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PROGRESS REPORT ON ELECTRON TUBES FOR PROXIMITY FUZES (U)

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PROGRESS REPORT

REPORT NO. PR-55-59
PROJECT TA-9101,9104,4105
DA-506-01-004,03-002,01-001
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DIAMOND ORDNANCE FUZE LABORATORIES
ORDNANCE CORPS • • • DEPARTMENT OF THE ARMY

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DIAMOND ORDNANCE FUZE LABORATORIES

DOFL PROJECT | DOFL REPORT

WASHINGTON 25, D.C.

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PROGRESS REPORT ON ELECTRON TUBES FOR PROXIMITY FUZES (U)

1 April - 30 June 1955

ORDNANCE CORPS • • • DEPARTMENT OF THE ARMY

FOREWORD

Part of the work covered in this report has also been included in the progress report for the related fuze project. This separate report is issued for the convenience of those whose primary interest lies in the design, development, and evaluation of electron tubes and related devices.

The N project designations relate as follows to DOFL program number:

Program Number		Project Numbers
5210	TA3-9104	N-67, N-92, N-101
5217	TA3-9104	N-67F, N-74, N-75
5225	TA3-4105	N-71
5226	TA3-9101	N-102
5235	TA3-9101	N-57, N-95, N-99, N-100
5236	TA3-9104	N-68, N-89

FOR THE COMMANDING OFFICER

W. S. Hinman, Jr.
Technical Director
Diamond Ordnance Fuze Laboratories

TABLE OF CONTENTS

1. RUGGEDIZED X-BAND KLYSTRON (N-57) CONTRACT DAI-49-186-502-ORD(P)-240 (Note 1)

1.1 DESCRIPTION

This project, N-57, covers the development of an X-band klystron suitable for guided missile fuzes. The R-1, developed at a contractor (1), is a ruggedized X-band reflex klystron which has a minimum power output of 100 mW. The primary requirement is reliable operation under a wide variety of mechanical and electrical conditions. Tubes are required to pass mechanical tests in the following order:

(1) Vibration of 25 g at 60 cps for one minute;

(2) Eight 200-g shocks, two in each of four directions with normal voltages applied;

(3) Vibration of 25 g at 60 cps for one minute.

1.2 STATUS

The development of the R-1 klystron was begun at the contractor's in September 1948 to provide the oscillator for guided missile fuzes. The Electron Tube Branch of the Diamond Ordnance Fuze Laboratories has monitored the technical work, evaluated the tubes produced, assisted in the solutions to the various tube development problems, and investigated the characteristics of the R-1 as they affect the use of the tube. This development has been successful

The principal requirements for the tube were 100 mW minimum of power, wideband FM characteristics, reliability under shock and vibration conditions encountered in guided missiles, low AM distortion, and long shelf life. The power and electronic tuning characteristics were achieved very early in the program. The initial design of the tube also had the required resistance to shock and the required low microphonic output. The R-1 was the first really rugged and non-microphonic klystron to be developed and has served as a prototype for a series of rugged klystrons used in applications other than guided missile fuzes. The most difficult problems encountered were:

(1) Erratic operation under vibration, due to minute loose particles in the tube;

(2) Spurious modulation of the output, due to ion plasma oscillations in the electron beam.

An extensive series of tests and inspections carried on at the Diamond Ordnance Fuze Laboratories located the source of the particles, and the introduction of refined production processes by the contractor and careful inspection procedures eliminated the problem.

Plasma oscillation effects detected in these tubes have been reduced to insignificance by a change in grid design. This change consisted of introducing a hole of suitable diameter in the smoother grid. This hole eliminated the trapping of ions in the drift space. Study of this problem in the R-1 has contributed to a better basic understanding of the phenomenon. Prior to this work the cause of the spurious modulations was not known.

During the course of development the contractor carried out an improvement program, based on experience with production tubes, which had as its objective the development of a tube with superior performance. This resulted in a ceramic tube of reduced size, and improved mechanical ruggedness, together with a reduction of AM distortion and a reduction of variation of modulation sensitivity with beam voltage.

The current tubes are the R-1A and the R-1B. The R-1A is the first production version of the R-1, and has glass seals and a glassed waveguide output. The R-1A incorporates optimized cathode and repeller shapes as well as a thick first r-f grid to reduce multiple transit electrons without reducing power output and bandwidth. The R-1B is an improved design of the R-1A incorporating metal-to-ceramic seals and reduced size; and is designed to have the following improved performance characteristics:

(1) Reduction in the variation of modulation sensitivity with beam voltage to less than 20%. (Present tubes vary from 3% to 35%.)

(2) Reduction in frequency change, with temperature, to less than 250 kc/°C, and a shift of less than 20 mc in five minutes after the tube has had a 30-second warm-up. (Present tubes have a frequency change of about 600 kc/°C and a shift of about 65 mc in a five-minute period.)

(3) Minimum power output 120 mW. (Present requirements on R-1A is 100 mW.)

(4) Minimum electronic bandwidth ±25 mc. (Present requirement on R-1A is ±20 mc.)

(5) Long life operation at 350°C. (Currently an envelope temperature of 250°C is the maximum.)

(6) Five-year shelf life. (Present tubes have at least one-year shelf life, and the limit has not yet been determined.)

Work on the R-1B has progressed to the point where tubes with ceramic-to-metal seals are being produced on an experimental basis with exceptionally high yields. Measurements on the R-1B show less variation in electrical parameters than in the R-1A, and indicate that the R-1B can be manufactured to meet all six design objectives listed above.

However, an effect previously found on only a small percentage of R-1A tubes has been found to occur on about 50% of the first R-1B's. The effect is a 5- to 30-cps fluctuation of the output frequency when the tube is modulated at a rate within the range 0.6 to 1.2 mc. The rate of modulation and the deviation required to cause this low-frequency fluctuation has been found to vary from tube to tube and with heater power and body temperature. From experiments performed thus far, it appears that the occurrence of the phenomenon is related to cathode activation temperature and drift tube design. The development contract has been extended to find a solution to the problem.

1.3 PROGRESS

Ten tubes, produced at the end of the last quarter, using reduced heater power for cathode activation, revealed no induced frequency fluctuations on first test. However, all of the tubes exhibited the phenomenon after aging from 4 to 8 hours. Further testing of earlier R-1B's revealed that frequency fluctuations could also be induced in all of these tubes when aged for approximately one hour or more.

Since the R-1B operates at a lower body temperature than the R-1A because of better heat conduction through the waveguide flange, a number of R-1A's were checked for induced frequency fluctuations while the body was cooled with a fan. It was found that, after 5 hours aging, virtually all of these tubes also had induced fluctuations when the body was cooled.

Less than 10% of the tubes exhibited the phenomenon at normal body temperatures after 8-hours aging. The theory that a certain amount of cathode coating evaporation must occur in order to induce the fluctuations was substantiated by aging a number of tubes with various heater voltages applied. With body cooling, tubes aged with a heater voltage of 7 volts developed frequency fluctuations in approximately 1.5 hours; tubes aged with a heater voltage of 5.7 volts required approximately 6 hours.

The above observations indicated that a somewhat drastic redesign of the tube structure was necessary to rid it of induced plasma oscillation effects. Work was started on redesigning the electron gun and the r-f gap. Several tubes were made with coarse second r-f grids and several with a hole in the second r-f grids with the idea of draining any ions collected in the potential minimum within the r-f gap. All of these tubes required more than 40-hours aging before developing induced frequency fluctions.

