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PART 1
SECTIONS 1-7
1/2A

DEPARTMENT OF ENERGY DECLASSIFICATION REVIEW

1ST REVIEW-DATE: 01/06/03 AUTHORITY: ☐ AOC ☒ ADC ☐ ADD NAME: Jason D Adams 2ND REVIEW-DATE: 10/29/02 AUTHORITY: ADD NAME: Ronald Williams	DETERMINATION [CIRCLE NUMBER(S)] 1. CLASSIFICATION RETAINED (2.) CLASSIFICATION CHANGED TO: FRD 3. CONTAINS NO DOE CLASSIFIED INFO 4. COORDINATE WITH: ____ 5. CLASSIFICATION CANCELLED (6.) CLASSIFIED INFO BRACKETED 7. OTHER (SPECIFY): ____

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Unauthorized Disclosure Subject to Administrative and Criminal Sanctions. Handle as Restricted Data in Foreign Dissemination. Section 144.b, Atomic Energy Act of 1954.

229 pages

RS 3466 (4467)

This is the first draft.

Needsto be proof read.

After reproduction, needs paging

of 1. Contents

2. Text

3. List of Illustrations

4. List of Figures

5. Figure Numbers Need Revision.

All figures were made from tracings.

Needs index with paging.

This is the original. There is one copy which does not have all the ~~figures and~~ photographs.

Portions of this report have been documented so their contents may not be mutilated.

For convenience of reading, this copy is in two parts. Ditto for the copy of this original.

~~Some figures are the original tracings - not reporduced for security documentation reasons. Other classified prints and tracings have not been documented.~~

ABEE and ABEE TESTER (U)

CONTRACT AT(30-1)-677

AN HISTORICAL ACCOUNT

of the

CONTRACTUAL, ORGANIZATIONAL, AND TECHNICAL DEVELOPMENT. (U) SS 11/29/01

by

CHARLES A. DEBEL

MOTOROLA INC.
PHOENIX RESEARCH LABORATORY
3102 NORTH INGLESIDE DRIVE
PHOENIX, ARIZONA

AUGUST 25, 1950.

PREFACE

The ABEE and ABEE Tester Contract No. AT(30-1)-677 between the Atomic Energy Commission and Motorola Inc. became effective June 27, 1949. Initially under the cognizance of the New York Office of the AEC, the contract responsibilities were later transferred to the Sandia Corporation, Albuquerque, New Mexico, an authorized representative of the Atomic Energy Commission and a branch of the Los Alamos Scientific Society. Motorola, the contractor, effected an evaluation of a production model of ABEE which was developed by the Sandia Corporation. With the information available, Motorola proceeded to design and develop an equipment suitable for mass production. The work was divided into seven parts; (1) evaluation of the Sandia model, (2) additional development, (3) fabrication of a laboratory model, (4) fabrication of a production model, (5) fabrication of a production prototype, (6) pilot production, and (7) production.

The contractual affairs began with a letter of intent which was to become definitive pending (1) the evaluation of technical specifications which would prescribe the equipment operating characteristics required for the class of operation and (2) the establishment of an equitable financial consideration. Additionally the product requirements developed during the year of activity, originally comprised the fabrication of 50 prototype models of ABEE and 6 similar models of the ABEE Tester.

One year later the contract requirements included in addition to the original requirements (1) 50 prototype ABEE models, (2) preparation for the production of ABEE, and (3) preparation for the production of the ABEE Tester. A later purchase order from the Sandia Corporation added, not a requirement of the above contract, the production of 540 ABEE equipments, 270 Antenna Assemblies, and 100 ABEE Testers.

To be covered by another contract with the Sandia Corporation were plans for continued development and improvement of ABEE.

This account describes the activities to approximately August 1, 1950; the activities beyond that time including (1) pilot production, (2) production, and (3) additional development.

That the program was effected at a location in comparative close proximity to Albuquerque was a considerable advantage to Sandia and Motorola. The many technical and other contacts were invaluable to the rapid progress of the technical aspects of the program.

The writer wishes to acknowledge the very excellent cooperation afforded by all groups concerned; (1) the New York AEC, (2) the Sandia Corporation, and (3) the Motorola activities in Chicago. Special commendation is given to the Sandia Laboratories of Engineering and Applied Physics for their assistance and enthusiasm which was evident throughout the year of great activity. The writer wishes to commend Helen Garvey for diligence in the preparation of this manuscript.

August 24, 1950 C. A. D.

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Introduction - The first contact - Purpose revealed - Letter of Intent Contract - Personnel Security Clearance - Target specifications - Preliminary Evaluation of The Sandia Production Model - Development Status of ABEE.

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This account of the Abee and Abee Tester programs is recorded during July, 1950, approximately one year after the initial contact, May 14, 1949, by representatives of the Sandia Laboratory and the Atomic Energy Commission. The Sandia Laboratory was a branch of the Los Alamos Scientific Society, a development of the Atomic Energy Commission. During the greater part of 1949, the Sandia Laboratory, at Albuquerque, New Mexico, was managed by the University of California. The management function was later to be assumed by the Western Electric Company.

On May 14, 1949, Motorola was visited by personnel of the Sandia Laboratories and the Atomic Energy Commission.

The Atomic Energy Commission wished to inspect the facilities of Motorola at Chicago to determine whether or not that organization would be suitable for new work which was to be subcontracted by the Sandia Laboratories. The visitors inquired to determine the extent of Motorola's interest in the fabrication of a few development models for the AEC. Motorola was interested in the proposed association with Sandia and the AEC. Accordingly, an inspection tour of the Chicago facilities was conducted to acquaint the visitors with the Motorola organization and facilities. The Sandia representatives present included R. A. Bice, T. F. Marker, J. H. Hoffman, W. G. Funk, and G. Bachand. E. O. Martin represented the Chicago office of the Atomic Energy Commission.

Shortly after May 14th, Robert Kirkman of the New York Atomic Energy Commission Security office contacted several Motorola personnel

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to initiate the procedure required to obtain security clearance. By June 24, 1949, clearance had been obtained for D. E. Noble, J. F. Silver, and M. E. Whitney of Motorola.

The first conference, June 24, 1949, was a visit by D. E. Noble, J. F. Silver, and M. E. Whitney to the New York offices of the Atomic Energy Commission. The following officers were contacted:

Morris Goldberg, Administrative officer, Technical Procurement Div.
George Bate, Assistant Director of the Technical Procurement Div.
Norman Arnstein, Electronic project engineer,
Murray Medvin, Attorney
L. Dale Hill, director of personnel
Neil C. McManus, Security branch
Peter C. Murphy, Chief of Physical Security
R. J. Smith, Jr., Director of the Technical Procurement Div.

It was at this meeting that Motorola was first advised of the nature of the work to be undertaken. The device was described to be in many respects similar to the APG5 radar system, which was produced by Motorola during World War II. The development had been undertaken by the personnel of the Sandia laboratory of Applied Physics. The stated objective proposed the development of a small group of samples; production was not contemplated. The units were to be prototype models upon which could be based a possible final manufactured equipment. The requirements were set forth in a letter contract and a secret letter to the contract, both dated June 27, 1949, from the United States Atomic Energy Commission to Motorola Inc.

The letter contract, No. AT(30-1)-677 and the letter to contract No.AT(30-1)-677 were dated June 27, 1949 and were signed by D. E. Noble, vice president of Motorola, on July 11, 1949.

The following presents the contents of the contract letters:

"1. This negotiated letter contract signifies the agreement of the Atomic Energy Commission (hereinafter called the "Commission") and Motorola, Incorporated (hereinafter called the "Contractor") that the Contractor shall proceed immediately to perform the work and services outlined in a secret letter, dated June 27, from the Commission to the Contractor. The contents of said letter, including the documents referred to therein, are hereby made a part of this letter contract with the same force and effect as if fully set forth herein.

2. All applicable articles required by Federal Law or Executive Order to be included in contracts for the type of work and services herein described are incorporated herein by reference.

3. Negotiations will be undertaken for the execution of a definitive contract which will be in a form agreed upon by the parties and will include all applicable articles mentioned in paragraph 2, and will also contain detailed terms and conditions as agreed to by the parties, which may or may not be at variance with the provisions of this letter contract.

4. (a) The Commission has obligated for the work under this letter contract, from obligational authority available to the Commission, the amount of Eight Hundred Thousand Dollars ($800,000.00). Pending the execution of a definitive contract, each expenditure, order, subcontract or commitment made by the Contractor in furtherance of the performance of this Letter Contract for an amount in excess of Five Thousand Dollars ($5,000.00) will be subject to the prior written approval of the Commission, and the Contractor shall notify the Commission in writing when and if the total of the amounts paid and then payable to the Contractor in its performance under this Letter Contract shall equal the amount of One Hundred Fifty Thousand Dollars ($150,000.00) and shall not expend or obligate any additional amounts unless and until it has secured the prior written approval of the Commission.

(b) Until such time as a definitive contract is executed, partial payments will be made as the work progresses at the end of each calendar month, or as soon thereafter as practicable, on estimates made by the Contractor and approved by the Commission and upon the presentation by the Contractor of properly executed and duly certified vouchers therefor, and/or other evidence satisfactory to the Commission. From each such partial payment there shall be retained twenty-five percent (25%) until the parties have executed the definitive contract, or until this Letter Contract is terminated pursuant to paragraph 5 hereof.

(c) All material and work covered by partial payments made shall thereupon become the sole property of the Government, but this provision shall not be construed as relieving the Contractor from the sole responsibility for all materials and work upon which payments have been made or restoration of any damaged work, or as a waiver of the right of the Government to require the fulfillment of all of the terms of this Letter Contract.

5. (a) In case a definitive contract is not executed by September 30, 1949, (or any subsequent date mutually agreed upon), this Letter Contract will terminate on the stated date or such subsequent date, as the case may be.

(b) The Commission may, at any time, terminate this Letter Contract in whole or in part for its convenience by written notice to the Contractor of such termination.

(c) In the event of termination of the work called for in paragraph 1 hereof, pursuant to either subparagraphs (a) or (b) of this paragraph 5, the Contractor will be paid (less payments previously made to it) the cost incurred by it in the performance thereof, plus the amount paid or to be paid by it for its account in settling, with the approval of the Commission, its obligations for commitments made in such performance. The Commission may, in its discretion, assume any such obligations. It is understood, however, that in the event of termination pursuant to subparagraph (b) of this paragraph 5, the amount to be paid to the Contractor may include a reasonable allowance for profit. Subject to the provisions of paragraph 4 (a) hereof, the total of such reimbursement to the Contractor (including all payments previously made), plus any profit that may be paid to the Contractor, together with the amount of any obligations assumed, shall not exceed Eight Hundred Thousand Dollars ($800,000.00).

(d) Upon payment or reimbursement to the Contractor, title to all equipment, work in process, scrap, wastage, finished products, materials, plans, information and other things for which the Contractor is paid or reimbursed, shall vest in the Government (if title has not already been vested in the Government). The Government will also become entitled to any rights under any commitment which it may assume, or for the settlement of which it shall have reimbursed the Contractor.

6. (a) It is understood that disclosure of information relating to the work contracted for hereunder to any person not entitled to receive it, or failure to safeguard all top secret, secret, confidential and restricted matter that may come to the Contractor or any person under its control in connection with the work under this contract, may subject the Contractor, its agents, employees and subcontractors to criminal liability under the laws of the United States. See the

Atomic Energy Act of 1946 (Public Law 585 - 79th Congress). See also Title I of an Act approved June 15, 1917 (40 Stat.217; 50 U.S.C. 31-42), as amended by an Act approved March 28, 1940 (40 Stat. 79); and the provisions of an Act approved January 12, 1938 (52 Stat. 3; 50 U.S.C. 45-45d), as supplemented by Executive Order No. 8381, dated March 22, 1940, 5 F.R. 1147.

(b) The Contractor agrees to conform to all security regulations and requirements of the Commission. Except as the Commission may authorize, in accordance with the provisions of the Atomic Energy Act of 1946, the Contractor will not permit any individual to have access to restricted data until the Federal Bureau of Investigation shall have made an investigation and report to the Commission on the character, associations, and loyalty of such individual and the Commission shall have determined that permitting such person to have access to restricted data will not endanger the common defense or security. The term "restricted data", as used in this paragraph, means all data concerning the manufacture or utilization of atomic weapons, the production of fissionable material, or the use of fissionable material in the production of power, but shall not include any data which the Commission from time to time determines may be published without adversely affecting the common defense and security.

(c) The Contractor will insert in its subcontracts provisions similar to subparagraphs (a) and (b) of this paragraph.

7. (a) Whenever any invention or discovery is made or conceived by the Contractor or its employees in the course of any of the work under this Letter Contract, the Contractor shall furnish the Commission with complete information thereon; and the Commission shall have the sole power to determine whether or not and where a patent application shall be filed, and to determine the disposition of the title to and the rights under any application or patent that may result; provided, however, that the Contractor, in any event, shall retain at least a non-exclusive irrevocable, royalty-free license under said invention, discovery, application, or patent, such license being limited to the manufacture, use, and sale for purposes other than use in the production or utilization of fissionable material or atomic energy. Subject to the license retained by the Contractor, as provided in this paragraph, the judgement of the Commission on these matters shall be accepted as final; and the Contractor, for itself and for its employees, agrees that the inventor or inventors will execute all documents and do all things necessary or proper to carry out the judgement of the Commission.

(b) Without waiving any rights accruing to the Government under the foregoing provisions, it is agreed that all provisions of the Atomic Energy Act of 1946 relating to patents and inventions are hereby incorporated by reference. No claim for pecuniary award under the provisions of the Act shall be asserted by the Contractor or its employees, ~~or its employees~~, or by any subcontractor or its employees, with respect to any invention or discovery made in the course of the work called for in this contract.

(c) Except as otherwise authorized in writing by the Commission, the Contractor will obtain patent agreements from all persons who do any part of the work under this contract, except clerical and manual labor personnel who do not have access to technical information, in the regular course of their employment, and will insert provisions to effectuate the purposes of subparagraphs (a) and (b) above in all such agreements and in all subcontracts.

8. Except as otherwise specifically provided in this letter contract, all disputes which may arise under this contract, and which are not disposed of by mutual agreement, shall be decided by a representative of the Commission duly authorized to supervise and administer performance of the work under this contract, who shall reduce his decision to writing and mail a copy thereof to the Contractor. Within 30 days from receipt of such notice the Contractor may appeal in writing to the Commission, whose written decision or that of its designated representative or representatives or board shall be final and conclusive. Pending decision of any dispute, the Contractor shall diligently proceed with the performance of the work under this contract.

9. The Contractor agrees to conform to all health and safety reulations and requirements of the Commission. The Contractor shall take all reasonable steps and precautions to protect health and minimize danger from all hazards to life and property, and shall make all reports and permit all inspections as provided in such regulations or requirements.

10. (a) The Commission shall have the right to inspect in such manner and at such times as it deems appropriate all activities of the Contractor arising in the course of the work under this letter contract, and the Contractor will permit such audits and examinations of its books and accounts as the Commission may request.

