTION COEFFICIENTS OVER SNOW AT THREE CENTIMETERS

Summary

The absorption and reflection of radar signals caused by a covering of loose snow on radar targets is being studied. Two experimental setups are being used. The first is an outdoor range using natural snow surfaces between two towers. The second is a cold chamber setup which uses a new wave-guide technique for automatically measuring attenuation through snow.

Progress

A new technique has been developed for the automatic measurement of attenuation through snow in a wave guide. A sample of the snow to be tested is placed in a section of wave guide terminated in its characteristic impedance. Directional couplers placed in the line are used to measure the magnitude of the wave

incident on the sample, the wave reflected from the sample, and the wave transmitted through it. The outputs of these couplers are rectified, fed into a single-pole triple-throw rotating switch, thence through an amplifier, and on to a recording meter. Thus a continuous record is made of the three voltages from which the attenuation can be computed.

The snow sample is contained in a special oven whose temperature can be automatically cycled from 0 degrees C. to -20 degrees C. It is hoped in this way to record attenuation continuously as a function of temperature.

This new technique for measuring loss was applied to measuring the attenuation in silicone fluids, and gave results consistent with known results.

FLASH GENERATOR

A 400-kilowatt pulse generator capable of producing accurately-controlled discharges in a neon lamp, for research in photosynthesis, has been under development. The project is now virtually completed and the drawings are being finalized.

The pulse generator (see photograph) produces 10-microsecond pulses at a recurrence frequency variable from about 5 to 100 cycles. The recurrence frequency setting accuracy is about 0.1 per cent. This accuracy is achieved by using a trigger circuit developed from a pair of cross-connected screen-coupled phantastrons. A chain of scaling multivibrators terminating in a counter-register permits the computation of the total number of light flashes over any desired period, depending on the counter-register used.

An additional pulse transformer is being designed to permit the use of certain lamps whose impedance has been found to lie between 1 and 5 ohms.

A shielded photoelectric monitor, with a built-in cathode follower, has been developed, and it is hoped that this will enable a study to be made of the light intensity during the flash.

Arrangements have been made with the Division of Physics to carry out an examination of the spectral distribution.

V

STANDARD FREQUENCY SERVICES

Routine operation and maintenance of the local services of the laboratory continued. Several minor breakdowns, chiefly in the standard 60-cycle power amplifiers, were repaired.

Three precision receivers have been installed to give continuous coverage from 15 kc to 250 mc for laboratory measurements.

VI

PAPERS AND PUBLICATIONS

"Recent Developments in Ultra-high-frequency Vacuum Tubes", presented by P.A. Redhead at a meeting of the Toronto Section of the IRE on October 23.

"Radio Noise from Sun, Moon, and Galaxy", presented by A.E. Covington at a meeting of the Royal Astronomical Society of Canada, held at Montreal on November 23.

"Deceleration and Ionizing Efficiency of Meteors", presented by D.W.R. McKinley at the 302nd Meeting of the American Physical Society, held at Los Angeles, Cal., on December 28-30.

* * *

The following papers were presented at the Annual Conference on Electrical Insulation of the National Research Council (U.S.A.) held at Pocono Manor, Penn., on November 1-3:

"Some Results on the Electrical Breakdown of Liquids Using Impulse Techniques", by W.D. Edwards;

"Static Dielectric Constant of Dipolar Materials", by J.H. Simpson.

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

"A Graphical Solution of the Equation of Motion of an Ion in a Time-varying Electric Field" (ERA-188, NRC No.2234), by P.A. Redhead.

A graphical method of computing the kinematic parameters of a charged particle moving in a time-varying electric field is described. Two sets of universal curves are presented from which the above parameters may be found without recourse to any geometric constructions.

"Some Characteristics of 10.7-centimeter Solar Noise" (ERB-242), by A.E. Covington.

Observations of 10.7-centimeter solar noise for 1947, 1948 and 1949 are described in detail. During this period the daily level of the radio emission showed variations closely associated with the existence of sunspots, and the equivalent temperature of the spotless sun decreased from 8×10^4°K to 6×10^4°K. Sudden bursts of noise occur simultaneously with solar flares or with the corresponding radio fadeouts, at an average rate of about one in every twenty-three hours of observation. A study of a group of 222 bursts shows that 27 per cent are simple, showing only a smooth rise and a gradual fall; about 17 per cent are complex, showing two or more maxima of comparable duration; about 9 per cent are groups formed of simple and complex bursts, and the remainder are unsuitable for classification chiefly because the intrinsic variations are masked by the residual receiver noise, or because the bursts have been incompletely recorded. The burst duration ranges from one minute to two and one-half hours, the most frequent value being five minutes. The burst intensities range from one-tenth to twenty-five times the quiet sun level of 60,000°K, the most frequent values being one-tenth to one-half that of the quiet sun level. The logarithm of the burst duration shows a tendency to be proportional to the logarithm of the burst intensity. Many of the bursts show an exponential decay.

"A Narrow Band Audio Amplifier" (ERB-247, NRC No.2233), by B. Thomas.

A very narrow band audio amplifier tuned to 90 cycles is described. The 3-decibel-down points are 0.4 cycles apart. The noise level with the input short-circuited is 2 to 3 x 10^{-8} volts, and with 5 megohms across the input is 5 x 10^{-7} volts. The total gain of the amplifier is 3 to 4 x 10^{6}.

"Supplementary Handbook of Instructions for Modified Equipment SCR-270 D-NRC" (ERB-249), by R.S. McClean.

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