The new electron gun was designed so that the accelerator grid could be removed completely to bring about a more thorough drainage of ions from the trap within the drift tube. Also, the area of the emitting surface was increased so that lower cathode operating temperatures might be possible. Of ten tubes produced with this gun, none had induced frequency fluctuations after 600-hours aging. The warm-up time of these tubes, however, was far greater than that acceptable for some applications. Accordingly, the gridless gun was redesigned using an emitting surface very nearly the same as that of older tubes. The first tubes of this design did not reveal induced fluctuations after several hundred hours aging but after slight changes were made in the focus electrode design to optimize efficiency, two tubes of this optimum design exhibited induced frequency fluctuations after approximately 40-hours aging. Tubes incorporating both the gridless gun and the coarse grids are now being processed.

Twenty-five additional R-1A's made by another contractor (2) were given production tests so that a comparison could be made with an earlier lot. Mechanical test results of this later lot (Feb '55) were very similar to those obtained with the first lot (Feb '54). Electrical tests, however, revealed an increase in average power output of approximately 10%, an increase in average bandwidth of approximately 30%, and an increase of average variation of modulation sensitivity of approximately 90%.

As a check of long-term mechanical reliability, 10 typical R-1A's were vibrated for 20 hours at 25 g. Since no resonances below 1000 cps could be found, the tubes were vibrated at 60 cps to simplify the test. None of the 10 failed.

1.4 PLANS

The investigation into a remedy for modulation-induced frequency fluctuations will continue, with the construction of experimental tubes incorporating various designs to reduce ion trapping and secondary emission.

2. LOW NOISE TRIODE OSCILLATOR (N-67) CONTRACT DAI-49-186-502-ORD(P)-191 (Note 3)

2.1 DESCRIPTION

This project, N-67, covers the development of an improved subminiature triode oscillator for use in fuze oscillator circuits. The objective of the program is to improve the microphonic and electrical noise properties of conventional fuze tubes. The QF-700, being developed under contract (3), is a T-3 glass envelope tube with a filamentary cathode. The electrical characteristics of the tube are: E_f = 1.4 v, I_f = 0.220 amp, E_b = 140 v, E_c = -7.5 v, I_b = 10 mA, G_m = 1520 micromhos, Mu = 8.2, plate dissipation = 1.5 watts, warm-up time = 0.10 second.

2.2 STATUS

When the task of decreasing oscillator triode noise was undertaken, three problems were found to exist. These were identified as follows:

(1) Quiescent noise. Quiescent noise consists of momentary changes of approximately one-third to one millisecond duration in the plate current and of such amplitude that voltages up to 50 millivolts are developed across a 10,000-ohm plate load, when the tube operates as a class A amplifier.

(2) Oscillation self noise. This noise is characterized by momentary changes in the developed grid bias, when the tube is operating as a class C oscillator, which is of such amplitude and time duration that a portion of the frequency spectrum falls within the pass band of fuze amplifiers. It is to be noted that the quiescent noise occurring at the anode of the tube when operating class A is almost identical in character to the noise occurring at the grid of the same tube operating in a class C oscillator circuit. Time duration, wave form, and frequency of occurrence are the parameters of the noise disturbances having common specifications in the two circuits. In both cases the majority of the noise occurrences are indicative of momentary reductions in space current.

(3) Microphonic noise. Microphonic noise is defined as those disturbances of the electrical output of a tube which are the consequence of a tube being subjected to mechanical forces when connected electrically as in (1) above. In the investigations conducted here, the technique of

white noise vibration, developed at this laboratory, has been used. The tubes are vibrated with a white noise excitation of 10 g integrated value over the band from 100 to 10,000 cps. It is to be noted that the vibration test is a summation of both quiescent and microphonic noise unless special precautions are taken to separate them.

Measurable success was first attained in the solution of the microphonic noise problem. A few quick, yet major, steps resulted in a significant reduction in the vibration-noise output of the tube. The shortening of the length of the tube structure resulted in a more rigid mount and an increase in the natural resonant frequency of the filament. This placed the filament frequency at a point in the spectrum where the probability of interaction with other electrode resonances was reduced. The present design of the QF-700 does not, however, completely meet the vibration requirements for this development; it is still under intensive study.

The first phase of the noise study, namely the quiescent noise problem, has been essentially solved. The percentage of tubes which fail to meet specifications for this reason is down to a few percent. Several factors were found to contribute to the reduction of this type of noise. The most effective steps taken included use of an enclosed anode, elimination of oxidized surfaces within the mount, reduction of the gas content, and protection of the mica spacers from bombardment by electrons. The last was accomplished by the use of grid bands and shields, thereby closing the ends of the grid structure to the passage of stray electrons.

The second, and more complex, phase of the work that is still under investigation is the noise produced when the tube is oscillating. In general, the solutions that have resulted in the reduction of quiescent noise have contributed markedly to the solution of this problem. The oscillating condition, however, introduces unique problems, including primary and secondary electron emission from the grid. These effects are particularly troublesome since they contribute heavily to the generation of spurious noise. Although means of reducing these emissions are currently under investigation, a complete elimination of secondary grid electrons introduces another problem. It has been found that this elimination results in an apparent decrease in the tube input impedance with the result that circuit loading and reduced developed bias are experienced. Therefore the solution to this problem lies in the control rather than elimination of secondary grid emission. Structural designs that so control the trajectories of the electrons as to eliminate insulator bombardment are being considered.

Quiescent noise is no longer considered a problem, since causes have been discovered, and precautionary methods adopted, so that less than five percent of the tubes exhibit noise outputs that exceed 10 millivolts. Most tubes show no noise greater than the one-millivolt ambient noise level of present test equipment. Because of progress in this phase of the program, major effort is being devoted to the problems of oscillation and microphonic noise. It is believed that the major specific mechanism causing oscillation noise in the tube has been discovered and investigations are in progress to exploit the theoretical findings. Similarly, a better understanding of the microphonic-noise mechanism has been attained, and emphasis is being placed on this problem in an attempt to provide tubes of the desired quality for the more critical fuze applications.

Experimentation has revealed one of the chief sources of microphonic noise output to be the intermodulation between the natural resonances of the filament and other structural components of the mount. This problem is complicated by a drift of the filament resonant frequency during warm-up, which amounts in some tubes to as much as 2000 cycles per second. This is a change of 25 percent in filament frequency. A mixing and detecting action has been found also to occur to a lesser degree between the resonant frequencies of the two filament strands. Noise output is observed when this difference frequency is in the passband of the amplifier. It is believed that this phenomenon is attributable to the fact that the effective emitting area of the filamentary cathode of the tube is modulated by the variation in the proximity of the filament strands to each other. Theoretical proof of this has been derived to substantiate observations. A similar action between the filament strands and the grid side rods has been found to be the source of the high output of fundamental filament frequency in an electrically centered tube. This latter source of microphonics is minimized by maintaining a minimum separation between filaments.

Another source of noise has been found to arise from variations in the plane of vibration of the filament. At 10 g excitation level this is a second order effect, but under sine-wave excitation, or at higher noise excitations, it may be of importance.