(b) The Contractor shall make such reports to the Commission, with respect to the Contractor's activities under the contract, as the Commission may require from time to time.

11. (a) All drawings, designs, specifications, data, reports, and other memoranda of record value prepared by, or otherwise under the control of the Contractor, in connection with the performance of the work hereunder shall be and remain the property of the Government and the Government shall have the right to use such drawings, designs, specifications, data, reports, and memoranda in any manner without any claim on the part of the Contractor for additional compensation.

(b) All such drawings, designs, specifications, data, reports, and memoranda shall be delivered to the Commission at any time they are requested. Subject to the approval of the Commission, the Contractor may retain and use copies of any of the foregoing material.

12. This negotiated letter contract is authorized by and has been negotiated under the Atomic Energy Act of 1946 and Executive Order No. 9816, dated December 31, 1946, in the interest of the common defense and security.

13. The term "Commission" as used herein means the United States Atomic Energy Commission or its duly authorized representative or representatives."

"This Secret Letter shall be a part of Letter Contract No. AT-(30-1)-677, dated June 27, 1949 and shall govern the performance by the Contractor of the work thereunder. The Contractor shall perform Jobs I and II as follows:

JOB I - ABEE PROJECT

Phase A - Engineering

1. The Contractor shall exert its best efforts and shall attempt to design, develop and reduce to acceptable manufacturing practices a radar device in accordance with specifications entitled, "Target Specifications for RQT S-4674 (NSA-9287)", dated May 23, 1949, a copy of which was furnished to the Contractor by hand on June 24, 1949. Said specifications, a copy of which is also on file with the Commission, are hereby made a part of this contract with the same force and effect as if fully set forth herein.

2. In the performance of the work services called for in paragraph 1 above, the Contractor shall furnish necessary technical personnel, labor and materials. When requested by the Commission, the Contractor will furnish the labor and technical personnel at such site or sites as the Commission may request. The Commission will furnish to the Contractor for the Contractor's guidance in the performance of such work existing preliminary prototypes. Title to such prototypes furnished by the Commission shall remain in the Government at all times. The Contractor shall perform the work called for hereunder under the technical direction of authorized representatives of the Sandia Laboratory, Branch of the Los Alamos Scientific Laboratory.

Phase B - Prototype Fabrication

1. The Contractor shall exert its best efforts to manufacture

and delivery f.o.b. Contractor's Plant, Chicago, Illinois or Phoenix, Arizona, under conditions as closely approximating production technique as possible, 50 prototype models, (hereinafter called "prototypes") in accordance with the design developed by the Contractor in Phase A above. The Contractor shall attempt to deliver the first twenty-five (25) prototypes on or before December 1, 1949, and the remaining twenty-five (25) prototypes on or before January 15, 1950. Shipments shall be made on Commission-furnished Government bills of Lading to such place or places as the Commission may direct.

2. In addition to the foregoing, the Contractor shall attempt to furnish the Commission, on or before January 15, 1950, with complete manufacturing drawings and specifications of the radar device developed by the Contractor pursuant to Phase A above, incorporating therein all changes requested by the Commission prior to January 1, 1950.

JOB II- ABEE TEST EQUIPMENT

Phase A - Engineering

1. The Contractor shall exert its best effort and shall attempt to design, develop and reduce to acceptable manufacturing practices, special test equipment for the radar device developed by the Contractor pursuant to JOB I hereof. This test equipment shall be designed and developed in accordance with specifications entitled, "Target Specifications for RQT S-4676 (NSA-9286)", dated May 23, 1949, a copy of which was furnished to the Contractor by hand on June 24, 1949. Said specifications, a copy of which is also filed with the Commission, are hereby made a part of this contract with the same force and effect as if fully set forth herein.

2. In the performance of the work services called for in paragraph 1 above, the Contractor shall furnish necessary technical personnel, labor and materials. When requested by the Commission, the Contractor will furnish the labor and technical personnel at such site or sites as the Commission may request. The Contractor shall perform the work called for hereunder under the technical direction of authorized representatives of the Sandia Laboratory, Branch of the Los Alamos Scientific Laboratory.

Phase B - Prototype Fabrication

1. The Contractor shall exert its best efforts to manufacture and delivery f.o.b. Contractor's Plant, Chicago, Illinois or Phoenix, Arizona, under conditions as closely approximating production technique as possible, six (6) sets of the special test equipment designed and developed by the Contractor pursuant to Phase A above. The Contractor shall attempt to deliver the first two (2) sets on or before December 1, 1949, and the remaining four (4) sets on or before January 15, 1950. Shipments shall be made on Commission-furnished Government Bills of Lading to such place or places as the Commission may direct.

2. In addition to the foregoing the Contractor shall attempt to furnish the Commission, on or before January 15, 1950, with complete manufacturing drawings and specifications of the special test equipment developed by the Contractor pursuant to Phase A above, incorporating therein all changes requested by the Commission prior to January 1, 1950.

GENERAL REQUIREMENTS

1. All work performed by the Contractor under this Letter Contract shall be tested and inspected by authorized representatives of Sandia Laboratory, Branch of the Los Alamos Scientific Laboratory.

2. (a) It is understood that disclosure of information relating to the work contracted for hereunder to any person not entitled to receive it, or failure to safeguard all top secret, secret, confidential and restricted matter that may come to the Contractor or any person under its control in connection with the work under this contract, may subject the Contractor, its agents, employees, and subcontractors to criminal liability under the laws of the United States. See the Atomic Energy Act of 1946 (Public Law585 - 79th Congress). See also Title I of an Act approved June 15, 1917 (40 Stat. 217; 50 U.S.C. 31-42), as amended by an Act approved March 28, 1940 (40 Stat. 79); and the provisions of an Act approved January 12, 1938 (52 Stat. 3; 50 U.S.C. 45-45d), as supplemented by Executive Order No. 6381, dated March 22, 1940, 5F.R. 1147.

(b) The Contractor agrees to conform to all security regulations and requirements of the Atomic Energy Commission. Except as the Commission may authorize, in accordance with the provisions of the Atomic Energy Act of 1946, the Contractor agrees not to permit any individual to have access to restricted data until the Federal Bureau of Investigation shall have made an investigation and report to the Commission on the character, associations and loyalty of such individual and the Commission shall have determined that permitting such person to have access to restricted data will not endanger the common defense or security. The term "restricted data" as used in this paragraph means all data concerning the manufacture of utilization of atomic weapons, the production of fissionable material, or the use of fissionable material in the production of power, but shall not include any data which the Commission from time to time determines may be published without adversely affecting the common defense and security."

Referenced in the letter to the contract AT(30-1)-677 were target specifications for RQT S-4674 (NSA-9287) and RQT S-4676 (NSA-9286) both dated May 23, 1949. These documents, temporarily loaned to Motorola by T. F. Marker, were to be used until suitable specifications had been prepared in conference between Sandia and Motorola.

Thus it was that from May 14 through the month of June, discussions were conducted at executive levels to formulate the objectives and begin a period which included contractual and technical development.

Organizational development to fulfil the project requirements was also to become an important factor. Suitable plant facilities with proper arrangement to fulfil security requirements as well the rapid and efficient development of a security approved personnel organization were to become important problems.

The personnel security clearance procedure required that the Atomic Energy Commission security questionnaire be completed by each individual. The information was then forwarded to the FBI which conducted an investigation. The results of the investigation formed a basis upon which the FBI and the AEC either approved or disapproved the individual's assignment to the ABEE and ABEE Tester projects.

The early requests were for emergency clearance which could be acted upon in about 4 to 6 weeks' time. The emergency (QE) clearances were then processed in greater detail. To obtain a permanent (Q) clearance, the time required to change a QE to a Q clearance was approximately 4 weeks. The above time estimates were approximate. Experience later showed that the actual time required was dependent upon the extent of travel, especially travel outside the United

States, as well as the number of moves related to residence and occupational changes.

The time required to obtain clearance for personnel assigned by Motorola to the Abee Projects was to have an important effect upon the rapidity, efficiency, and economy with which the program could be prosecuted.

By June 30, the cleared personnel associated with the ABEE project included:

1. D. E. Noble, Motorola Vice President, Director of the Communications and Electronics Divisions, Director of Research.

2. J. F. Silver, Chicago, General Manager, Communications Division.

3. M. E. Whitney, Chicago, Government Contract Coordinator.

Examination of the Sandia laboratory model of ABEE was effected by P.J. Sturm and E. D. Kirk who were transferred from Motorola, Chicago, to the Sandia Base. The introduction took place during the July 13, 14, 15, conference, at which time Mr. T. F. Marker, project engineer, SLE(Sandia Laboratory, Engineering) was introduced; Motorola would perform the work specified in the contract letter dated June 27, 1949, under the technical direction of Mr. T. F. Marker, authorized representative of the Sandia laboratory.

Motorola personnel, P. J. Sturm and E. D. Kirk, were properly cleared and began preparation July 15 for preliminary testing of the Sandia prototype. Space was made available within the Sandia facilities. The initial objective was to become familiar with the ABEE model and schematic circuits. Sandia personnel were interviewed to discuss the problems encountered during development.

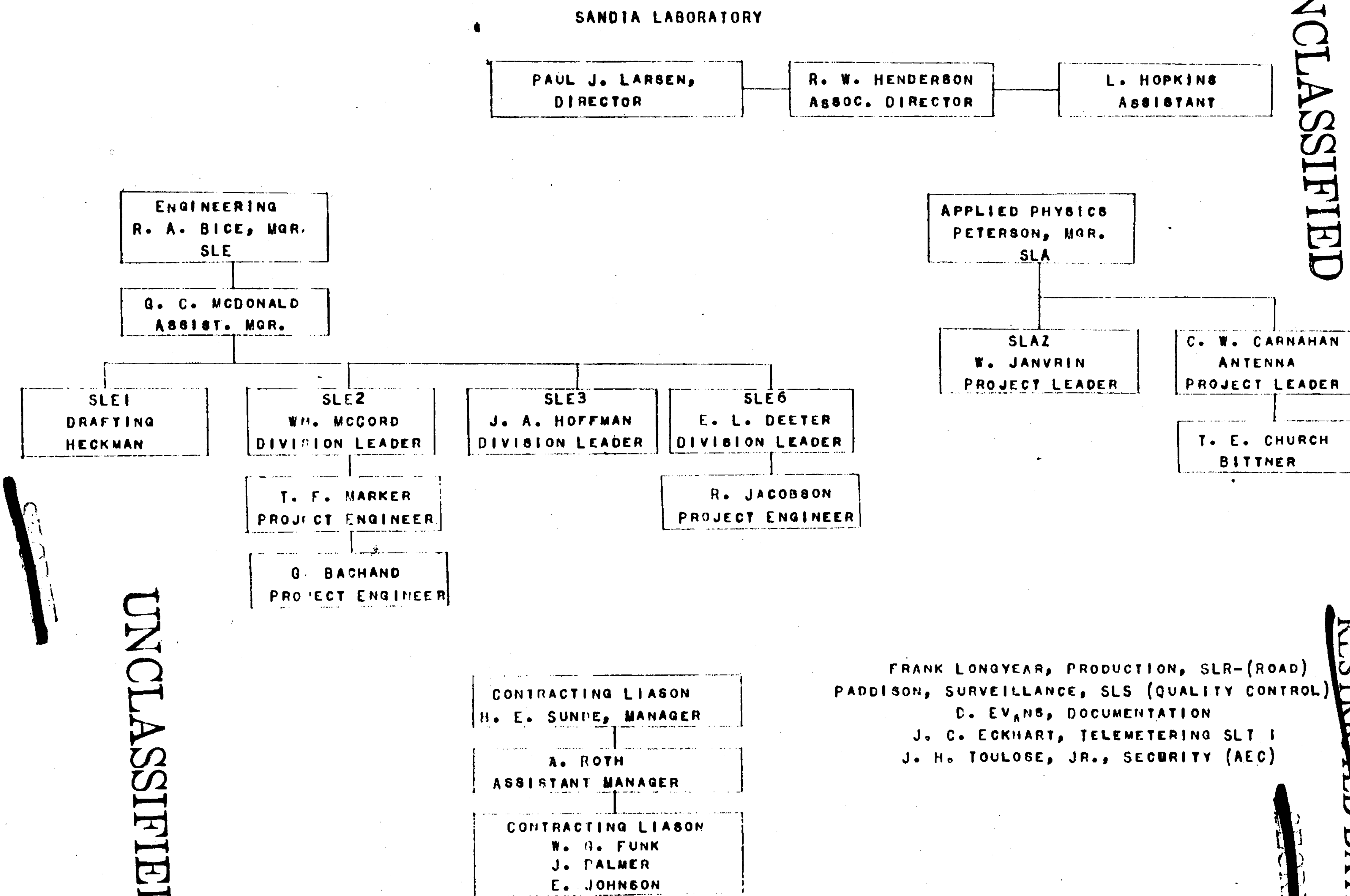

FIG. 1

PORTION OF SANDIA LABORATORY ORGANIZATION JULY 1949

UNCLASSIFIED

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RESTRICTED DATA

On July 13, 14, 15, M. E. Whitney visited the Sandia Laboratory to contact the Engineering, Applied Physics, Contract Liaison, Documentation, Security, and Telemetering groups. The relationships of these groups within the Sandia Corporation is presented in Fig. 1. The significant problems at this time were judged to be:

1. Schedule.
2. Antenna.
3. Test Equipment
4. Specifications.
5. Requirement for the assignment of additional engineers to the work which would necessitate additional personnel security clearances.
6. Need to move the project from the overloaded Sandia facilities in order to accelerate the work.
7. Preliminary test of the Sandia production model.
8. List of material emphasizing critical components.

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RESTRICTED DATA

15

UNCLASSIFIED

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~~RESTRICTED DATA~~

The target specifications of ABEE were requested to facilitate familiarization with ABEE as well as for future work. The information was transmitted to P.J. Sturm, project engineer, Motorola Inc., Sandia Liaison Group by letter dated July 20,1949, from T.F. Marker, Technical Assignments Staff, SLE. These target specifications replaced and superceded the target specifications for RQT S-4674(NSA-9287) dated May 23, 1949.

The target specifications for ABEE are presented on the following pages.

"1. The following specifications are applicable to ABEE. All of the following shall be considered as target developmental specifications only.

A. Sandia Laboratory Specifications.

SLSP-15 (General Specifications for Electronic Equipment).

SLSP-40 (Development Specification for Dynamotors)

B. Joint Army Navy Specifications.

JAN-1-A tubes, Electron, Radio.

JAN-C-5 Capacitors, Mica Dielectric, Fixed.

JAN-1-6 Instruments, electrical,measuring.

JAN-1-10 Insulating Materials, ceramic, radio Class L.

JAN-R-11 Resistors, composition.

JAN-C-92 Capacitors, air dielectric, variable trimmers capacitors.

JAN-C-173 Coating materials, moisture and fungus-resistant.

JAN-R-184 Resistors, fixed, wire-wound.

JAN-1-225 Interference measurement.

JAN-P-14 Plastic Materials, molder, thermosetting.

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JAN-C-17A Cables, coaxial and twin conductor for radio frequency.

JAN-R-19 resistors, variable, wire-wound.