2.3 PROGRESS

The effort on this project for the past quarter has been devoted almost exclusively to the development of improved tubes based on the present knowledge of the microphonic problem. Preliminary tests of C-4 construction (see Progress Report PR-55-25, January-March 1955) in actual fuzes indicated low sensitivity. Sensitivity of the C-4 tubes averaged about 3.25 whereas N-67's averaged about 4.5. It has been observed that tubes with high input capacitance often perform poorly as oscillators in fuze circuits; therefore, the low sensitivity of the C-4 tubes probably can be attributed to the high input capacitance of that design. The emphasis has been transferred to "G" construction which was described in the last Quarterly Progress Report (PR-55-25, January-March 1955). Modified versions of "G" construction have given good results in the laboratory on both oscillator performance and noise characteristics.

The associated investigative programs of this project have been continued. The filament motion study, utilizing the special double-anode diodes, has concentrated upon an analysis of filament motions relative to the various configurations of the filament suspension. The first phase of this work has been completed and future work will be directed toward finding methods of minimizing filament motion effects.

2.4 PLANS

The major objective for the coming period will be to complete the examination of the C-4 and "G" construction tubes, including full circuit evaluation and field tests where possible. The results of these investigations will be used to determine the future form to be taken by the QF-700. In addition, all currently active portions of the investigative phase of this project will continue.

3. PRODUCTION TESTS AND FRANKFORD ARSENAL LIAISON WORK (N-67F)

3.1 DESCRIPTION

This project, N-67F, covers the production testing of the N-67 triode at DOFL for use in the construction of experimental fuzes.

3.2 STATUS

The N-67 incorporates most of the proven features of the QF-700 tube, which is still under development. It has been released for fuze production and is being used as the oscillator tube in most of the current bomb, rocket, and mortar fuzes under development as well as those in production.

At present the project is providing tubes to the various programs in order to maintain fuze production. Tubes are also being supplied to Zenith, Emerson, and the University of Florida for use in their work on fuze research and production.

3.3 PROGRESS

Production tests were conducted on 2427 tubes. Tubes subjected to tests under rocket specifications were 31 percent acceptable, while those tested under mortar and bomb specifications were 53 percent acceptable. A total of 2235 tubes were supplied to the following programs:

T-750 (bomb)
T-2031 (rocket)
T-293 (mortar)
T-790 (bomb)
Radio Research (Florida)

A quantity of QF-700 tubes of the new C-4 construction were included in the tubes delivered to the T-2061 program for evaluation in the rocket fuze.

3.4 PLANS

All future work concerned with the N-67F program is being transferred to Division 60 and will be handled by Branch 63.

4. DEVELOPMENT OF A HIGH-G, LOW MICROPHONIC TRIODE OSCILLATOR (N-68)

4.1 DESCRIPTION

This project, N-68, covers the development of a subminiature fuze oscillator triode employing metal-to-ceramic seals, and based on a conically-shaped structure which is designed to withstand greater shock and have lower microphonic output than current structures. The current design of the tube consists of a conically-shaped anode and conforming dome-shaped mesh grid. The filament is a self-supporting arch structure.

4.2 STATUS

The design and development of the N-68 tube was initiated as the result of a request, on 1 December 1949, for a rugged, non-microphonic tube of simplified structure.

The main contribution toward these objectives was the development of a rugged, hairpin-filament structure which would be self-supporting and, more important, would withstand high shock. The further development included conforming the grid and anode to the hairpin shape, evolving finally into a dome-shaped grid and anode, the whole assembled in a metallic-ceramic structure.

The first fifteen months' effort produced various structures in glass envelopes, most of which were of the T-9 (1-1/8 inch OD) size. While the actual structure fitted into a T-3 bulb, great difficulty was experienced in retaining the alignment of the structure during glass-sealing. However, sufficient T-3 samples were produced to indicate the value of the design in meeting the specified requirements.

In March 1951, all effort was turned to developing a metal-ceramic version. The problems of metal-ceramic sealing and, in particular, the problem of obtaining uniform distribution of heat to the seals had to be worked out. The result was that, while satisfactory tubes were sometimes made, it was not until 1953 that tubes could be produced with uniformity and good yield.

Figure 7, page 18, National Bureau of Standards Report 5A119, "Quarterly Progress Report on Electron Tubes for Proximity Fuzes, 1 December 1951 - 31 March 1952," shows the details of the first metal-ceramic tube design.

The cathode is an oxide-coated zirconium ribbon. Zirconium was chosen because of its favorable combination of electrical and mechanical properties.

Tubes based on this design have been made with the following average characteristics:

Item	Average	Minimum	Maximum
E_f (volts)	1.5	1.3	2.0
I_p (ma)	4.01	1.9	12.0
G_m (µmhos)	776.	600.	1200.0
mu	9.13	6.0	11.0
E_g (volts on osc.)	61.	50.	94.
Resistance (Interelectrode)		1000 megohms	
Capacitance µµf (fg)	2.30	2.11	2.89
(gp)	4.42	4.18	4.60
(fp)	0.015	0.006	0.02

Warm-up time: Of the order of 1 second.
Resistance to shock: Up to 40,000 g in gun test.

Work has been done on the design described in progress report PR-54-54, 1 January - 31 March 1954. The cathode is .0003-in. sheet titanium, formed into a conical dome, with strengthening grooves.

Tubes of this design have the following typical characteristics:

E_f (volts)	0.85
I_f (amperes)	2.0
I_p (ma)	10.

G_m (μmhos)	2500.
mu	10.
E_g (volts on osc.)	75.
Sensitivity (volts)	8.
Warm-up time (seconds)	0.4

4.3 PROGRESS

Tube construction and tube quality are being limited by the quality of the filament parts. No technique used to date has been entirely satisfactory for producing these parts. Since the filaments are formed from material .0003 in. thick, there is some question as to whether this thin material can be accurately formed by commercial methods. Manufacturers of precision stamped parts in the jewelry industry feel that it is possible, using highly skilled craftsmen, to produce a forming die capable of rapidly forming these parts in a press. The die, however, would have to be made for one specific material, and have a definite annealing schedule.

The titanium material now in use has proven to be superior to other materials. It is, however, permanently hardened after being heated in oxygen, nitrogen, or water vapor. Only work hardening can be annealed out in vacuum or in inert, dry gas.

Tubes made with glass envelopes also show that these filaments can be cracked by bending the filament leads. A check on some open filament tubes showed this to be the cause of failure. The filament coating also shows poor adherence when the coating is of the desired thickness.

An apparatus was devised to test the strength of filaments of various materials while heated in a bell jar. Some of the chromium alloys were found to compare favorably in hot strength with titanium, adhered well, and did not tend to crack.

Tests with nickel show poor results due to its softness at the elevated temperature, and the need for a high heating current. Some tests with nickel in the form of a mesh (heavier than used in earlier tests) show good performance and good adherence of the oxide coating. A chromium plated nickel mesh also gave good results.

A few tubes were completed with Inconel-Chrome alloy filaments. Initial test results on these tubes appear promising.

4.4 PLANS

(1) Obtain satisfactory filament parts.

(2) Produce enough tubes for circuit tests.

5. COLD CATHODE TRIGGER TUBE (N-71) CONTRACT DAI-49-186-502-ORD(P)-192 (Note 3) CONTRACT DAI-49-186-502-ORD(P)-194 (Note 4)

5.1 DESCRIPTION

This project, N-71, is concerned with the development of a cold-cathode, gas-filled, trigger tube with a very high input impedance. The QF-391, developed under contract (3), is a subminiature T2X3 tube with barium cathode, signal grid, keep-alive auxiliary grid, and anode. (Figure 1, page 23, National Bureau of Standards Report 5A119, "Quarterly Progress Report on Electron Tubes for Proximity Fuzes, 1 December 1951 - March 1952.") The gas filling is a mixture containing 99% Ne, 1% A at 27 cm Hg pressure. Under static conditions the tube operates in the Townsend discharge region, with a conduction current on the order of 10^{-9} ampere. The tube is sensitive to a positive signal, and when triggered is capable of conducting peak currents of 6 amperes or more. The normal anode-cathode voltage before conduction is 160 - 200 v dc. In addition to the development of the QF-391, work under this project is conducted on other types of trigger tubes and voltage regulator tubes, as noted below.

5.2 STATUS

The development of the QF-391 was initiated in February 1947 under contract (3). The original specifications were amended several times during the course of the development and each time improvements were made in tube performance.

Work was suspended at the contractor's (3) in August 1949 to afford the sponsor an opportunity to examine the suitability of the tube for its expected application. Results of this study were promising and the work was reactivated in December 1950. A pilot production run of several thousand tubes has shown that it is entirely feasible to make this tube on automatic machinery at reasonable yields.

It was found that utilization of the QF-391 trigger grid-anode gap offered the possibility of high sensitivity to a negative signal and an extremely high input impedance. The development of a tube specifically designed to capitalize on this fact was initiated, and led to the QF-831, lot CA4, which meets the requirements but demands that the input network to the grid be isolated by impedances of the order of 10^{14} ohms.

At this point it was decided to try to develop a tube which retains a reasonably high value of input impedance, yet permits a shunt leakage from grid to ground of the order of 10^{10} to 10^{11} ohms. The first tube to exhibit these characteristics is the DG-3, designed to be used in a circuit in which the grid operates at or near cathode potential.

Basic studies of the QF-391 static and dynamic characteristics have been carried on at the DOFL Electron Tube Branch and at another contractor (4).

The work of the Tube Branch was initially concerned with the measurement and interpretation of static characteristics of the QF-391, and has been extended to include the effects of such changes as tube geometry, gas fill, and electrode materials.

The dynamic response of tube and circuit is under investigation by the contractor (4). This effort is directed toward a study of the effects of tube characteristics on circuit behavior, with the ultimate goal of determining the optimum tube characteristics to achieve maximum sensitivity.

5.2.1 QF-391 is the cold cathode tetrode, sensitive to the application of a positive signal. No further development on this tube is under way.

5.2.2 QF-831 is a negative-signal triode now under active development. Two designs are now available: (a) Lot CA4 which offers high sensitivity and repeatability under repeated firings but requires that a very high impedance of the order of 10^{13} ohms be maintained between grid and ground in a floating grid circuit, and (b) Lot DG3 which offers moderately high sensitivity but permits an impedance of the order of 10^{10} ohms between grid and ground in a non-floating-grid circuit.

5.2.3 QF-848 is a negative-signal tetrode. Since the triode (QF-831) is basically simpler and perhaps less costly, and since the tetrode has not demonstrated any marked advantage over the triode, the QF-848 has not received any recent attention.

5.2.4 QF-847 is a 1000-volt triode which responds to either a positive or negative signal. Development work on this is reduced to low priority.

5.2.5 QF-840, 180 volts, and QF-840B, 240 volts, are voltage regulators. The QF-840 and QF-840B are satisfactory for their intended applications. It is believed that the present design could readily be adapted to other voltage requirements should they arise.

5.3 PROGRESS

During the past quarter major emphasis was placed on securing tubes of maximum sensitivity and repeatability, which will also function in a circuit tolerating leakage resistance in the order of 10^{10} ohms. In particular, effort was aimed at improving the repeatability of the referenced-grid type tube (QF-831, Lot DG3) which shows a minimum of 10 - 15% unstable tubes in any given test, and an average deviation of ±40% in successive readings of volts to fire. Variations of Lot DG3 included changes in geometry, gas filling, and grid position. These modifications of the DG3 construction did not result in over-all improved repeatability.

When tested in a modified floating-grid circuit, however, this tube showed improved repeatability but was sensitive to grid to ground leakages of 10^{12} ohms.

Improvements in repeatability through circuit redesign were achieved by biasing the grid to a sensitive point by means of a capacitance voltage divider circuit. Lot CA4 tubes (originally designed as a floating grid triode) were used. Preliminary results indicated greatly improved repeatability over the DG3 with a tolerance limit on leakage of about 5 x 10" ohms as compared to 10^{10} ohms for the DG3 in the referenced-grid circuit and 10^{13} ohms for the CA4 operating in the floating-grid circuit.

Two new designs, developed for referenced-grid type operation, show promise of combining sensitivity with repeatability and tolerance to leakage resistance. These designs are (1) a tube incorporating an auxiliary cathode which, in limited testing, has shown very good repeatability and moderate sensitivity with 1 or 2 seconds regulating time; and (2) a tube employing a cylindrical cathode and anode which fires at low voltage ($\leq$1 volt) with good repeatability. However, the average regulation time is about 18 seconds and the average extinction voltage is 145 volts. This design incorporates a trigger grid in a constant starting voltage diode.

Static characteristics of the tubes of current interest were measured. Additional measurements are required and analysis of results will be reported in the next quarter.

A general analysis is in progress (4) in which an equivalent circuit of the positive signal QF-391 is approximated and solved on an analog computer. Revised computer results indicate good agreement for time-to-fire at high rates-of-rise, but deviate considerably at the low rates-of-rise. Efforts to check the computer results have led to (1) the solution of a simplified version of the original non-linear circuit; (2) the analysis of a similar circuit containing a linear inductance; and (3) the installation of a bench test to compile data on actual tubes.

5.4 PLANS

(1) Continue development of negative-signal tubes with emphasis on combining sensitivity with repeatability and tolerance to leakage resistance.

(2) Continue laboratory studies of tube properties, and features of tube and circuit combinations.

(3) Continue investigation of basic mechanisms of trigger tube operation.

6. ELECTRICAL AND MECHANICAL MEASUREMENTS ON TUBES FOR GUIDED MISSILE FUZING (N-74, N-75)

6.1 DESCRIPTION

These projects, N-74 and N-75, cover electrical and mechanical measurements, and investigations of tubes employed in guided missile fuzes with the following specific objectives:

(1) Determine microphonic disturbances generated by tube types employed in the video-frequency range, when operated in specific circuitry and subjected to 40 -- 10,000 cps vibration at various acceleration levels.

(2) Undertake special investigative problems as assigned, and carry out an analysis program on defective tubes.

(3) Advise work sponsors on testing and quality control procedures to be employed in determining electrical and mechanical reliability of tubes.

(4) Determine survival under specific conditions of high impact shock, centrifuge acceleration, and vibration.

(5) Establish maximum acceleration values and a concomitant frequency spectrum for tubes employed, without sacrifice of original electro-mechanical operating characteristics.

6.2 STATUS

Originally established in July 1952, these projects were initially inactive due to a scarcity of scientific manpower. The work was activated toward the latter part of Fiscal Year 1953, and various problems have been investigated.

On assignment, shock and vibration tests have been completed on various subminiature tube types in specific circuit applications and a general environmental program is being considered. Although the emphasis has been on specific applications and investigative problems, the tendency recently has shifted to the mechanical environment that the tubes can withstand.

6.3 PROGRESS

6.3.1 Strike Voltage - Type 5643 Thyratron

The question has arisen as to the effect on reliability of the 5643 thyratron when "sparked" with a high-voltage Telsa or induction coil.