JAN-C-20A capacitors, fixed, ceramic dielectric.

JAN-C-25A capacitors, D.C., paper dielectric, fixed.

JAN-R-26 resistors, fixed, wire-wound power type.

JAN-S-28 sockets, miniature.

JAN-C-71 connectors, type N.

JAN-C-76 cable (hook-up wire).

JAN-P-77 plastic materials, cast, thermosetting.

JAN-P-78 plastic materials, laminated, thermosetting.
(for nameplates)

JAN-P-79 plastic materials, laminated, thermosetting, rods and tubes.

C. AN Aeronautical Specifications.

AN-QQ-A-696 Anodic films, corrosion-protective (for) aluminum alloys.

AN-D-13 drawings and data lists.

AN-M-12 Magnesium alloy, process for corrosion protection of.

AN-P-61 plating, cadmium

D. Navy Specifications.

16T30 Transformer, inductors for audio frequency and power.

E. Federal Specifications.

QQM-151 Metals general specification for.

F. Army Navy Electronics Standards Agency.

Standard Components list.

II. Target Development Specification.

A. Classification and Intended Use.

A-1. The term "radar" as used herein shall include all components of the radar proper, antenna, dynamotors necessary to operation of the device.

A-2. The radar shall effect the closure of a relay upon the reception of an echo from a terrestial target within certain specified ranges.

It shall perform this operation at various conditions of temperature and altitude after storage for a minimum period of two years.

A-3. Additionally the closure of the firing relay shall effect the operation of a secondary timing device located within the radar package.

A-4 Each radar is required to function within the terms of this specification on the first application to its intended use.

B. System Requirements and Performance.

B-1. DOE b(3)

B-2. DOE b(3)

The radar shall not have spurious responses beyond any range setting such as to cause premature ranging.

B-3. DOE b(3)

B-4. The frequency will be specified only by verbal communications between Motorola Inc. and the Sandia Laboratory.

B-5. The radar shall operate to its intended use under temperature conditions of minus 65° to plus 165° F and humidity of 0 to 95% at all temperatures.

B-6. DOE b(3)

B-7. The radar shall withstand vibration at 10 g amplitude in three (3) mutually perpendicular planes for forty-five (45) minutes when cycled from 10 to 300 cycles.

B-8. The radar shall operate to its intended use at all altitudes up to 50,000 feet without damage to the unit.

B-9. The radar shall operate from a primary power source of 24 to 30 volts d.c. The maximum current drain per radar shall be 10 amperes.

B-10. A dynamotor in accordance with Sandia Laboratory specification SLSP-40 shallbe used to supply all high voltages to the radar.

B-11. The radiating system of the radar shall employ an antenna having a V.S.W.R. throughout the necessary band of frequencies of not more than 1.6.

B-12. The antenna shall be designed so as to cover all frequencies of the radar..

B-13. The beam width of the antenna shall be less than 30° in the E plane and greater than 30° in the H plane. The gain shallbe approximately 15 db.

B-14. The radar package, not including the antenna and dynamotor, shall occupy a cylinder eight (8) inches in diameter by twelve (12) inches long. The dimensions given shall be the inside dimensions of the enclosing can or cover.

B-15. The weight shall be kept as small as possible consistent with good practice.

B-16. The unit shallbe capable of operation to its intended use within thirty (30) seconds after application of the primary power. If practicable no auxiliary heating shall be required.

B-17. The unit shall not radiate until armed by auxiliary equipment. The contacts of the auxiliary arming device are capable of 5 amperes at 100 volts d.c.

C. Design.

C-1. The design must be in accordance with the accepted practice for military airborne equipment.

C-2. When no specification of the Air Force, Army, Navy or Sandia Laboratory applies, the best commercial practice will be applicable.

C-3. The design shall conform as near as practicable to a design set forth by the Sandia Laboratory Engineering Department in the form of a sample unit, schematic diagrams and other drawings.

D. Construction.

D-1 Construction of the unit shallbe as light as practical with good reliability.

D-2. The construction shall be in accordance with good practice for airborne radar equipment."

A laboratory model of ABEE, received by P. J. Sturm on July 21, was not the prototype to be evaluated by Motorola. The earlier model was used for study until the prototype could be completed. Early delivery of the prototype was requested in order that Motorola personnel could conduct tests prior to August 1. The technical information was required for a conference scheduled to be held on August 2nd.

Power was applied to the laboratory model; all circuits operated without failure. An evaluation of the circuit operation was not made. Later the model was moved to a new location and was in operation after several electrical troubles had been corrected. Minor delays were the result of an inventory necessitated by a change of administration from the University of California to Western Electric. E. D. Kirk began the machanical design drawings to describe an electro-mechanical assembly suitable for production. By July 30, the Sandia prototype was nearly complete. Mechanical interferences required the range deck to be hand fitted to the main assembly. Fig. 2 presents the block diagram of Sandia ABEE prototype.

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Preliminary temperature, humidity, and vibration tests were conducted during June 30 and July 1, 1949. The test information is presented below:

"HEAT RUN (TEST #1)

TIME STARTED -- 4:00 P.M. 7/30/49

AIR FLOW:

3500 cubic feet of air per minute blowing thru a chamber nine feet by ten feet by five feet (including coils) - working space - nine feet by five feet by five feet.

RELATIVE POWER OUTPUT AT START - 1.16

RELATIVE HUMIDITY - 22%

THERMO-COUPLE NO.	Location	4:20	4:40	5:00	5:20	5:40
#1	Air Temperature	97°	120°	138°	153°	181°
#2	2E26 (on glass)	102°	124°	142°	156°	185°
#3	Wet Bulb	79°	99°	100°	108°	120°
#4	2C40 (on cathode)	95°	122°	139°	154°	182°
#6	i-f Strip (on chassis)	104°	132°	142°	164°	190°
#7	3C45 (on glass)	110°	130°	152°	167°	195°
#8	2C39 (hole in rear)	108°	128°	148°	166°	194°
#9	Pulse Trans. Wind.	100°	120°	142°	157°	184°
#10	CK1013 T.R. supply	100°	120°	141°	157°	183°
POWER OUTPUT		.95	.80	.92	.90	.95

AT 180° NOTICED WAX DRIPPING FROM LOWER DECK.

"ABEE"

HUMIDITY TEST (TEST #2)

TIME	RELATIVE HUMIDITY	POWER OUTPUT (REL.)
6:10 P.M.	36% @ 140°	.87
	51% @ 141°	.82
	78% @ 140°	.80
6:30	70% @ 153°	.80
	79% @ 153°	.80
	83% @ 153°	.85
	85% @ 153°	.85
	88% @ 153°	.85
	93% @ 153°	.87
6:35	97% @ 153°	.87
6:46	98% @ 153°	.80

After 45 minutes at 98% humidity total increase of 15 milliamperes from the dynamotor.

After 2 hours of soaking at 145°F., 98% humidity - unit re-energized, - power .93. Current from dynamotor = 30 milliamperes above starting reference.

Condensation formed in the cool vinylite covering for the cable leading from the chamber to the dynamotor and saturated the wires.

Small current rise in total current taken from dynamotor noted approximately 10 minutes after humidity reached maximum.

After stabilizing for one hour at 98% humidity, B/ cycled five times with no failures. Filaments allowed to cool, reheated allowing 25 seconds warm-up time — B/ applied — no failure, power down however approximately 1 db below reference.

Thermistor bridge off directional coupler 26.5 db down total power matched into dummy load.

Temperature dropped rapidly to + 15°F. from 150° F., 98% RH.

At 65°, power decreased 20 to 30 db.

Filament 2C39 intact, two flyback power supplies still operative as indicated by glow in cold cathode and thyratron tubes. Pulse transformer receiving pulse as indicated by ionization glow.

Air temperature was held at 50° and chamber dehumidified. Door opened to chamber and room temperature allowed to enter. Power immediately re-established to within 1 db of reference.

COLD TEST (TEST #3)

TEST STARTED AT 11:09 P.M. 7/30/49

Relative power - 1.15, current 150 milliamperes from dynamotor. Put can (housing) on and sealed with tape. Temperature 51° F. Temperature drop was 8° to 9° per minute.

Dropped to -65° F. at 11:45 P.M. — Power output normal (to within ± 1 db).

12:13 A.M. current from dynamotor stabilized at 148 milliamperes at -65° F.

"ABEE"

VIBRATION TEST (TEST #4)

TIME - 3:20 P.M., 7/31/49 (First Test)

Unit was mounted with the panel side clamped to the table (thru the handles and on the edges of the panel).

LATERAL MOTION - .020 double displacement. At 26 C.P.S. A ½ inch cantilever flexure developed at the top of the assembly (no supports at top).

SECOND TEST - 4:00 P.M.

Vertical motion, unit was mounted in the same manner as in the first test but with the handles raised off of the table (unit weighs 16 pounds 5 ounces).

.020 double displacement.

At 50 C.P.S. (3Gs) 2C40 cavity vibrated.

At 55 C.P.S. — hold-down springs for 2E26 and 3C45 strikes glass on tubes.

Spring on T.R. Box is useless.

Started cycle for second test at 4:31 P.M. (10 C. P.S. to 57 C.P.S. at 3 Gs).

STOPPED CYCLE at 5:02 P.M.

Increased displacement to .035 (3.8 Gs at 55 C.P.S.)

2C40 vibrates at 55 C.P.S., the stand-off insulator holding the grid lead to the 2C39 broken in two.

Long unstrapped wires wave. Modulator pulsing tubes wave in sockets. The whole cavity assembly waves, the decks wave independently, RELAY ARM vibrates axially with the bearings, all terminal boards with cantilever suspension wave, the I.F. strip waves independently of mounting. Test over at 5:52 P.M.

THIRD TEST - 9:00 P.M.

Horizontal mounting (tubes on I.F. strip in up-right position) at 35 C.P.S. Slight vibration. At 45 C.P.S. cavity assembly, tubes, long leads, terminal boards wave. At 50 C.P.S. small pulse transformer waves. At 55 C.P.S.

waving of all components increases in temp.

At 9:27 P.M. - Raised to 5 Gs at 55 C.P.S.

At 25 C.P.S. components start to vibrate. At 45 C.P.S. waving of all components (cavity travels 3/16 of an inch).

5G test was five minutes long.

At 9:45 P.M. rotated unit 90° in mounting to repeat test.

At 60 C.P.S. relay is useless.

Four minutes at 55 C.P.S., three minutes at 60 C.P.S.

Started cycle at 9:58 P.M., stopped at 10:07 P.M.

It was concluded from the tests that one or more components could not withstand the high temperatures. High humidity operation was faulty as evidenced by an increase in plate supply current of approximately 20%. Low temperature operation effected a 20 to 30 db decrease in transmitter power output; the cause was not determined. The greatest deficiency occurred during rhe vibration tests. The maximum acceleration to which the equipment was subjected was 5 g at 55 cycles per second. The vibration frequency was varied from 5 to 55 cycles and all components vibrated excessively. The test was discontinued because it was judged that higher accelerations would be destructive.

Discussions with the various portions of the Sandia organization revealed much information concerning the status of ABEE development, the problems encountered, and the effectiveness of the solutions. Additional study and evaluation by Motorola personnel revealed other information. The facts were compiled and reported by P.J. Sturm in the Outline of ABEE Development, August 1, 1949, which follows:

This document consists of 24 pages
No 3 of 4 copies, Series A

This document consists of 21 pages
No. 1 of 1 copies, Series B

OUTLINE

OF

ABEE DEVELOPMENT

August 1, 1949

by P.J. Sturm

Motorola Inc.

Chicago, Illinois

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I. ANTENNA

A. Status

1. Development

a. Tests run on open test horn projecting from bottom of test plane. E & M Patterns available. Generalized specification as to proposed gain, impedance and pattern fairly well fixed by SLA. No specific antenna model for unit fabricated as yet. Various drafting layouts of proposed models available at SLA. Fabrication of parabolic reflector for one model started and rough elementary feed available (SLA). No tests started on any model since no integrated model exists.

2. Points of Controversy

a. Transmission Line feed from ABEE to antenna

Coaxial — generally favored
Waveguide — would be considered

Points in favor of coaxial line include ease of fabrication and installation and the fact that cavity output and antenna feed are coaxial. However, coax requires quick disconnect connector and may introduce attenuation problem which is undesirable. Points in favor of waveguide are possibility of no disconnect problem and rigid construction as contrasted to coax which may have dielectric problems when flexed over extreme temperature range.

b. Antenna Feed

Horn feed
Slot antenna
Dipole and reflector

Opinion is divided over desirability of these three. Much preference exists for slot type antenna which could be adapted to space available around nose plate. However, antanna must be broad band (VSWR 1.6 throughout + - 6.5%) and development of slot antanna of this characteristic may be lengthy.

c. One vs Two Antennas

Hoffman favors two antennas for reliability reasons. Others open to suggestions if one antenna could be made to handle output of two ABEE'S.

d. Location of Antennas.

Antennas may be located in space on nose plate (5" deep), or in space available around nose plate. Since nose plate must be removed by personnel, antenna must be removable from system by quick disconnects (personnel on time limit) and must be light in weight in this case; however, mechanical problems would be minimized here. If antenna is located around nose plate, there is no major weight or disconnect problem; however, space here is limited, complicating the design. It is to be noted that changes in front end structural design are always coming through, and may interrupt development based on present space allocations.

3. Estimate on Future Progress

a. At present it appears that two men are engaged in this problem full time. In addition, they are concerned over a report on theoretical study that occupies their time. This seems to indicate slow progress here.

b. Antanna fabrication is predominately mechanical and all reports indicate that model shop of SLF is well overloaded and slow on delivery.

c. Test facilities for flight testing any antenna design here appear good; however, test site for ground pattern testing is still in elementary stages and is a retarding factor. We are welcome to use proposed elaborate test site near here.

d. Theoretical studies have been made and this should serve to guide future designs with a favorable bearing on the time factor.

e. Security considerations will retard development since antenna location concerns other more highly classified components.

B. Producability

1. In view of the above mentioned early stage in development, it is impossible to make an engineering estimate at this time.

2. Vendors

   a. Quick disconnect coaxial fittings are being investigated by SLE and one type is on order.

   b. A specific type of cable is preferred from a low loss standpoint if coax transmission is adopted.

C. Chronological Developments

1. July 22: SLE was informed by SLA that antenna would be turned over to Engineering after pattern gain and impedance are determined. Since antanna, one version of above mentioned possibilities, is a double partial parabolic dish reflector with elementary dipole and splash reflector feed, the development on this element of the ABEE is in rather an embryonic stage. This seems to imply that the company will be presented with an extensive development and test program on antennas.

II. RANGE CIRCUITS

A. Status

1. Development

a. The range circuit appears to be well advanced in its development. Here the design has been cleaned up with respect to component tolerances, notably tube characteristics. This has resulted in settling on specific tube types in the circuitry. SLA reports that circuits are quite stable and numerous tests in lab and in flight have been completed, which are included in a report available. Circuits have been incorporated in an integrated ABEE (9" x 13" cylindrical package) and operated successfully according to SLA. Design changes are still in progress at present.