This question originated from the fact that one contractor found that the grid-firing characteristic changed due to "sparking". The "sparking" process is used by some tube manufacturers to eliminate leakage paths across insulating surfaces in processing tubes. The effects of this process on tube parameters and life are a subject of controversy.

A life-testing rack was constructed and put in operation with ten thyratrons to study the effects of "sparking" upon these tubes. The rack was built so that a control lot of "unsparked" tubes could also be observed.

Observations indicate that "sparking" produces a permanent decrease in tube oscillation, thereby producing a higher dc tube drop within the thyratron and appears similar to an accelerated life test for the tubes. This oscillation, developed across the tube, is observed to be as great as 9 volts peak-to-peak when the tube is fired with a square pulse on the plate (the tube is diode-connected so that both grids are connected to the plate - MIL-E-1b Pulsed Emission Test). The frequency of this oscillation ranges from 100 to 400 kc for new tubes and increases to values above a few megacycles due to "sparking" or operation life. A few minutes of "sparking" not only increases the frequency but can reduce the amplitude to values as low as 100 mV.

In other types of circuitry, where the thyratron is fired with the grid, cathode-to-plate oscillations ranging to 20 volts (p-p) are observed with comparable frequencies. "Sparking" and operation life have very little effect in raising these frequencies.

The oscillations across the thyratron appear to be of the relaxation type, caused by the tube, and in some instances influenced by external circuitry.

Experimental work on this problem was completed during the last quarter, and a technical memorandum was prepared on the analysis during the present quarter.

6.3.2 Vibration of Subminiature Tubes

This investigation is being conducted to determine the effect of continuous vibration at the frequency of maximum response below 1000 cps with acceleration levels of 5, 10, 15 and 20 g.

Preliminary observations indicate that the condition of the mica bumpers could be a fairly reliable index of tube noise and life. The characteristics observed were the condition of the cathode sleeve and grid rod holes in the mica and whether or not the mica bumper points are pressed tightly against the glass. This fact will be checked constantly in future vibration tests.

A separate technical memorandum is being prepared on each tube type as work is completed.

6.3.3 Effect of Shock on Subminiature Tubes

The effect of repeated shock impulses of approximately 110 g with an impulse time of 8 milliseconds will be the object of this investigation. Work has just started on this problem.

6.3.4 Reporting

A technical memorandum "Defective Subminiature Tube Analysis for Fuze Project Reporting Defect", dated 8 June 1955, was issued. By request, technical memoranda were sent by the Tube Laboratory to the various fuze projects on the test results of their particular tubes.

6.4 PLANS

(1) A general environmental (shock and vibration) study will be made on all subminiature tubes used in guided missile fuzing. Shock measurements are to be performed at approximately 110 g with an impulse time of 8 milliseconds. Vibration tests will be made at 20 g from 40 to 1000 cycles. Tubes used as class A amplifiers will be vibrated at the frequency that produces the maximum output.

(2) The program of examination and reporting upon defective tubes will be continued.

7. FUZE TUBE RESEARCH (N-89)

7.1 DESCRIPTION

This project, N-89, is concerned with basic investigations of noise phenomena encountered in fuze tubes, and with the application of the results of these investigations to improvement of fuze-tube design.

7.2 STATUS

During the course of this project the following investigations have been carried out:

(1) Study of the origin of spike noise in the QF-700 tube. It was established that the noise arises from bombardment of insulating surfaces. As a result of this study bands and shields were found to be effective in reducing this type of noise.

(2) Study of the mechanism of noise production from electron bombarded insulators. The results of this study showed that the floating surface potential of an electron-bombarded insulator can, under certain conditions, become unstable, and a sudden shift of this potential can give rise to spike noise.

(3) Study of the effects of processing on tube noise and stability in the QF-700. As a result of this work an understanding of the origin and nature of "climbing plate current" and means for its control has been obtained.

(4) Study of the contaminants released from QF-700 tube parts during processing. This study has led to an improved processing schedule which minimizes the deleterious effects of contaminants.

The study of the mechanism of noise production from electron-bombarded insulators, showed that the secondary-emission properties of an insulator are of fundamental importance in the production of spike noise. The secondary-emission coefficients of insulators are not available in the literature. A complicating feature in experiments on insulators is that layers of material transferred from the cathode are deposited on the insulator surfaces. To study the secondary emitting properties of insulators, a special bent-beam tube was constructed so that the insulator target is not exposed to the cathode.

7.3 PROGRESS

Tests were made, with apparatus developed during the previous quarter, in which the secondary electron emission of two different insulators is compared by deflecting the primary electron beam across a nickel target, with the test specimens of insulator material located at the two ends of the target. The beam is pulsed once on the insulator, then twice on the nickel target, to supply sufficient secondary emission to restore the insulator to its initial condition. Some of the primary beam was intercepted by the deflecting electrodes on the first tests causing a loss in primary beam current. This was corrected by flaring the deflection plates. Stray current was found to be striking the glass envelope, and additional shielding was required around the target structure.

A comparative test between an uncoated mica and a mica specimen spray-coated with M_gO_2, showed higher secondary emission current from the uncoated mica. There is still considerable uncertainty as to the accuracy of the measurements. The value of the measured secondary emission ratio appears to be too low, and the maximum obtained near 200 volts appears to be at too low a voltage. The tests were interrupted by cathode failure.

Approximately 20 subminiature oscillator tubes were constructed in order to obtain an improved design for a tube structure intended to test the possible improvement in the signal-to-noise ratio in a fuze tube. Although all structural changes are not completed, these tubes show several improvements. Performance is found to be better than for the earlier tubes. Tests so far appear to be favorable, though further tests are needed.

7.4 PLANS

(1) Continue development of secondary emission measurement techniques.

(2) Investigate improved fuze tube designs.

8. NON-MICROPHONIC, HIGH-G, TRIODE OSCILLATOR TUBE (N-92) CONTRACT DAI-49-186-502-ORD(P)-188 (Note 5)

8.1 DESCRIPTION

This project, N-92, covers the development of subminiature triode oscillators which would use glass-to-kovar seals and tungsten-wound ceramic cathodes. The contract was originally assigned to a contractor (5) for the purpose of performing research and development to evolve the design of a series of fuze tubes to withstand high accelerations and to be non-microphonic. This project was specifically set up to diverge from the former approaches to the problem (i.e., improvements in hearing-aid tubes), and it was stipulated that reproducibility and mass production be stressed as paramount objectives. The tube design is aimed primarily to provide tubes for high-g fuzes and, if possible, to satisfy the requirements of fuzes where low microphonic output is required. The BL-102 triode is the first of the above-mentioned series and is intended for use in oscillators.

8.2 STATUS

In November 1949, the contractor (5) was requested to consider the problem of developing a non-microphonic, quick-heating and rugged (40,000 g) triode, suitable for use in fuze oscillator circuits. The contractor was requested to take a new approach to the problem, rather than to improve existing filamentary triodes which had been derived from hearing-aid tube designs. A tube structure utilizing kovar-glass sealing techniques, and eliminating the glass base and mica supports of conventional tubes was conceived by the contractor.

From the inception of this project, the major effort has been directed toward overcoming the problems involved in making a cathode structure to meet these requirements. Initially, a stretched filamentary cathode was used but it was found to be microphonic due to the low resonant frequency and insufficiently rugged because the force necessary to accelerate the tensioning spring was transmitted to the filament.

In February 1952, the contractor developed the so-called "barber pole" cathode. This consists of a tungsten ribbon wound in a spiral on a ceramic rod. This construction was attractive from its inherent non-microphonic properties and resistance to high-g shock. Difficulties were encountered in adherence of the coating to the cathode, and of the metal spiral to the ceramic.

These problems have been overcome by overlaying the ceramic with powdered fire brick. This material has compliance which is sufficient to secure the ribbon filament during warm-up.

The N-92 triode at present has a flat-strip filament spirally wound around a 0.040-in. diameter ceramic rod, and is appropriately called a "barber pole." The cathode and grid structures are sealed to the plate with glass-kovar seals. A KIC getter is installed between the plate and an extra connection which is brought through the glass.

At present, the primary requirements on the tube are:

(1) Withstand setback of 40,000 g for 0.012 second with a spin of 150 rps on a 3/8-in. radius.

(2) Warm-up time not greater than 0.25 second.

(3) Filament supply voltage of 1.9 to 2.5 volts with 1.3 amperes maximum.

(4) Microphonic and self-noise output shall not be greater than 10 mv when subjected to 10 g of white noise from 100 - 10,000 cps.

(5) Size shall be approximately T-2 or T-3 and not to exceed 1.15 in. in length.

(6) Tube shall develop the maximum bias consistent with a maximum sensitivity-to-noise ratio in a specified oscillator circuit.

8.3 PROGRESS

Eighty-four tubes were received during this quarter. All tubes were of the double-eyelet, basket grid type with .0685-in. I.D. grids and .089-in. I.D. plates. The design was frozen throughout this period so that complete effort could be directed toward determining the cause of the initial drift in developed bias, and improving the emission.

Initially, tubes were fabricated with various aggregates of firebrick and one lot with pure kaolin. Results indicated that the aggregates and the kaolin were all satisfactory, and were not contributing to drift to any degree. To evaluate the extent that end-effects were contributing to drift, tubes were fabricated with 9 cathode turns, the 7 center turns oxide coated on a

.200-in. ceramic. This construction did not expose the end turns directly to the plate and drift was improved. Copper rods were inserted in the cathode sleeves of the same model and drift was reduced by about one to two volts. These tubes, while exhibiting low drift, also exhibited relatively low developed bias (36 v) and sensitivity (2.6). These tubes had low perveance as exhibited by the diode curve, and, as it was determined that the major portion of the drift could be attributed to end-effects, effort was directed toward improving emission in the stock tube. As this period closed, the emission has been improved considerably by a-c aging and the developed bias ranged between 50 - 60 volts.

Reverse winding the filament, or winding the filament with a pitch opposite to that of the grid, has considerably reduced the spread in the values of G_m, r_p and μ. An automatic filament winder has been completed and will be evaluated in the coming period. A small number of cathodes were electroplated by a process developed at National Bureau of Standards. In this process, only the tungsten ribbon is coated with emissive material without binder. Tubes were fabricated with this cathode, and showed promise. This method of coating the filament will be investigated further.

8.4 PLANS

The major emphasis in the future will be on further improvement of the emission properties of the tube, and on modifying the cathode to eliminate end-effects.

9. REFLEX KLYSTRON RESEARCH FOR GUIDED MISSILE FUZING (N-95)

9.1 DESCRIPTION

This project, (N-95), covers research and development on klystrons for use in guided missile fuzing applications.

9.2 STATUS

A program of klystron research in support of guided missile fuze requirements has been active in the Electron Tube Laboratory since 1950. Various problems of interest to the fuze program have been studied.

9.2.1 The "floating drift tube" klystron is a single-cavity, two-gap klystron with a drift tube which can be voltage modulated. This type of klystron design was investigated as a possible replacement for the reflex klystron, since it has the advantage of a smoother mode shape and requires only one power supply. Operable tubes were designed and constructed, and a thorough evaluation of their capabilities was completed. It was demonstrated that the floating-drift tube had a smoother mode shape than the reflex klystron; however, at the voltages and frequency desired for fuze operation, the power and bandwidth obtainable in this design were inadequate. It was concluded that under the conditions imposed by current guided missile fuze requirements this design did not offer sufficient promise to be continued, although this type of klystron is applicable in high-voltage, higher-power systems. These experiments proved that multiple-transit electrons were the cause of the distortion problem.

9.2.2 The monotron. This was a theoretical study only, investigating the characteristics of several types of single-cavity oscillators for fuze use, especially at higher frequencies. Some interesting new theoretical results were obtained, but the practical ranges of voltages and frequencies were not useful for fuze purposes.

9.2.3 A method was devised for eliminating multiple-transit electrons in reflex klystrons by spreading the beam in the repeller space. The method was successful insofar as multiple-transit electrons are concerned, and it is also believed that the tubes now being investigated, using a tilted beam, will be at least as free from distortion and will be more efficient and have greater bandwidth.

9.2.4 Plasma ion oscillations. Ion oscillations were observed in the R-1 klystron about January 1952. It was observed that the r-f output of the tube, instead of being essentially monochromatic, often contained a pair of sidebands whose frequency separation from the carrier was somewhere between 600 kc and 15 mc, the most usual separation being about 5 - 6 mc. Further investigation established that these sidebands were at times as strong as 40 db below the carrier, and that they were the result of some phenomenon which produced both AM and FM of the klystron simultaneously. Interest in eliminating these sideband signals arose after it was established that, in missile fuzing systems which utilize the FM spectrum of the R-1, the ion oscillation sidebands could cause a malfunction of the fuze; indeed, in the field, the misfire of a test missile has been attributed on at least one occasion to ion oscillations in the R-1. Investigation of the problem revealed that ion oscillations can occur in high-vacuum electron tubes wherever the electronic configuration permits a stable potential minimum to occur. The early models of the R-1 did possess such a minimum, and it was found that the trouble could be eliminated by leaving a 0.050 in. hole in the center of the smoother grid. It was thought, however, that an effort should be made to explain, insofar as possible, the necessary physical conditions for the existence of these disturbances. To date it has been possible to amass a considerable amount of data on experimental tubes, to obtain three distinct classes of disturbances, and to eliminate certain theoretical pictures of the nature of the oscillations.

9.2.5 Space charge effects in klystrons. During the past year a theoretical and experimental study has been carried out on the effects of the d-c field of the space charge in klystrons.

The calculation of space charge effects in reflex klystrons has been completed by SEAC. An analytical small-signal theory of the same problem has also been obtained and is in substantial agreement with the numerical calculations. The analysis of space-charge effects has been extended to cover two-cavity klystrons.

A report describing the inflection-point method of measuring the loaded Q of single-ended cavities is being prepared.

A ten-amplifier electronic analog computer has been ordered. In addition, a non-linear function generator has been constructed. With this equipment the laboratory will be able to solve certain mathematical equations which describe the performance of certain electron tubes. Some of these problems are listed below:

(1) The efficiency of the monotron oscillator in higher-order cavity modes.

(2) The firing characteristics of certain thyratron triodes.

(3) The potential distribution in a planar tetrode, including the effects of secondary electrons.

9.3 PROGRESS

The characteristics of a reflex klystron are poorly predicted by theories which neglect the effects of spare charge in the tube. In particular, the over-all efficiency of a given tube will be many times less than the theoretical value. The results of the SEAC calculations are being compared with highly detailed measurements on five tubes. It appears that when this comparison is completed there will be excellent agreement between the measured characteristics and the performance predicted by the new theory. Some of the calculations were briefly discussed in a paper presented at the Conference on Electron Tube Research, East Lansing, Michigan, on June 13. It is intended that a paper will be published to make generally available the results of the SEAC work.