2. Points of Controversy

a. Range Selector

A variable capacitance must be adjusted in the Range Gate Generator circuit in selecting the firing altitude. The method of varying this is as yet undetermined. Methods under consideration include the autotune, for remote operation, toggle switches, etc.

b. Delay line in Pulse Width Discriminator

Lumped constants vs. delay cable (used at present).

c. Series filaments in ABEE

Simple series filaments off 28 volts as compared to some source of 6 volts power, either off dynamotor, vibrator supply, or batteries, Battery method not favored.

3. Estimate of Future Progress

a. At present SLF is fabricating first 8" x 12" cylindrical package to be completed, wired, and tested before July 28. This unit will be complete, excepting the Delay Timer which later is to be included in the package.

b. The results of vibration, shock, temperature, humidity, and pressure tests on this unit should reasonably establish the tentative design of the Range Circuits, assuming that all components can be supplied.

B. Producability

1. This unit offers no specific problem and appears adaptable to production techniques. Further tests are indicated to check the tolerance of the circuitry. Circuits can be cabled, excepting possibly two leads which must have reduced wiring capacitance according to SLA. Mechanical layout appears to offer no major difficulty. Line test techniques may be elaborate.

2. Vendors

a. Since the circuitry is developed around specific tube types, the 2C51 and the 6AS6 supply of these components is limited to a single vendor, Western Electric.

C. Chronological Developments

1. July 21: Breadboard of ABEE having faithful control circuits, but differing predominately in power supplys installed in company office. A notable observation is that set up required approximately two hours of debugging before proper operation ensued.

2. July 22: Information today reveals range unit must maintain 5% accuracy, once set, from -65° F to 165° F. This seems to indicate further compensation or temperature control development on the ranging circuits, since the circuits as now designed probably would fail these specifications.

3. July 22: Breadboard unit failed from tube trouble, Cathode to filament leakage in 6AS6.

4. July 26: Academic analysis seems to indicate that two weak points in the range circuits might exist.

The coincidence circuit, as presently designed, depends for its operation upon a unique suppressor grid control characteristic; also the Bootstrap integrating circuit utilizes three $\frac{1}{4}$ watt neon bulbs for voltage determining devices. It seems questionable as to how dependable these neon bulbs will be since ionization voltage depends upon electrode spacing, gas pressure, presence of contaminating agents, etc.

III RECEIVER

A. Status

1. Development

a. Development may be considered complete on this unit. The local oscillator cavity, TR tube and cavity, crystal mixer and IF strip are unchanged from the APG-5, except for minor modifications in the detector and video stages, and rearrangement of the filaments. In general, the original APG-5 strip is satisfactory regarding center frequency, gain, noise figure, and rejection, and while it was suggested that the pass band be opened as wide as possible to allow for more frequency drift in the transmitter and local oscillator, the present band pass could be used.

2. Points of Controversy

a. Hoffman favors that the IF strip be redesigned to include all modern practices, and possibly be decreased in size. From their standpoint, unit is satisfactory except for above changes.

3. Estimate of Future Progress

a. Since this unit has offered no major problem there has been little need for further development. It appears that any further changes will be developed by the company.

B. Producability

1. Since the major units of the receiver were in production during the war, there are only minor production problems existent, provided the company does not make major changes itself.

2. Vendors

IF Strip - No problem foreseeable. Local Oscillator, mixer and TR - No problem provided security does not interfere with procurement from original vendors. Many original dies might be used on the plumbing.

C. Chronological Development

1. July 25 - SLE favors the use of a connector fabricated by Winchester for all power connection problems. Thus the Jones connector on the I.F. Strip may have to be replaced with this item.

IV. DELAY TIMER

A. Status

1. Development

a. Print on proposed circuit design available. Laboratory breadboard tests are now in progress and reports to date available.

2. Points of Controversy

a. Considerable concern exists at present as to whether delay timer, a safety device to protect unit from misfire, should be actuated by:
   1. Transmitted pulse
   2. Power from dynamotor
   3. Received pulse

b. Further concern exists over whether timer should be directly dependent upon ABEE or independent ABEE.

c. No decision has been reached by SLE as to definite location of timer; either inside ABEE package or in separate package.

d. Definite determination as to whether first acting ABEE operates one or both timers, or second acting ABEE operates one or both timers has not been reached to date.

3. Estimate on Future Progress

a. This unit as proposed by circuit diagram is quite simple consisting only of one tube, one relay and several capacitors and resistors. A breadboard could be constructed and tested readily provided this method of timing is satisfactory to AEC. Since this timer must be extremely reliable, over and above the ABEE reliability figures, it seems that the design of this unit may remain in a state of flux for some time. However, the basic operation is simple, and probably the final unit will be of simple construction.

B. Producability

1. If the present design of the timer is suitable, production should be simple, involving only several additional electronic components. The only major problem here is meeting the reliability figures which demands rigid line test and inspection.

2. Vendors

No foreseeable problem unless future designs incorporate unique circuit elements on mechanical components which might require vendor development time or security problems.

C. Chronological Developments

1.

V. MODULATOR

A. Status

1. Development

a. The development of the modulator is complete insofar as providing a working unit is concerned; however, while this unit seems to represent circuit ingenuity, this development at first sight appears weak from the standpoint of reliability. The design is completely modified from the APG-5. The circuit has been operated in the 9" x 14" chassis satisfactorily. Test information on this unit has not been made available to date. It appears that the most recent design has had very few hours of test operation since most long run trails were performed on maphroditic hookups employing, in many cases, circuits of the APG-5.

2. Points of Controversy

a. In general there is agreement between all sections here regarding the merits and disadvantages of the modulator. It is generally conceded that:

1. The output pulse transformer is a laboratory designed and fabricated device, and consequently cannot be purchased as a stock item. It is pointed out that the construction is basically simple; however, this appears to be a subjective response and further investigation into this unit should be made.

2. The high voltage power supply for the transmitter tube is of the R.F. fly-back type such as used in most TV receivers. The reliability of these devices is questionable.

3. The tube used in the TR power supply and the transmitter power supply is a relatively untried cold-cathode high voltage rectifier and there is question here as to the reliability characteristics of this element.

4. The above mentioned tube in the transmitter supply is operating at or slightly above rated load.

5. There is disagreement over whether the thyratron filament of the switch tube will require special circuitry to establish emission early.

b. It is pointed out that the R.F. fly-back high voltage supply represents a considerable saving in weight and space. To date the circuit has been operating satisfactorily; however, tests are in the early stages and apparently it has been in operation for only a brief time.

c. To all appearances, the design of the modulator indicated a radical use of circuit elements to achieve an end with the result that the reliability may be low.

3. Estimate on Future Progress

a. Design changes on this circuit apparently have stopped and further changes or recommendations are apparently left to the company. There have been recommendations for various changes to improve the pulse waveform and also eliminate a tube section, but no action in this direction here appears to be contemplated.

b. The pulse transformer in question is designed and specified and a model is being fabricated to be incorporated in the 8" x 12" AREE prototype. Tests on this unit may reveal data regarding this circuit element.

B. Producability

1. In view of the above questions on the basic designs of the circuit, it is difficult to estimate production problems, considering possible future changes. As the circuit stands at present, few major problems limit its adaptation to production since the various circuits were in production

successfully during the war and later. On the other hand, to establish the required reliability with these circuits seems to be a major problem that may prove extremely difficult to overcome.

2. Vendors

   a. Several tubes are single vendor devices.

   b. The pulse transformer must be fabricated since it is not a standard item.

   c. Design changes may include a potted artificial line of stipulated characteristics which must be fabricated.

C. Chronological Developments

1. July 26: It is reported that Raytheon has made three attempts to develop a pulse transformer to the specifications required by ABEE design. These have all been unsuccessful to date, The difficulty arises out of the turns ratio of 8 : 1 required in this application. The difficulty of keeping the leakage inductance low for an impedance transformation of 64 : 1 forms a design problem. Approximately twenty pulse transformers designed by SLE-R are being fabricated at Sandia Labs for tests. A pilot run such as this should reveal any design problems of major importance.

VI R.F. UNIT

A. Status

1. Development

a. Development of this unit seems to be approximately 50% complete. Exhaustive studies of various electrical characteristics of the modified transmitter cavity, employing a 2C39 lighthouse triode, have been made and will be available within four to six weeks. However, these studies lean toward the academic stress on methods, with the exception of a few, which evaluate the transmitter from the standpoint of tube tolerances, both electrical and mechanical, and general difficulties of duplication. The transmitter development evolved under the supervision of Mr. ~~Coop~~er formerly of Radiation Lab, no longer with this organization, who figured in the APG-5 re-entrant cavity work. Relations between this transmitter and the packaging problem, with regard to temperature, tube life, R.F. leakage etc. have not been considered too thoroughly.

b. The local oscillator, TR assembly and crystal mixer of the APG-5 remain unchanged and are reported to be quite satisfactory. As a result this portion of the ABEE could be considered as substantially completed, except for the changes demanded below. This, of course, presupposes that the company might use all existing designs that can be applied to this unit without modification.

2. Points of Controversy

a. The major problem existant in this entire unit seems to be the requirement that it operate on more than one frequency. This introduces the following complications.

1. The antenna must be broad banded to handle the frequency range. Replaceable tuned antenna units cannot be used.

2. The re-entrant cavity-type oscillator is basically a single frequency device not adapted to large frequency excursions. Therefore, some provision must be made to supply several replaceable tuned systems to set the ABEE on the band desired, prior to drop. Naturally provision for tuning over the entire band with one cavity system would be extremely desirable; however, to date, no tuneable system utilizing the re-entrant cavity has been devised.

3. Directly contrasted to the above demand for several tuned systems, is the requirement that Army personnel be presented with a minimum of complex operations for setting ABEE on frequency. Methods considered, to date, for changing frequency have included:

   Stocking spare tubes and grid cylinders, the frequency determining element, which are cut to frequency at the factory.

   Stocking tubes with grid cylinders formed by the tube manufacturer as an integral part of the tube; these cylinders could be cut to frequency at our factory.

   Stocking a portion of the cavity containing grid cylinder and tube as a permanent part of the unit, pretuned at the factory, thereby eliminating mechanical tolerance problems; this assembly could be substituted by some clamping device to the remainder of the cavity which would be a permanent part of the ABEE. Stocking entire RF units pretuned to the desired frequency.

   Stocking entire ABEES which are sealed at the factory and pretuned. This is considered as undesirable by SLE since this would introduce an impossible stockpile problem.

The first consideration above violates the basic requirement of 3 from the standpoint of complex operations. The second consideration introduces delivery problems as well as the unknown, since this has never been tried, and thus may become a development problem in itself. Since the last two considerations are frowned upon by SLE, the only solution, at present, seems to be the cavity that can be broken into two units. Rough sketches are underway on this (by Motorola).

4. The local oscillator and TR cavity must be tuned for each frequency independent of which solution is chosen from the above. This may alter the design of the integrated unit from the APG-5 design, thereby making it impossible to use existing dies, requiring an easily removable coupling between local oscillator and mixer injection probe, as well as other changes.

3. Estimate of Future Progress.

a. Tests are still being run on the re-entrant cavity incorporating varying diameter grid cylinders. These tests are aimed at increasing the versatility and general efficiency of the device as an RF power source. However it appears that this work will be of minor value in setting this unit into production.

b. It is earnestly suggested that along with the antenna and test equipment, this component of the ABEES be given the earliest attention. While fairly extensive information is available in our files from Northwestern studies of this cavity, the cavity, as employed in this unit, has been considerably modified mechanically, and the RF power level has been increased; thus, this information may only serve as a guide rather than an accurate reference.

B. Producability

1. Certain points regarding production of these units have been discussed in 2 above. It is to be noted that production problems continued throughout the period of manufacture of the APG-5. Non-uniform tube tolerances, both mechanical and electrical, as well as grid sag, and variation of spot frequency checks were constant troubles. It seems safe to assume that these problems will continue unless

design methods circumvent depending on the tube manufacturer's tolerances etc. In line with this reasoning, it has been pointed out that Machlett manufacturers a tube the equivalent of the 2C39 which, while higher in cost, is held to closer tolerances and employs such techniques as gold-plated elements etc. In view of the fact that this tube is rated to oscillate within the band specified for ABEE, as contrasted to operating the 2C39 outside its rated frequency limits, immediate investigation of the Machlett type seems to be indicated.

2. Vendors.

2C39 - G. E., Machlett, Eimac. It is reported that G.E. tubes are held to better mechanical and electrical tolerances; therefore they are preferred.

1B27 - Bomac, single source at present.

2C40. -

1B21B -

Machined parts and hardware which do not disclose the nature of the cavity or frequency may be farmed out.

C. Chronological Developments

1. July 26: Bomac, only source of supply of TR tubes used in ABEE indicated that spring finger contact on discs of tube undesirable; prefer cavity that clamps both discs of tube tightly.

2. July 26: It is apparent that this unit was designed for a climate of 10-30% relative humidity. The high voltage pulse and points of high electrostatic field intensity in and around the cavity seem to be operating just below air breakdown point. These levels produce 4 kw peak power in the pulse.

3. July 26: A report on 10 g vibration and shock test on the current 2C39 cavity is available.

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VII. MECHANICAL DESIGN

A. Status

1. Development

a. The development of the housing, pressure seal, and dehydrating element, and the problems of heat dissipation, etc. have been given scanty attention. The 8" x 12" unit affords some data concerning component placement, and some thought was given to making the unit mechanically rigid; however, to date, no data exists as to shether packaging presents a serious problem. It seems unlikely that the ABEE, as operated during flight, or drop, will present the heat problem encountered in the APG-5. However, on test, the heat element appears serious.

2. Points of Controversy

a. There exists a definite feeling that thermostated heating elements to stabilize the cavity and chassis temperature over the specification range would be undesirable; however, it is admitted that should it be absolutely necessary fof reliable operation, it might be accepted.

b. See VI R.F. Unit for general picture of mechanical problems existant in cavity design.

3. Estimate of Future Progress

a. It is anticipated that the 8" x 12" unit will be completed prior to 1 August. Scheduled tests on this assembly should reveal pertinent data for guidance in production design.

b. Progress beyond the delivery of the 8" x 12" unit on the mechanical aspects of the ABEE, by this laboratory, is apparently not anticipated.

B. Producability

1. Reference to the experience accrued in the APG-5 design should contribute much toward expediting the production of the mechanical aspects of ABEE. It is felt that a drawn cylindrical housing comparable to the 9" x 14" container for the APG-5 should suffice for this application. Attention should be paid to the pressure seal in view of the long term storage requirements.

2. Other aspects of the layout resolve themselves into standard JAN specification electronic assembly practice.

3. It is apparent that careful sequential assembly techniques should be studied in view of the component crowding and the possible necessity of point-to-point wiring. This may be necessitated by the short pulse length employed with its rapid rise time, which predicates low wiring capacitance.

4. It is noteworthy that all insulation must be non-nutrient in the support of fungus. It is further indicated that mercury compounds for anti-fungicidal treatment may not be used.

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VIII. DYNAMOTOR

A. Status

1. Development

a. Specifications have been written on this unit and three development contracts have been let.