A study is being made of the performance of a low-voltage, low-power X-band reflex klystron operated as a direct Doppler detector. Successful operation depends upon the fact that the power output of a reflex klystron can be made sensitive to the load presented to the tube, particularly the reactive component of the load. If the phase of the load varies periodically, the power output of the tube will vary with the same period. It has been possible to detect reflected signals (from a 4-kc Doppler wheel) which were approximately 90 db below the outgoing signal, the klystron producing a power output of about 15 mW. An effort is being made to achieve 100 db or greater with 10 mW or less without resorting to narrow-band amplifiers in the detector circuit.

An investigation concerning the operation of a magnetron oscillator under extremely short pulse conditions has been started. Very little is known about the behavior of a magnetron when it is pulsed for a time which is comparable to the damping time of the cavity. Analysis of the oscillations appear to be difficult when the tube is always in the transient condition. Nevertheless, pulses of the order of 2×10^{-8} second duration have been successfully applied to an X-band magnetron. In order to achieve high range resolution in a radar system, it would be desirable to reduce this pulse duration. It should be possible to do this at a higher operating frequency. In principle, if a magnetron could be built to oscillate at a few mW wavelength and could be pulsed at approximately 10^{-9} second, a range resolution on the order of a few inches could be obtained. There appear to be many applications for such a radar.

9.4 PLANS

A paper describing spare charge effects in klystrons will be completed. The computer should be ready for problems early in the quarter. A program for magnetron study will be established.

10. TRANSMIT-RECEIVE TUBE EVALUATION (N-99)

10.1 DESCRIPTION

Project N-99 covers the evaluation of transmit-receive (TR) tubes, and investigation of TR tube problems which are of importance to radar-type fuzes for guided missiles. The TR tube should be characterized by mechanical ruggedness, shoul' ' afford adequate crystal protection before and after storage, and have a recovery time which permits reliable system operation at ranges of a few hundred feet when used in conjunction with a transmitter delivering 0.2 μsec pulses of 90-kw peak power at a pulse repetition rate of 400 pps.

10.2 STATUS

Initially, the Type BL-9 X-band TR (5) was chosen for experimental use because its characteristics approached those required. When it was learned that the same type of tube could be obtained without a gas reservoir (Type BL-30) the electrical characteristics of the two were compared. After it was found that the characteristics were similar, the type BL-30 was adopted for use because of its smaller physical size, lighter weight, and more rugged external structure.

Initial measurements of characteristics at room temperature have been made on 106 tubes comprising six specific groups, as they were received from the manufacturer. The minimum power to produce the v-f discharge, and recovery time as a function of echo signal strength, have been made on a limited number of tubes. Investigations of relaxation oscillation phenomena have been made under various ignitor-circuit operating conditions. These were simplified searches to determine whether any serious oscillatory conditions existed. Representative tubes of each series have been chosen for shelf-life tests. These tubes are being stored at room temperature, and periodic checks of their characteristics are made.

During preliminary vibration tests on the type BL-30, ignitor circuit failures occurred in the frequency range 40 - 60 cps at 15 g acceleration. Because of these failures, more extensive vibration tests were performed, and it was found that the glass insulation around the ignitor electrode was breaking and allowing the electrode to short. To overcome this, a ceramic insulator like that used in the BL-9 was tried and resulted in considerable improvement. Several BL-30's and BL-9's have been subjected to 100 g shock tests with no harmful effects to the ignitor circuit evident.

Shelf-life characteristics of the type BL-30 TR tube are being studied. The results after one year show an increase in recovery time and leakage power.

The characteristics of the type BL-95H band-pass TR tube are being evaluated. This tube, which uses quartz wool as a filler and is equipped with a thermostatically controlled heater, has shorter recovery time and should be more rugged because of a shorter ignitor electrode.

The spike leakage energy of the BL-30 and BL-95H TR tubes is being studied using the variable-pulse-width method.

Work on an X-band viewing system to study the leakage power characteristics of the TR tubes is continuing.

10.3 PROGRESS

Ten BL-30 TR tubes were received during the quarter from the manufacturer and subjected to evaluation tests. None showed any mechanical troubles and all tubes were usable electrically.

Twenty BL-95H band-pass TR tubes were received from the contractor (5) and are at present undergoing electrical and mechanical evaluation. The results so far are inconclusive.

Tentative purchase specifications for the BL-95H TR tube have been written.

Spike leakage measurements were made on fifty BL-30's after shelf aging from one to two years. All of the tubes passed the 0.5 erg specification after one year shelf life. The maximum leakage energy was 0.345 ergs and the average was 0.147 ergs.

10.4 PLANS

TR tubes that are received will be evaluated according to tentative specifications.

Evaluation of BL-95H type TR's now on hand will be continued.

Work will continue on the study of spike leakage energy.

Development work will continue on a high-voltage ultra-fast sweep circuit used on the high-speed micro-oscillograph X-band viewing system necessary in the study of leakage power characteristics of the TR tubes.

11. MAGNETRON EVALUATION (N-100)

11.1 DESCRIPTION

Project N-100 is for the purpose of evaluating magnetrons for use in guided-missile fuzes. Problems investigated include mechanical ruggedness, stable operation after storage, effects of short warm-up time and loading on starting ability, and other special properties required in fuze use.

11.2 STATUS

This project was initiated in July 1952 with an investigation of the possible use of the magnetrons 4J52 or L3036 (6). The 4J52 is an X-band, 50-kw pulsed magnetron operated at 15 kv, 15 a. The L3036 is an experimental, ruggedized version of the 4J52. Tests on a small number of tubes established that both types had no resonances below 1200 cps. In addition, the tubes would pass the following tests without failure:

500-g shock on NRL shock machine, and
15-g acceleration from 60 - 500 cps.

Both the 4J52 and the L3036 had a heater rattle when accelerated above 10 g, but could be considered mechanically reliable for periods of vibration of less than one hour. From these and other tests it was concluded that the 4J52 was sufficiently rugged for the intended use and that the increased ruggedness of the L3036 was not sufficient to offset its additional complexity of fabrication.

Although new tubes of both types started stably with a cathode-conditioning time of only 90 seconds, there were indications that deterioration of starting qualities occurred after storage. The instability of these tubes was found to be caused primarily by moding. Very little sparking occurred, and stability improved somewhat with running time. This starting stability was improved considerably by reducing the rate of rise of the applied voltage pulses from 225 kv/μsec to 170 kv/μsec but the reliability of stable starting with only a short warm-up after storage is yet to be determined.

In cooperation with the manufacturer (6), a specification was written for a prototype 4J52 to include requirements necessary for reliable operation under conditions peculiar to guided missile applications. The tube was designated the L3037. It is effectively a 4J52 fabricated and processed with extreme care so as to meet more stringent stability requirements after storage.

Present work involves the testing of new and old tubes both electrically and mechanically, and serves a dual purpose. By testing all tubes prior to use in experimental units, the probability of magnetron failure in these units is lessened, while data is obtained to determine the reliability of tubes of various lots.

Each shipment of L3037 tubes receives the following tests in sequence:

(1) After a warm-up of 90 seconds, measurements are made of average power output, filament current and missed pulses for the following conditions: E_f=12.6 v, epy=14 kv, rrv=170 kv/μsec, D_u=10^{-4}, prr=400 cps.