Eicor --- Deliver twelve units approximately third week of August.

Carter --- Deliver twelve units approximately fourth week of August.

Holtzer Cabot -- Deliver twelve units approximately third week of September.

NOTE: We are not permitted to contact these contractors regarding the dynamotors for security reasons. All details and specifications must be handled by SLE.

2. Points of Controversy

a. From a reliability standpoint, series filaments, such as is being employed in the present ABEE, is considered undesirable. A feeling exists that possibly a filament winding could be incorporated in the dynamotor. If this method should be decided upon, the decision must be made at a very early date, so the change can be incorporated in the specifications. It is gathered that changes of this nature are extremely slow in taking effect.

b. There is further feeling expressed by SLE that possibly the company should undertake the purchasing of the dynamotors, possibly through one of its other departments, for security reasons. There is considerable doubt, however, as to whether this procedure could be put into effect in the short time available.

3. Estimate on Future Progress

a. See 1.a above.

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B. Producability

1. This unit will not be produced by the company.

2. Vendors

See above

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X. TEST EQUIPMENT

A. Status

1. Development

a. The test equipment is completely undeveloped. Definite requirements cannot be wholly defined at this time.

2. Points of Controversy

a. There still exists some confusion as to whether the test equipment will consist solely of the echo box in the flight test box and the main unit with integrated facilities for checking power, frequency, range, etc. Hoffman mentioned the possibility of a few additional more-elaborate equipments for lab use in checking the ABEE in every detail. This thought has been questioned by others.

3. Estimate on Future Progress

a. It seems evident that detailed thought concerning test equipment has been postponed in favor of completing ABEE. While cursory specifications are available, detailed methods and determination of needs apparently will be decided by the company subject to SLE approval.

b. Certain laboratory test equipments such as artificial range measuring devices, etc. are being investigated by SLA and at least one of these units is being fabricated for SLA use. Data on the results of these investigations should prove of use in the analysis of the test equipment problem.

B. Producability

1. Indeterminable

2. It is noteworthy that the test equipment will have to pass almost all the test specifications of ABEE with the exception of temperature. Anti-fungicidal treatment and humidity tests are major problems with these units as indicated by SLE.

Mr. D. E. Noble returned to Sandia early in July. Among other things the Abee Tester development was discussed. The Phoenix facility was proposed because of its proximity to Albuquerque. Also Dr. A. C. Tregidga's extensive experience with instrumentation would be of value. Because only a small quantity of testers would be produced, fabrication at Phoenix was suggested.

On July 13, 14, 15, Mr. M. E. Whitney visited Sandia and talked with the Engineering, Applied Physics, Contracting Liaison, Documentation, Security and Tele-metering groups. The delivery schedule, antenna, test equipment, and specifications were discussed. The problem of obtaining clearance for additional engineers was presented, and the need for removal of the work from the Sandia laboratory was considered in view of the excessive work load under which Sandia was operating. Also discussed were (1) preliminary testing of the Sandia prototype and (2) a bill of material, including critical components. During the meeting, the objectives of the new contract were stated to be (1) to complete as soon as possible a laboratory model, a prototype, and pre-production samples and (2) to be ready for mass production by the required time. While the contract with Motorola did not specify mass production, it was understood that mass production was an objective which would be effected following approval and type acceptance of the pre-production samples. The manufacturer for mass production had not been determined and would be the subject of other future Sandia activities.

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Executive Contacts - Plant Facilities - Phoenix Laboratory - Critical Time Requirements - Conference at Sandia - Early Specifications and Changes - Continued Evaluation of the Sandia Production Model - Phoenix Staff Personnel.

During the week ending July 23, 1949, Mr. N. C. McManus, representing Mr. R. W. Kirkman and Mr. N. Arnstein of the New York Atomic Energy Commission, visited Motorola in Chicago to review the necessary security measures and to become familiar with space intended for engineering, production, and purchasing in the plant at 1327 Washington Boulevard. Following the visit of the AEC officials, a letter, dated July 27, 1949, was forwarded to Mr. Arnstein in New York describing the advisability of conducting the ABEE and Tester parallel development at the Phoenix Laboratory. The following reasons were cited:

1. A high degree of contract liaison and coordination would be required during the early stages of development. The Phoenix location would be convenient because its location is approximately two hours by air from the Sandia Laboratory.
2. Because the Sandia shop facilities were overloaded, much time would be saved by utilizing the Phoenix facilities for the preliminary model work.
3. In addition to his instrumentation experience, Dr. Tregidga would be able to contribute to the development of the prototype.
4. Plant facilities could be more quickly adapted to meet security requirements.
5. Parallel development of ABEE and the Tester would be facilitated by conducting the two activities at the same location.

In evaluating the objectives stated by Sandia, that speed was all important in carrying out the contract, the Motorola opinion expressed that the ultimate objective could best be realized by the intermediate step, utilizing the Phoenix Laboratory. While the Chicago facilities were being prepared for security, work could begin immediately at Phoenix. With the exception of the ABEE tester, Motorola expressed the opinion that ABEE production at Chicago was desired in order that the Phoenix laboratory may remain as intended, a research laboratory. The plan included the temporary assignment of Chicago engineers to the project at Phoenix. The engineers would then be returned with the project to Chicago to assure continuity and uninterrupted progress. Accordingly a request for security clearance of the Phoenix facilities was forwarded to the New York Atomic Energy Commission.

The growth of the Motorola organization to meet the project requirements was a development paralleling the evolution of the technical and contractual aspects of the program. Shortly after the letter of intent contract had been executed for the Atomic Energy Commission by W. E. Kelley, Manager, New York operations office, and for Motorola by D. E. Noble, vice president, Motorola immediately proceeded to take the necessary steps to obtain security clearance for the Motorola personnel who would become associated with the new work. Accordingly, on July 7th clearance requests were made for W. Wolbrink, A. C. Tregidga, F. B. Posey, C. H. Beringer, E. Conrad and P. S. Ferrell.

The several phases of activity for the development of Abee and its tester were now well underway. The phases included technical evaluation of the ABEE prototype, mechanical evaluation, determination of the status of the development with respect to quantity production, and re-organization of the Phoenix laboratory to relieve the overloaded

Sandia facilities.

The following personnel had been cleared during the month of July:

P. J. Sturm	Project Engineer
E. D. Kirk	Draftsman
K. N. Bergan	Engineer, Chicago
C. J. Hoppe	Draftsman

Other Motorola personnel awaiting clearance included:

L. P. Morris	Chief Engineer, Systems, Chicago
A. M. Trauscht	Secretary, Chicago
L. C. Harder	Purchasing Agent, Chicago
H. Magnuski	Chief Engineer, Communications, Chicago
W. W. Wolbrink	Draftsman
A. C. Tregidga	Senior Engineer

The major activities by the end of July comprised the collection of technical information and preparation for a conference at Sandia which had been scheduled to convene August 2, 1949. The conference report was recorded by T. F. Marker by letter, August 9, 1949, to R. A. Bice, Manager of the Sandia Engineering Department:

"1. On August 2, 1949, a conference was held in the Sandia Conference Room, Sandia Laboratory, with representatives from Motorola, Inc., New York AEC, and Sandia Laboratory. Those present at the meeting were:

D. Noble, Motorola
M. E. Whitney, Motorola
J. Silver, Motorola
Dr. A. Tregidga, Motorola
P.J. Sturm, Motorola

Norman Arnstein, N.Y. AEC

R. A. Bice, SLE
L. A. Hopkins, SL TAD
J.A. Hoffman, SLE-3
L.D. Smith, SLE-3
A. VanEvery, SLE-3
R. E. Jacobson, SLE-6
T. F. Marker, SLE-R
W. G. Funk, SLCL
J.H. Toulouse, AEC
J.E. Palmer, SLCL
C. W. Carnahan, SLA-2
W. A. Janvrin, SLA-2

2. Motorola requested that the Abee project be moved to their Phoenix facility during the construction of a research prototype. It was pointed out that the Sandia model shop is, at the present time, heavily overloaded. Since it has already been agreed that the test equipment development would take place at Phoenix, it is desirable to keep the two projects together in the early phases. The plan to move the project to Phoenix was concurred in by the Laboratory members present.

3. The antenna will be a parallel project with development by Motorola and the Sandia Laboratory. Motorola will make pattern measurements at the Sandia (West Lab) pattern site, with fabrication taking place at Phoenix. The program will be carried in two parts;
(1) the development of "on the nose parabolas".
(2) "off the nose systems" to eliminate problems of nose loading. The highest priority will be given to an antenna system on the nose since it is mutually agreed that this appears to be the best solution from a time scale standpoint. The transducer between antenna and radar proper will be coaxial cable, probably RG-14U. It is agreed that while waveguide offers the lowest attenuation, the short run necessary does not justify its application when production problems are considered, particularly, in view of the fact that waveguide fabrication and bending is a highly specialized art, necessitating an additional security cleared vendor.

4. Motorola will seek to develop a radar having the shortest possible warm-up time with a target of 30 seconds being desirable. It is agreed that this remains an item for additional study before a decision can be reached.

5. For the present, Motorola shall plan to incorporate the delay timer in the Abee package providing a delay variable between 0.1 and 1.0 second within $\pm$ 10%. The cross connections between delay timers shall remain for the present as now envisaged in the schematic which has been turned over to Motorola.

6. It is agreed that frequency changing shall be accomplished by a split cavity arrangement which will permit stocking the tubes and frequency determining elements as a single package.

7. Motorola expressed concern over the use of such items as 1/4 watt neon bulbs, circuits that depend upon voltage reulation, series filaments, and delay cable. These items will receive further study by Motorola during the design of the research prototype."

Copies of the meeting report were distributed to

R. W. Henderson, SLTAD
R. P. Petersen, SLA
H. E. Sunde, SLCL, and
E. L. Deeter, SLE-6, in addition to those

present at the conference.

The Motorola request to complete the technical evaluation of the Sandia prototype at Phoenix was desirable to facilitate progress. The step was a logical one for the reasons previously stated. In addition, the contract letters provided that the Motorola design, development, and fabrication could take place at Chicago or Phoenix.

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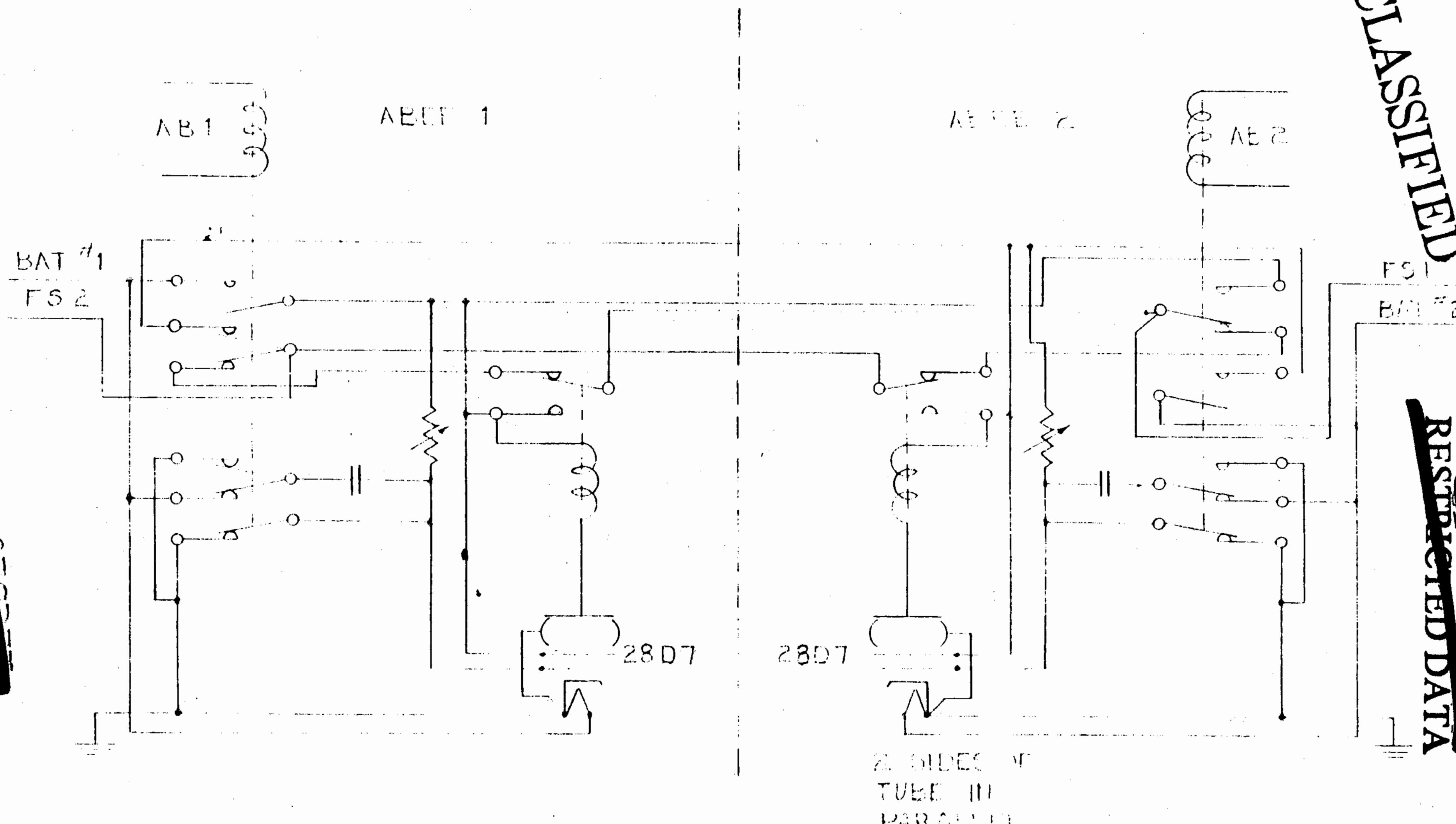

FIG. 3

PROPOSED USE OF DELAY TIMER

(FOR INFORMATION ONLY)

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The antenna development and fabrication were not previously a part of the contract requirements. The theoretical investigations prior to engineering design and development were being conducted by the Sandia Laboratory of Applied Physics.

Item B-16 of the Target Specifications for ABEE, July 20, 1949, required operation of ABEE within 30 seconds after the application of primary power. The conference report recorded that technical problems were present which would necessarily require further study to ascertain the practicability of this requirement.

Paragraph A-3 of the July 20 Target specifications referred to the function of the firing relay to operate a secondary timing device located within the radar package.

Paragraph 5 of the conference report specified that variable delay from 0.1 to 1.0 seconds ± 10% would be required. The cross connections between delay timers ~~was~~ were also specified in a schematic diagram which is presented in Fig. 3.

The conference decisions, ~~as~~ recorded above, effected a modification of II C 3, July 20 target specifications. The August 2 conference decision recorded an agreement to utilize a split cavity arrangement to enable a change of the radar operating frequency. The Sandia prototype (and the schematic diagram forwarded to Motorola) suggested the following type construction, see Fig. 4a, which was a fixed frequency transmitter. The grid cylinder length determined the frequency of operation. The operating frequency could be lowered by (1) removing the tube, and (2) replacing the grid cylinder with one having a greater length.

The receiver included a local oscillator constructed according to the principles of the APG-5 local oscillator utilizing a 2C40 lighthouse tube.

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This local oscillator could be tuned over the desired range without replacing its grid cylinder. The split cavity transmitter, Fig. 4 b, was specified to "permit stocking the tubes and frequency determining elements as a single package".

(1), (2) Later tests were to show that the 2C40 tube exhibited excessive frequency change during the desired operating time. This later required a new local oscillator development using a different tube.

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A letter to P.J. Sturm dated Aug. 4, 1949, indicated that Icor Inc. had requested and received approval to modify the specification SLSP-40 as follows: (1) paragraph I-6 changed to require 2200 volts high potential test, instead of 2500 on the output windings, (2) S-11 wound for the 12 inch engineering samples only, and (3) paragraph L-1 is waived to the extent to allow vendor to ship the 12 dynamotors as a single package; the storage conditions outlined in the paragraph were applicable. The early August conference at Sandia effected agreement that ABEE and the test equipment development would be continued at Phoenix. Early action was taken to expedite security clearance for the Phoenix laboratory as well as transfer of equipment and documents to the new location. Elementary investigations of an unclassified nature were conducted during the first two weeks of August, pending receipt of the necessary documents and equipment. The shipment was expected to arrive on or about August 8, 1949. Clearance requests had been iniated for additional engineering personnel and guards. By approximately August 15, the documents and equipment had arrived, and clearnace had been approved for the required guards and laboratory facilities. The security cleared personnel at Phoenix as of August 15 included the manager, one engineer and two draftsmen.

A 24-hour guard system was inqugurated. Engineers who had not yet received the necessary security clearance were assigned to work in an uncleared area on the delay timer, radio frequency power supply for the transmitter, pulse width discriminator delay line and a multivibrator circuit which could be adapted to the ranging circuits. The assignment of this work had prior approval of Sandia with the

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understanding that no information would be disseminated concerning the application of these components. Other classified work had been assigned to cleared personnel.

By the end of August the cleared staff had been increased by two additional engineers, a model maker, an engineering assistant, two laboratory assistants, and one wireman. Each new man was introduced to the project by a discussion of the required security measures.

The move from Sandia to Phoenix necessitated delays caused by the transfer of equipment and the establishment of cleared personnel and facilities. With a desire to maintain the urgent time schedule, overtime work was requested and granted to compensate for the time required to organize the work at the new location.

It was further requested on August 8, 1949 that the Sandia production model be temporarily transfered to the Phoenix Laboratory to facilitate the instruction of Motorola personnel.

Contract negotiations continued during the month of August. According to the New York AEC request dated August 19, 1949, steps were taken to develop information in order to negotiate a definitive contract. Several additional items or information were necessary before the contract could be drawn. The required information included the target specifications for the development of ABEE and the ABEE Tester. Other required information included salary schedules, personnel policy summary, and the project cost estimate.

During the month of August the evaluation of the Sandia production model continued. Examination during the month indicated that the development was approximately 60% complete. Also the Sandia model, as evaluated by Motorola, failed to meet some of the Sandia target specifications which are discussed in the following sentences.

The specifications for the transmitter through August required the use of a split cavity type transmitter which was at the time considered the only practicable means for proper transmitter operation. A tunable transmitter at this time had not yet been developed. Other r-f circuits had not yet been designed. These included the transmission line to the antenna with a method for quick disconnection of the antenna from the transmission line. The ABEE antenna had not been completed. A remote range selector was not included and a delay timer had not been designed for the ABEE package. The accuracy of range circuits and the reliability of operation of some circuits had not yet been determined.

During August the circuit and system operation of ABEE, Sandia prototype, underwent investigation and evaluation. Component circuits were reconstructed in the laboratory and subjected to detailed examination. The transmitter tube, type 2C39A, was found to be satisfactory. The desirable i-f amplifier characteristics and mechanical layout had been determined and forwarded to Chicago for fabrication. Series tube filaments connected across the primary source of power were considered undesirable. Accordingly the dynamotor specifications were revised to specify a filament winding.

Engineers who had not yet received security clearance were assigned to develop unclassified circuits. The circuit investigations included (1) the delay line for the pulse width discriminator, (2) a radio frequency power supply for the transmitter, (3) a range multivibrator analogous to the circuit intended for ABEE, and (4) the delay timer. Other studies by cleared personnel included (1) methods by which the ABEE housing would be sealed, (2) the practicability of making the grid cylinder (the frequency determining elements for the transmitter) an integral part of the 2C39A tube, (3) the availability of required components, and (4) the reliability of the components selected for the various circuits.

By the end of August a cleared area and a twenty-four hour guard system had been established within the Phoenix Laboratory. The compliment of cleared personnel had been increased by the addition of:

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W. W. Wolbrink	Draftsman
A. C. Tregidga	Senior Engineer
F. G. Posey	Laboratory Assistant
C. H. Beringer	Laboratory Assistant
E. Conrad	Engineer

Others awaiting FBI clearance included:

P. S. Ferrell	Secretary
P. W. Sokoloff	Senior Engineer
R. R. Roberts	Guard
C. R. Goforth	Guard
J. S. Bolin	Guard
C. O. Mueller	Phoenix Blueprint
E. P. Hannum	Laboratory Assistant
W. A. Schaper	Senior Engineer
J. K. Saville	Secretary
D. A. Smith	Junior Engineer
I. D. Pomeroy	Assistant Engineer
E. Mueller	Phoenix Blueprint
E. W. Rafter	Shop Foreman
R. W. Elsner	Senior Engineer
H. E. Brannoch	Janitor
J. E. Bartling	Junior Mechanical Engineer
R. O. Blackert	Assistant Engineer

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Tester-Technical Evaluation - Conference - Development and Manufacturing Schedules - Additional and Revised Specifications - Plans Toward Definitive Contract - Cost Estimate - Development and Redesign - ABEE and ABEE Tester personnel.

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The ABEE Tester program, overshadowed by the early attention applied to ABEE, was begun following the September 6-7 conference at Sandia. While the original letter of intent contract prescribed the development of a laboratory model and six production models (approaching production techniques as closely as possible), early action was not taken. The reasons were threefold: (1) the design would be determined by and, therefore, necessarily follow the ABEE program; (2) the specifications, although a part of the letter of intent contract, were incomplete and inadequately described the requirements; and (3) personnel assigned to the program had not received the required personnel security clearance.

The first evaluation of the Tester program was stated in the "Outline of ABEE Development"dated August 1, 1949, ".......... completely undeveloped". The early efforts to initiate this project were begun during a conference at Sandia during September 6-7. Dr. A. C. Tregidga had been "cleared" and participated. The introduction was most general; the average system function was described and target specifications (Replacing RQT S-4676 (NSA-9286) of the letter of intent contract) were delivered to Motorola. The new specifications are presented with an account of the September 6-7 conference which was devoted rather exclusively to an evaluation of the ABEE equipment and its revised specifications. One result of this confeence was a part of the target specifications, ".......... the technical direction of the contract shall be a function of the manager of the Sandia Laboratory Engineering Department (SLE), by whom additional information and assistance shall be furnished from Sandia Laboratory to Motorola."

The same person was specified, in the September 6-7 target specifications

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for ABEE, to assume direction of the ABEE project. Mr. T. F. Marker, cognizant Sandia project engineer, was responsible for liaison and coordination, reporting to R. A. Bice, the manager of SLE.

Further technical evaluation of ABEE, the Sandia production model, was conducted by Motorola at Phoenix during September.

The stability characteristics of local oscillator, TR device, i-f amplifier, and range circuits received special attention. That much of the development centered around the APG5 series radar was significant because the operating precision of the ABEE was required to be much greater than that of the APG5. The Target development specifications for ABEE prescribed range operation within 100 feet which required a time measurement within 0.2 microseconds. The following is offered to present the effect of the prototype operation in light of the range accuracy requirement.

Laboratory test showed that a ten percent change of either filament or plate voltage to the local oscillator effected frequency changes which varied from 0.4 to 1.6 mc/s depending upon the tube used. It was particularly disturbing that a positive change of voltage applied to the 2C40 gave a positive change of frequency for some tubes - and a negative change for other tubes.

Malfunction of the TR tube was detected. The long time constant circuits prevented application of keep alive voltage to the TR tube for several milliseconds. Without the proper protection afforded by use of the TR circuit, the fragile silicon crystal of the receiver would be subjected to excessive voltage pulses which could destroy the crystal. This malfunction could cause operational failure of ABEE.

The i-f pass band was approximately 6 mc., to permit operation in spite of transmitter and local oscillator frequency changes. In the ABEE application a drift in frequency of a few megacycles would effect a change of signal rise time within the i-f amplifier, seriously modifying the range accuracy. This was considered without introducing the additional malfunction which could be effected by frequency changes accompanying changes of ambient temperature. This was later found to be of even greater significance.

The stability and reliability of the range circuits were evaluated. Particular examination was made of the coincidence circuit and range gate. The function of the coincidence circuit was to pass a video pulse after time coincidence of the reflected signal and a standard time-reference pulse generated within ABEE.

Examination of this circuit revealed the utilization of a plate voltage of 300 volts, 120 volts in excess of that recommended by the manufacturer. Anticipating circuit failure and consequent unreliability of ABEE, it was apparent that redesign was necessary.

The range gate was merely the standard reference pulse, generated within ABEE, which predetermined the firing range of ABEE. It was the output (a video square wave) of a multivibrator which, in time coincidence with the return signal, would initiate operation of the circuits preceeding the firing relay. For precise timing use, it would be required that the time duration of the range gate be constant within 0.2 microseconds. The time duration as a function of plate voltage was determined and is presented in Table 1.

Plate Voltage	Range Gate Time Duration
260 volts	4.1 microseconds
290	3.9
320	3.7
	0.4 usec. variation

Table 1.

Range Gate Time Duration as a function of Plate Supply voltage.

Another test with a different multivibrator tube produced a 0.5 usec. time variation. It was noted that the 0.2 usec. rise and fall times did not vary with a change of plate voltage within the limits 260 to 320 volts. Other tests demonstrated that with the same plate voltage variation and with constant multivibrator bias, the time variation was 0.3 usec. With constant plate voltage (290 V.) the gate width varied 0.05 usec as the bias voltage was varied from -27 to -33 volts.

The errors in range operation without introducing the effects of variable temperature were judged to be excessive. This was apparent especially in view of the fact that the error of one circuit only was in excess of that prescribed in the Target specifications. Cumulative errors of other circuits would further reduce the range accuracy.

Following the coincidence circuit was an integrating circuit. After the acceptance of a predetermined number of pulses, the integrated voltage would be sufficiently high to cause a neon tube to conduct. This would signal operation of the firing relay. Inasmuch as the firing voltage for neon tubes varies from tube to tube as well as with age, it was considered that the incorporation of this type firing circuit would contribute to operational unreliability.

A comprehensive evaluation was made prior to a conference scheduled to be held at Motorola, Phoenix, on September 6 and 7. That development had been approximately 60% completed was substantiated by the final evaluation. The conclusion was supported by the fact that the prototype was a laboratory model. The prototype demonstrated that the combination of circuits into a system was practicable. The following engineering phase would require (1) the organization of the external conditions under which ABEE was to operate (system specifications), (2) the resulting conditions which would be imposed upon the operation of the various electric and electronic circuits within the ABEE system (circuit specifications), and (3) the reduction of ABEE to acceptable manufacturing processes.

Interim technical discussions, laboratory evaluation, and the specifications which had evolved during the early months of the ABEE program were considered by Motorola in preparation for the September 6-7 conference.

The following is a summary of the Sept. 6-7, 1949 conference at Motorola, Phoenix. The summary dated September 7,1949 was signed by D. E. Noble, J.C. Starks, assistant manager, Development Engineering Department, Sandia Laboratory, and T. F. Marker. It was addressed "To All Concerned":

"The purpose of this meeting was to examine the development of the ABEE unit and to attempt to establish the scope of the development and the time scales for its completion.

Early in the conference it became apparent that insufficient information had resulted in over-optimism, and that the proposed program could not be completed in the desired time. The factors contributing to this situation are as follows:

1. The scope of the contract as conceived by the Sandia Laboratory

Engineering Department was considerably broader than the original conception on the part of the New York office of AEC and Motorola Inc. The expanded scope was discussed to some extent during the August meeting but was further developed at this conference. The desired scope of the contract is a full-scale development program of the ABEE unit with its associated power supply and antenna to the extent necessary to meet target specifications which will be outlined in a separate memo. The original conception of the New York AEC office and Motorola was that the required scope covered only the packaging of an acceptable prototype in a form adequate for quantity production.

2. The status of the available prototype as furnished by Sandia was originally thought to be more advanced than tests by Motorola at their Phoenix Laboratory would indicate to be the case. Considerable and extensive re-design appears to be required to meet the target specifications, in addition to the routine changes required to package for mass production.

3. Delay in obtaining clearances for key personnel resulted in equivalent delay in bringing to bear adequate facilities to properly evaluate the scope of the problem and to consider the solutions possible to arrive at a unit which would meet target specifications.

As a result of these factors and the realization of their importance, it became apparent that since the original desired program could not be attained in the available time, it would be necessary to mutually agree on possible alternates for consideration and decision by Sandia as to the course to be pursued from this time forward.

1. Based on present knowledge and experience, Motorola feels that for the completion of the program within the time scale involved, the best they could undertake would be the repackaging of the prototype as delivered by Sandia with only those changes required for the re-packaging.

In this program Motorola would undertake to deliver to Sandia during the month of November 1949 one hand-built prototype representing the proposed packaging, and to deliver additional prototypes off production tools and representing ~~the~~ production techniques, at such a rate and within such a time scale as to permit Sandia's testing of these pre-production units and giving a design release in time to allow shipment of production units to ROAD during the month of July.

If this plan is adopted, additional conferences will be required to further tie down the details of delivery dates on the pre-production prototypes.

It is felt that this solution is likely to be unacceptable inasmuch as major requirements for proper functioning are not satisfied by the prototype as delivered by Sandia, and production therefore would not reflect these improvements which are at present considered mandatory.

2. Because of possible future applications of the ABEE, as well as the requirements for refinements over and above the furnished prototype, Sandia has requested and Motorola has agreed to consider a long-term development program to be consumated by the delivery of prototypes from production tools and representing production techniques which will in all respects meet the requirements of the target specifications as agreed to during this meeting and outlined in a separate memo.

   The estimated time scale for the completion of this program would be the delivery to Sandia during the month of September 1951 of the first of the production units for ROAD from production tools and incorporating all changes found necessary during the testing of the early prototypes.

   Additional conferences would be required on this program to further outline the dates for the various steps in the development.

3. Realizing that the present situation does not permit as an immediate solution a two-year development program, and that the present target specifications cannot be met within the time scale involved for the immediate program, an attempt was made to outline two alternate plans, which represent in terms of engineering judgment the best compromise between desired performance and desired delivery dates, which the combined personnel of Sandia and Motorola were able to formulate at the present time and under the present conditions.