(2) One 200-g shock on the NRL shock machine in each of four possible directions while filament current is monitored.

(3) Fifteen minutes vibration at 15 g, 60 cps, while spectrum and filament current are monitored.

(4) Repeat test (1).

Tubes not required for immediate use are stored for shelf-life tests.

11.3 PROGRESS

Fifty-five L3037 magnetrons were given complete electrical and mechanical tests. All of the tubes passed the first electrical test and were extremely stable. After a warm-up of 90 seconds, a maximum of 0.15% missed pulses were recorded.

Mechanical test results were not so favorable, however. All of the tubes passed the shock tests but four developed open heaters on vibration. Examination of these four revealed that all heaters failed at a point adjacent to the heater-cathode weld. Accordingly, an investigation was initiated by the manufacturer to determine a means of correcting this weakness. Pending completion of this investigation, the shipment of tubes has been discontinued.

11.4 PLANS

It is expected that tube shipments and mechanical evaluation testing will be resumed in August. In addition, stored tubes will be checked for effects of shelf life.

12. DEVELOPMENT OF SUBMINIATURE BEAM DEFLECTION OSCILLATOR FOR VT FUZES (N-101)
CONTRACT DAI-49-186-502-ORD(P)-193 (Note 3)

12.1 DESCRIPTION

Project N-101 covers the development of a QF-826 beam-deflection oscillator tube with a filamentary cathode. The tube is in a T-3 glass envelope, and is operable as an oscillator in the frequency range from low audio to mid-UHF.

A schematic drawing of the tube is given in Progress Report PR-54-69, 1 April - 30 June 1954. The principles of operation are given in the same report.

12.2 STATUS

The QF-826 beam deflection tube was invented by Dr. Robert Adler of the Zenith Radio Corporation. The QF-826 project was formally authorized on 10 September 1952. A contractor (3) is developing the tube for improved electrical and mechanical performance and improved manufacturability.

A "rubber-sheet model" of the tube was built to study the effect of dimensional variations within the tube. It proved to be a very useful tool in design of experimental lots of tubes.

Equipment has been constructed to obtain the characteristic curves of the tube. The circuit and curves are discussed in NBS Report 12.2-388R. A recent modification of the circuit permits simultaneous observation of the three curves and two reference lines on an oscilloscope.

Investigation of microphonics of the tube indicated that the tube would probably be low in microphonics after being mechanically improved. Later tests showed that there was a marked decrease in microphonics as the contractor (3) began to make the tubes according to accepted production line techniques. Further improvements in microphonics were observed after modification of the mechanical design of the tube. Noise output of the oscillating tube has been observed with the tube in both quiescent and vibrating conditions. Swept sine wave and white noise vibration have been used in the evaluation of microphonics.

Many of the tubes in early production lots showed lack of symmetry and poor electrical centering of the beam. These difficulties have been almost completely eliminated.

Since contract inception, the contractor (3) has delivered 69 lots totaling approximately 2400 tubes. Cathode current averages five milliamperes with 150-volt B+ supply and 1.4-volt filament supply. The tubes will withstand uniform acceleration of 10,000 g in any direction. All sampled tubes have passed the MIL-E-1B test for glass strain.

Microphonics is still a major problem in the QF-826, with the filament-resonance signal being one of the major sources of microphonic output. Other microphonic signals have been observed but have not been definitely identified.

Power output is another point of concern, and steps are being taken to increase the power capability of the tube.

12.3 PROGRESS

During the quarter ending 30 June 1955, the contractor delivered a total of 465 tubes. Of this number, 185 were of the new "C" construction design which is a ruggedized version of "A" construction and has the modifications of locking micas and a preform button. This type of construction has been delayed considerably because of the supplier's failure to deliver, on schedule, parts which met specifications, and also because of the technical difficulties encountered by the contractor (3) in the assembly of tubes using the preform button (strains develop and envelopes crack after sealing). The mortality rate has been very high in the production of "C" construction tubes with only 185 tubes being produced from 500 mounts. It has been observed from data obtained from tubes tested thus far that there is no reduction in the microphonic output of tubes of present "C" construction when compared with tubes of "A" construction having similar dimensions and sensitivities.

The remaining 280 tubes received during this quarter were a series of lots of "B" construction which are being used to determine the best location of the anode aperatures for that type of construction. It has been found that the "B" construction tubes are superior to "A" construction in power output, but are radically inferior in terms of sensitivity.

The DOFL-designed four-beam tube has been modified and several tubes produced with very good test results. Mica punches are being obtained to facilitate the assembly of these tubes and aid in further modification.

A small high-temperature hydrogen furnace is being used to develop techniques for metalizing ceramic surfaces for use in the ceramic work on the QF-826. Bids have been requested from various manufacturers on parts to be used in the ceramic tube.

A problem concerning the variation of probe voltage during operation has been encountered. Some investigations have been made as to the cause, but no answers to the problem have been found as yet.

12.4 PLANS

The tubes of various lots will continue to be evaluated as received, with respect to microphonics and quiescent noise.

Modifications will be made in the "C" and "B" constructions to reduce the microphonic output and improve the operating characteristics of these designs. Development work will be continued on the four-beam, and ceramic versions of the QF-826.

Investigations will continue to be made to determine the cause of the variation in probe voltage and what can be done to reduce or control this effect.

13. TRANSISTORS (N-102)

13.1 DESCRIPTION

This project, N-102, covers research and development on transistors. Ordnance applications place special requirements on transistors not met by current transistor developments. The current objective of the semiconductor program at DOFL is the establishment of a facility that will make it possible to produce specialized transistor devices, and to study the relation between the bulk properties of semiconducting materials and the equivalent circuit parameters of transistors.

13.2 STATUS

This project was formally established at the beginning of Fiscal Year 1954. Progress to date includes the setting up and operation of the basic equipment for producing and testing transistors, experimentation with point-contact transistor action on a micromanipulator setup, and the design, fabrication, and testing of point-contact transistor units sealed in glass.

Work is continuing on refinements in instrumentation of the major equipment items being used in the facility. Equipment is now available for converting unpurified polycrystalline germanium to purified single crystal material.

13.3 PROGRESS

The temperature controller for the single-crystal furnace was placed in operation this quarter. Only one crystal was grown, but the result indicated that the degree of temperature control available would be sufficient. No attempt was made to control the purity content of the material, but measurements are planned to determine the crystal orientation.

Unpurified germanium obtained from a commercial supplier was zone purified in both helium and vacuum to determine the relative merits of the two ambients. Vacuum processing resulted in the purified portion of the ingot having an average resistivity of 60 ohm-cm, whereas the helium processed material gave 46 ohm-cm. The starting material was the same in both cases - 2 ohm-cm. The vacuum processed material was also more uniform in cross-sectional area indicating less temperature fluctuations. It is suggested that the reason for the improved resistivity in vacuum might be the loss of impurities evaporation, and there is some qualitative information to support this. Experiments are underway to repeat the processing using purified and doped germanium in order to determine the effects quantitatively.

13.4 PLANS

Zone purification studies in vacuum and helium will be continued using doped germanium. Incidental to this will be the development of doping procedures.

Single crystals will be grown using the temperature controller to develop techniques. Some doped crystals will be grown to determine resistivity gradients.

Studies on the relationship between the properties of the bulk material and the equivalent circuit parameters of the transistor will continue. As soon as practical it is planned to check the analytical studies experimentally.

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