   The two plans involved represented, first, an attempt at a compromise which would permit testing by Sandia of prototypes from production tooling before giving a release for quantity production. Second is a proposal by Motorola, based on the desire to submit to Sandia as finished an engineering design as possible, hoping that engineering development could continue up till the time of the production of the original prototypes from production tools, thus incorporating the maximum possible amount of improvement over the present prototype within the allocated time. This would involve the delivery of the first prototypes from production tools as the first prototype of any type which would incorporate all of the proposed solutions to the problems involved. This will be expanded in the following paragraph. It should be pointed out that this proposal requires a gamble on the part of Sandia for the entire unit, processes and tools prior to receiving any complete samples of the proposed unit. This may be desirable when all the factors are considered.

   Both of these compromises are agreed to apply to a unit having the following discrepancies, with the furnished prototype, corrected in the manner listed below:

A. Two remote range positions will be provided requiring only a two-position switch on the pilot's panel and choosing two preset range positions, presetting to occur before installation of the gadget in the delivery vehicle.

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B. Regulation of the voltage supply and/or other refinements of circuit and/or tolerances required to obtain ≁ - 5% ranging accuracy.

C. Operation from -65° F. and humidity from 0 to 95% on the basis that the unit may be heated from an external power source separate from the battery supply, until 5 to 15 minutes before it is called upon to function, and further on the condition that, if the unit is opened under conditions of high temperature and humidity, on re-sealing it will be dried or otherwise returned to a desirable operating condition before being called upon to function.

D. The unit will be packaged in whatever manner is required to meet the vibration requirements of 10 g for a period of 45 minutes along each of 3 mutually perpendicular axes between 10 and 60 cycles, the cyclic rate being 10 to 60 to 10 in a period of 1 minute, and that individual components will withstand similar accelerations between 60 and 300 cycles.

E. Operation from a primary power source of 24 to 30 volts with a total drain not to exceed 12.5 amperes.

F. Present antenna design with changes to include only those necessary to incorporate a plastic plate over the assembly and to adapt it to quantity production.

G. Operation within 30 seconds after the application of internal power on the basis that preheating will be available from an external source as previously indicated.

H. [redacted] DOE b(3)

I. All design criteria in these compromise proposals shall be based upon operation in the original frequency band. The new frequency band is considered to apply only to the long-term development, and date of September 1951, on the basis that adequate space shall be left in the compromise designs to permit incorporation at a later date of an RF package which will meet the target specifications within the new and desired band.

J. These compromise designs are based on the use of Type N Connectors and RG8/U Coaxial Cable into the antenna, and no quick disconnect feature on these connections shall be guaranteed, but every effort will be made to arrive at an acceptable solution to the quick disconnect problem within the proposed time scales. In particular, Motorola agrees to investigate on a separate unclassified basis the possibility of adapting AN connectors to a quick disconnect feature by means of additional mechanical alterations.

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K. The incorporation within the ABEE of a delay timer adjustable from 1/10th of a second to 1 second with an accuracy at any setting of ± - 10%.

1. The first compromise suggested involves the following conditions and dates:

A. First hand-made model to be ready January 15, 1950, plus or minus 15 days, but not to be type-tested.

B. Continued development and hand-production of additional units up to July 1, 1950.

C. July 1, 1950, initial production prototype to be delivered to Sandia Laboratory by Motorola.

D. The Sandia Laboratory will permit Motorola to commit for tooling and parts with such lead time as Motorola judges to be adequate in order to be ready for July 1 production.

E. Motorola will start production of the 200 units July 1.

F. July 15 Motorola will deliver the first of 25 units.

G. By August 15 will be delivered the balance of the first 25 units.

H. It was estimated that the remaining 175 could be delivered at a rate of 25 per week beginning August 22.

I. On this basis, Sandia anticipates granting a conditional production release on or before December 15, 1950, and a final production release on or before February 1, 1951.

2. An alternate proposal advanced by Motorola was put forward with the thought that the time between 15 January and 15 July might be more profitably spent in additional engineering development rather than Sandia testing. This proposal would envision continued close cooperation and coordination between Motorola and Sandia and would involve an indeterminate number of prototypes, each representing Motorola's proposed solution to one phase of the overall problem, but no prototype representing Motorola's solution to the entire problem as outlined above would be guaranteed delivery prior to the delivery of the first units off production tooling. On this basis Motorola would undertake to deliver to Sandia on or before July 15, 1950, the first units off production tooling and representing production techniques of the quantity of 200 required by Sandia Laboratory Engineering Department for their tests.

It is anticipated that the first partial prototype would be submitted to Sandia by 15 January plus or minus 15 days but not necessarily physically delivered to Sandia Laboratory. The handling of the liaison on these partial prototypes shall be subject to agreement between Sandia and Motorola.

In any event Motorola proposes to release all tools by such time as they consider adequate to quarantee delivery of units from production tools by 15 July 1950. It is expected all tools will have to be released not later than 1 March 1950.

This proposal is submitted for Sandia's consideration, since it involves the deletion of all Sandia testing of complete and/or final units of any type of construction prior to production, and requires the maximum gamble on an item which Sandia indicates is of major importance from a functional standpoint in their overall program.

Pending decision by Sandia and proper instruction to Motorola of the program to be followed, Motorola shall proceed on an interim basis to investigate those portions of the compromise specifications which can be investigated with present personnel and facilities and which are adaptable to either of the compromise proposals. Every attempt shall be made to expedite the solution to these mutual problems both at Phoenix Laboratory and by the farming out to other Motorola facilities of those items which can be investigated on an unclassified basis. Motorola has already indicated their plans to so handle the development of the i-f strip and the delay timer, and in addition will undertake development on a parallel basis of a quick disconnect connector."

The status of the ABEE development was presented to the Sept. 6-7 conference.

The conference report by D. E. Noble dated September 7, 1949, contained the following information:

"My letter to T. F. Marker of August 23rd outlined the transition of the ABEE contract from its first explanation to us in the New York office in June to its present status as a full development contract. As I emphasized, we do not object to the change but feel that it is necessary that the nature of the transition be understood so that there will be an appreciation of the problems encountered as the result of the new conditions presented by the proposed contract. I can now add further detailed information based on additional analysis at our Phoenix Laboratory.

Detailed investigation of ABEE now definitely substantiates the earlier evaluation which indicated that the development prototype of ABEE was 60 per cent completed. This confirms the verbal report that Motorola gave at the August 2nd conference at the Sandia Laboratory. This same information is also included in the written report of Motorola to the New York AEC office dated Sept. 1, 1949.

In order to evaluate the extent of the development work remaining, the following summary is presented, giving Sandia's specifications in contact to the estimated performance characteristics of the prototype furnished to Motorola by the Sandia Laboratory.

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SANDIA SPECIFIES	PROTOTYPE REALIZES
1. 3 remote range positions	None. Could be realized with 1 engineer month development.
2.	DOE b(3)
3. Operate from -65° F. to + 165 ° F. and humidity of 0 - 95%	Operation at one specific temperature. If package is sealed humidity has no effect. Can be realized by some of the following: 1. Temperature stabilization of package. 2. Local OSC and transmitter filament voltage stabilization. 3. Possible AFC on local OSC. 4. Stabilization of power supply. 5. Opening band pass of IF strip. 6. Temperature compensation of oscillator cavities.
4.	DOE b(3)
5. 10 g vibration for 45 minutes from 10 to 300 cycles	4 g vibration for short periods from 10 to 60 cycles. 60-300 cycles not investigated. Realized by complete mechanical redesign.
6. Operation from primary power source of 24-30 volts at 10 amperes	Questioned by Motorola. In view of efficiency figures of Eicor, the maximum power available to ABEE is 120-150 watts. Possibly realized by ABEE in present form, but with any electrical modification, will probably exceed this power stipulation.
7. Antenna VSWR 1.6	In view of the present stage of antenna; this cannot be fully evaluated; however, since quick disconnects have not been designed, the 1.6 figure is open to question.

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8. Antenna shall cover all frequencies of ABEE.	Same as above.
9. Antenna beam width Less than 30° E plane More than 30° H plane	Same as above.
10. Antenna gain 15 db.	Questioned. See above. All four of these antenna specifications can be approached through thorough development program of about three engineer months.
11. Operation from cold start within 30 seconds	Impossible. Present ABEE will not meet reliability figures with this specification adhered to. Under no circumstances is this advised. Can be realized by pre-heating of filaments for 5 minutes prior to drop.
12. Quick change of frequency of ABEE	Not realized. Can be realized by extended cavity development.
13. Change of original frequency band to a different band	Not realized. Can be realized by extended redesign of 1. transmitter oscillator 2. T.R. cavity 3. local oscillator 4. mixer and RF plumbing 5. antenna
14. Quick disconnect for antenna	Not realized. Not designed at present time.
15. Reliability greater than 1 failure in 800	Not realized. Series filaments, neon tubes for voltage reference devices, questionable high voltage supplies, tubes operating outside mfgrs. tolerances no preheat period, etc. General clean-up necessary to approach this reliability insofar as production is concerned. In addition without elaborate precaution against transmitter and local oscillator frequency drift, the unit will fail to operate, merely due to the receiver drifting off tune with change of temperature and voltage. This must be corrected as indicated by 3 above.
16. ABEE incorporate delay timer	Not realized. Can be realized by development program of approximately one engineer month."

The Target specifications which were mutually agreed upon by Sandia and Motorola during the ~~July~~ September 6-7 conference. The Tester specifications (I) were signed by T. F. Marker and D.E. Noble. The Abee specifications (II) were signed by D. E. Noble, J.C. Starks, and T. F. Marker.

"I. Target Specifications for ABEE Tester.

1. The Abee Tester is to be considered as that piece of equipment, together with the necessary accessories, required to perform a complete field test of the ABEE.

2. A complete field test is defined as including all tests of ABEE necessary to determine the satisfactory functional performance.

3. Following are a list of the basic design requirements for the ABEE Tester.

   a. The tester shall have the minimum practicable weight and cubage. It is desired that the weight should not exceed 70 pounds.

   b. The Tester shall be capable of withstanding conditions of temperature, humidity, vibration and shock as specified by Procuring Agency.

   c. When prepared for shipment the Tester shall be splashproof (i.e. when sprayed from any direction, water shall not enter the Tester.)

   d. For the purpose of design of the Tester to withstand long term storage, the Tester shall be considered as being protected by Class B packaging during storage.

   e. Shock mounting shall be provided for such components or assemblies within the Tester as may require such protection.

   f. The Tester shall be capable of being placed in operation rapidly in the field.

   g. Calibration circuits, if required, should be self-contained, and all controls necessary for calibration should be located on the front panel of the equipment. All connections and controls necessary for operations of the Tester shall be located on the front panel of the equipment.

4. A case sturdily constructed to serve also as a carrying case and a shipping chest should be used. Packaging for equipment to Sandia Laboratory should be Class B Commercial Pack. Such a case should have a removable cover over the front panel. The cover should provide storage space for cables, etc. used in conjunction with the Tester.

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5. It is realized that the design of the ABEE Tester ultimately will depend largely upon the design of ABEE. Therefore, the technical direction of the contract shall be a function of the manager of the Sandia Laboratory Engineering Department (SLE), by whom additional information and assistance shall be furnished from Sandia Laboratory to Motorola.

6. It is presently anticipated the following functional tests will be incorporated:

    1. Measure transmitter power
    2. Measure receiver sensitivity and noise susceptibility
    3. Check range accuracy
    4. Measure VSWR of antanna by means of simple device
    5. Measure frequency
    6. Test delay timer
    7. Provide all necessary control circuits.

II. Target Development Specifications

A. Classification and Intended Use.

A-1. The term "radar" as used herein shall include all components of the radar proper, antenna, and dynamotors necessary to operation of the device.

A-2. The radar shall effect the closure of a relay upon the reception of an echo from a terrestial target within certain specified ranges. It shall perform this operation at various conditions of temperature and altitude after storage for a minimum period of two years.

A-3. Additionally the closure of the firing relay shall effect the operation of a secondary timing device located within the radar package.

A-4. Each radar is required to function within the terms of this specification on the first application to its intended use.

B. System Requirements and Performance.

B-1.

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B-2. [redacted] The radar shall not have spurious responses to echoes beyond any range setting such as to cause premature ranging.

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B-3. Any range setting shall be accurate to ± 5 percent or better.

B-4. The frequency will be specified only by verbal communciations between Motorola, Inc., and the Sandia Laboratory.

B-5. The radar shall operate to its intended use under ambient temperature conditions of minus 65° to plus 165° F and humidity of 0 to 95% at all applicable temperatures.

B-6. [redacted]

DOE b(3)

B-7. The radar must withstand cyclic vibration of 10 to 55 cycles per second for 45 minutes in each of three mutually perpendicular planes. Vibration is to be at a constant amplitude corresponding to an acceleration of 10 times gravity at 55 cycles per second, and is to cycle from 10 to 55 cycles per second and back in 1 minute intervals. Components will be tested up to 300 cycles. Conditions of testing will be agreed upon by the Sandia Laboratory and the contractor. High frequency vibrations and shock tests will be given the equipment. Conditions for this will be by mutual agreement between the Sandia Laboratory and the contractor.

B-8. The radar shall operate to its intended use, after being subjected to any pressure altitude up to 50,000 feet, without damage to the unit.

B-9. The radar shall operate from a primary power source of 24 to 30 volts d.c. The maximum current drain per radar shall be 12.5 amperes.

B-10. The dynamotor shall also be in accordance with certain Sandia Laboratory specifications and shall be used to supply all necessary voltages to the radar.

B-11. The antenna shall be designed so as to cover all frequencies of the radar.

B-12. The size and weight of the system shall be kept as small as possible consistent with good practice and within space limitations defined by Sandia Laboratory.

B-13. The unit shall be capable of operation to its intended use after application of the primary power within a time agreed upon between Sandia Laboratory and Motorola, Inc. If practicable, no auxiliary or preheating shall be required to meet the warmup time. The contractor shall attempt to keep the warmup time to a minimum. The target value of warmup time is thirty seconds or less.

B-14. The unit shall not radiate or be receptive to signals until armed by auxiliary equipment.

C. <u>Design</u>.

C-1. The design must be in accordance with the accepted practice for military airborne equipment.

C-2. When no specification designated by Sandia Laboratory applies, the best commercial practice will be applicable.

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C-3. The design shall be based on a design set forth by the Sandia Laboratory Engineering Department in the form of a sample unit, schematic diagrams and other drawings.

D. Construction.

D-1. The construction and workmanship shall be in accordance with good practice for airborne radar equipment and any applicable specifications designated by Sandia Laboratory.

The technical direction of the contract shall be the function of the Manager of the Engineering Department, Sandia Laboratory.

E. Time Scale.

E-1. The program is predicated upon quantity production by 1 September 1951. The contractor shall exercise all possible diligence to improve this date if practicable."

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It was agreed during the conference that the ABEE and Abee Tester projects were to become a full scale development program. The cost estimate, which was being prepared, was modified accordingly, and the New York office of the Atomic Energy Commission was informed of the changed status by letter on Sept. 21 ~~and~~ that Motorola would supply the necessary information to assist the formulation of a definitive contract.

The cost estimate would include the development of the continuously variable tuning within the new frequency band which Mr. Marker indicated would be required after July 1, 1950. The outline estimate was indicated as follows:

1. Development and construction
    - a. 200 ABEE units complete systems.
    - b. 12 test equipment units.
2. Complete production setup preparing for quantity production.
    - a. tooling and production test equipment.
    - b. plant re-arrangement and preparation
3. Security factors
    - a. guards salaries.
    - b. special physical factors required.

There were several questions which Motorola asked for clarification. 1. In the wage and salary schedule would it be required to list the classifications for those individuals such as accountants, who in the Motorola organization would now be charged to overhead,

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and would not be charged directly. 2. In the outline submitted by the AEC personnel department it was stated that salary approval up to and including $8,000. per year were the responsibility of Motorola. Those over would be submitted on AEC form 37 for prior approval by the AEC. The question was asked if this means there must be approval before personnel getting over $8,000. per year could be assigned to the project, or did it mean that salary changes in this category must be submitted for prior approval. 3. The letter of contract stated that when requested by the commission the contractor would furnish the labor and technical personnel at such site or sites as the commission may request. This was broad in its scope and Motorola requested clarification so that it could be properly considered in the cost estimate. 4. It was desired to know the AEC policy concerning allowable overhead items. Motorola assumed that several sets of drawings would be required, that instruction books would not be prepared by Motorola and spare parts were not to be included in the cost estimate at this time. It was further indicated in the letter of September 21 that Motorola would base plans of full scale production based upon a rate given to Motorola, an estimated minimum of 35 units per week and a maximum of 75 units per week.

Efforts were being made to complete cost estimate by Oct. 15. Because the letter of intent would expire on Sept. 30th, it was at this time requested that the letter of intent be extended 30 days or longer as required in order to negotiate the definitive contract.

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Throughout the month of September, the development and redesign of component circuits was accelerated. Operations were handicapped in that there was a shortage of cleared personnel. The technical progress is presented in abbreviated form:

TRANSMITTER 2C39A Split cavity design completed by machine shop. Tunable cavity and drawings complete. Test showed that tuning range was 400 mc/s.

TR. The tube type selected. Visit to Bomac by O. J. Glasser, Major, U.S.A.F., revealed that: the 1327 would function properly at the desired frequencies. Lower frequency operation practicable. TR tube recovery time after decay of transmitter output would be unchanged. A minimum gap spacing (two turns at lowest frequency) necessary to protect crystal mixer; gap would "break down" with lower applied r-f voltages; voltage stress on silicon crystal would be minimized. Lower frequency operation would not impair tube life. Tube life estimated to be 700 to 800 hours of operation. Present Bomac production was 200 per month which would be increased. Guaranteed shelf life is one year. All tubes factory tested and aged for 3 weeks. Tubes which pass the three week's test should last indefinitely.

I-F AMPLIFIER. Mechanical and electrical design specifications delivered to Chicago for fabrication of the i-f strips. The following specifications were established:

Size: ------------------------ Minimum, consistant with high reliability components. Enclosed layout specifies maximum dimensions.

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Weight:------------------------Open

Power:-------------------------Absolute minimum, compatible with other technical characteristics. Maximum total drain 22 watts.

I.F. Freq.:--------------------30 mc $\pm$ 1 mc

Pass Band: --------------------10 mc $\pm$ 1/2 mc at 3 db down

I. F. Gain:--------------------100 db (tube g_m = 4500 micromhos)

Noise Figure:------------------Not over 6 db. Nominal 4.5 db or best figure that can be met.

Video Gain:--------------------25 db

Video Limiting level:----------40 volts

Output Impedance:--------------See schematic

Output Signal Polarity:--------Positive

Tubes:-------------------------Open, except JAN specs miniature series

Specified Components:----------Tube sockets - EBY, ceramic connector, power-Winchester A7P connector, input-Bayonet BNC (Note 1)

All Components:----------------Greatest reliability, highest quality

Circuit:-----------------------See suggested schematic. All circuiting open, Except for:

(a) D.C. restorer on grid of output stage

(b) Allowance for blanking and AGC on 2nd, 3rd and 4th I.F. stage grids (see note 2)

Crystal current jack should be small. For space available see layout. Possible cascade input investigation recommended.

Phase distortion characteristics should be such that pulse of less than .5 microseconds duration, of extremely short rise time, will pass substantially unaltered.

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All components should be selected with the understanding that reliability of this unit must be a maximum.

This unit must pass tests exceeding JAN specs. on temperature, humidity, vibration and shock.

Note 1. Requirement of BNC bayonet input connector dropped, to allow use of special crystal connector.

Note 2. Blanking and AGC on 2nd and 3rd stages only, in accordance with schematic diagram furnished.

VIDEO CIRCUITS: Evaluated operation of circuits with plate supply regulation using miniature tubes. Delay line for pulse width discriminator completed and ready for test. Integrater circuit undergoing redesign. A complete range circuit completed - ready for test of laboratory model.

HIGH VOLTAGE POWER SUPPLY: Radio frequency supply constructed and tested. Considered inadequate for ABEE because of (1) poor voltage regulation and (2) non-uniformity of tube characteristics which cause inconsistent output characteristics.

DYNAMOTOR: Specifications changed to include 6.3 volt, 400 cycle supply for filaments - approved by Sandia Engineering (SLE)

HOUSING: Design partially complete. Design for pressure seal completed.

CHASSIS: Major dimensions had been established.

Motorola personnel cleared during September included:

P.S. Ferrell	Secretary
P. W. Sokoloff	Senior Engineer
R. R. Roberts	Guard
C. R. Goforth	Guard
J. S. Bolin	Guard
C. O. Mueller	Phoenix Blueprint

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E. P. Hannum	Laboratory Assistant
W. A. Schaper	Senior Engineer
J. K. Saville	Secretary
D. A. Smith	Junior Engineer
I. D. Pomeroy	Assistant Engineer
E. Mueller	Phoenix Blueprint
E. W. Rafter	Shop Foreman

The clearance requests during September included:

K. A. Hale	Tool & Die Maker
J. Soriano	Laboratory Assistant
B. G. Bartee	Stock Clerk
R. S. Bailey	Senior Engineer
J. M. Hagen	Detail Draftsman
W. T. Shawler	Tool & Die Maker
J. C. Gundry	Assistant Engineer
P. Brennan	Guard
E. S. Shapard	Assistant Engineer
C. B. Boenning	Assistant Engineer
H. R. Dell	Assistant Engineer

By the end of September, 1949, the technical personnel assigned to the ABEE and ABEE Tester project comprised the following cleared personnel:

<u>ABEE TESTER - P8</u>

A. C. Tregidga	Senior Engineer
E. Conrad	Engineer
F. G. Posey	Laboratory Assistant
W. A. Schaper	Senior Engineer, P7, P8 consulting engineer

<u>ABEE - P7</u>

P. J. Sturm	Senior Engineer
P. W. Sokoloff	Senior Engineer
I. D. Pomeroy	Assistant Engineer
D. A. Smith	Junior Engineer
E. P. Hannum	Laboratory Assistant
C. H. Biringer	Laboratory Assistant

<u>MACHINE SHOP</u>

E. W. Rafter	Foreman

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<u>DRAFTING</u>

E. D. Kirk	Draftsman
C. J. Hoppe	Draftsman
W. W. Wolbrink	Draftsman

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PHOENIX BLUEPRINT

C. O. Mueller
E. Mueller

GUARDS

C. R. Goforth
R. R. Roberts
J. S. Bolin

MOTOROLA, CHICAGO

D. E. Noble	Vice President
J. F. Silver	General Manager, Communications Division
L. P. Morris	Chief Engineer, Systems
H. Magnuski	Chief Engineer, Communications Division
M. E. Whitney	Government Contract Co-ordinator
L. C. Harder	Purchasing Agent
A. M. Trauscht	Secretary to the Vice President

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Emergency - Conference at Sandia - Unlimited Budget - Relaxed Target Specifications - Motorola Recommendations - Expanded Personnel Organization Required.

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In the course of events, ~~August~~ October, 1949, saw great pressure applied to the ABEE program. Already compressed to a great extent, the time schedule was again to be revised to assure completion of the program at an earlier date. The various factors which could be brought to bear upon the course of this activity were several and varied. Not the least was the course of international diplomatic developments. Announcement by the President of the detonation by Russia of its first atomic bomb changed the objectives from compliance with existing time scheduling to the necessity for early completion of the ABEE program. The resulting conference at Sandia was reported by P. J. Sturm:

"On October 6, 1949, a conference was held at the Sandia Laboratory to reconsider the time schedules established for the production of ABEE, which were determined at the Motorola Laboratory in Phoenix on September 7. Representatives of Sandia Laboratory Administration, SLE, SLA, SLCL, the R&D Board and Motorola were present.

As a result of certain diplomatic and technical developments, the delivery of production units of ABEE and ABEE Test Equipment to the Sandia Laboratory at an earlier date than was previously established has become of major importance, and the following relaxation in specifications and budget was proposed by the Sandia representatives as a measure which might assist Motorola in establishing production prior to July 1, 1950.

1. Unlimited budget.
2. Reduction of pulse power from the 3-5 KW specified in the target specification to a value more readily stabilized around 1 KW.
3. Permission to employ any of the following transmitter cavities:
   (a) split cavity
   (b) entire plug-in R.F. units
   (c) continuously variable frequency cavity.
4. Relaxation of ± 5% overall range accuracy to ± 10% overall accuracy.
5. Minimum of two remotely-selected ranges.
6. Permission to utilize switched line-controlled range gate in place of continuously variable multivibrator gate.
7. Possible increase in available power from batteries, dependent upon further investigation by SLE.

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8. Increased development cooperation from SLA, especially regarding propagation attenuation tests and relative drift between transmitter and local oscillator frequency.
9. Changing tolerance of battery voltage from 24-30 volts to 26-28 volts.
10. SLA acceptance of antenna development with only Motorola cooperation in mechanical design and test, and readying for production.
11. Unsealed housing.
12. Elimination of delay timer from ABEE package.
13. [redacted] DOE b(3)

It was mutually understood by Sandia Laboratory and Motorola that any of the above expediencies which might be adopted for the first units would not be continued throughout production, but would be corrected in future production deliveries to conform as nearly as possible to the existing written budget specifications.

It was generally conceded by Motorola that the above-mentioned considerations would materially assist in a possible earlier delivery. Points (1), (2), (3c), (4), (8), (10), (12), and (13) were accepted at the conference by Motorola as immediately effective changes in specifications which would enable earlier delivery, provided a contracting of the time schedule was possible. Points (3a), (3b), (5), (6), (7), and (11) were considered debatable as definite factors in the time scales with presently available information.

It was concluded, as a result of the discussion, that these various debatable considerations should be investigated further by Motorola along with certain definite studies of the relative drift of transmitter and local oscillator frequency. This work was also to be undertaken on a parallel basis by SLA. At the completion of these studies, Motorola would submit their minimum time schedule for production."

Additional information was contained in the conference report by G. R. Bachand and R. A. Bice of the Sandia Laboratory:

"1. Mr. P. J. Larsen, Director of Sandia Laboratory, called a meeting on 6 October 1949 with representatives from Motorola and Sandia to discuss the possibilities of reducing the Abee time scales. Those attending were:

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D. Noble, Motorola Inc.
A. Tregidga, Motorola Inc.
P. J. Sturm, Motorola Inc.
H. Magnuski, Motorola Inc.

P. J. Larsen, SLDIR, Sandia
R. W. Henderson, SLTAD "
L. A. Hopkins, SLTAD "
R. A. Bice, SLE "
R. P. Petersen, SLA "
J. C. Starks, SLE "
E. L. Deeter, SLE-6 "
J. W. Jones, SLE-6 "
J. A. Hoffman, SLE-3 "
C. W. Carnahan, SLA-2 "
T. F. Marker, SLE-R "
G. R. Bachand, SLE-R "
L. D. Smith, SLE-3 "
E. E. Pace, SLCL-1 "
T. L. Allen, SLA-2 "
B. J. Bittner, SLA-2 "
Maj. Bradley, R&D Bd. "
Cmdr. Mandelcorn, R&D Bd. Sandia
R. F. Rutz, SLA-2 "

2. Status of Motorola Program. Mr. D. E. Noble stated that Motorola at present has 29 people on their staff at Phoenix and will have a total of 40. On the APG-5 program during the war, fewer senior engineers were assigned than on the present Abee program. Mr. Noble felt that it was most desirable to keep the system compact at one laboratory with one person carrying the responsibility. Also, any parallel work carried on by Motorola would be a gamble.

3. Cavity Design. The three choices of cavity design are

a. Continuously tunable cavity
b. Fixed cavities with interchangeable R.F. deck
c. Replace entire units

Mototola at present has a tunable cavity which has a minimum power output of 1 KW over the old band. The time scale is not affected by the development of the tunable cavity. By using 4 fixed cavities, it would be possible to use plug-in R.F. decks; that is, simple connecting devices for easy replacement. The tuning adjustments would probably be simpler with the fixed cavities, but the advantages of the tunable cavity would probably outweigh this feature. To replace entire radars would be a storage problem.

4. Frequency Stability. Henry Magnuski, Chief Engineer of the microwave development group in Chicago, reviewed this problem with prime emphasis as to how the stability affects reliability. Since Motorola

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had no data on the first few seconds of operation of Abee, the seriousness of the problem is not yet known. However, the grid-cathode spacing of the 2C39 transmitter tube will change as the cathode current changes. Motorola is awaiting the arrival of a spectrum analyzer to aid in making these tests. Although it is true it is possible to operate Abee into a dummy load, the antenna change over switch would probably be a greater problem than getting the frequency stability desired.

5. Range Accuracy.

   a. Sandia Laboratory has stated that if relaxing the range accuracy to ≁ - 10% will aid in meeting the time scales, this should be done. Motorola would prefer not to incorporate voltage regulating circuits. The present status is that Motorola will run range accuracy tests and give Sandia the specifications they think can be held.

   b. If the battery voltage can be held to ≁ - 2 volts, Motorola feels this may help them achieve the range accuracy desired.

6. Delay Timer. Sandia Laboratory made the decision to remove the timer from Abee. Only a pair of contacts will be provided in Abee subject to later confirmation.

7. Antenna. Since Motorola prefers to handle all components of the radar, they will undertake the production design. Assuming the antenna performs satisfactorily electrically and it can be ruggedized, the main problem is fitting the antenna plate on the nose. SLA has the responsibility for the electrical design, SLE the mechanical design, and Motorola the production design. Mr. Noble stated the frozen antenna unit will require about 120 days for tooling.

8. Sealing of Unit.

   a. The first approach is to have no sealing but the unit must operate at 7 psi with no permanent damage to any components. The military stated they would not test at 40,000 feet altitude. Since pressurized connectors would be a factor in delaying the time scales, this is the preferable solution.

   b. If the unit does not operate at 7 psi, then sealing will be resorted to with perhaps a check valve installed as a safety feature.

9. Range Selection.

   a. [redacted] DOE b(3)

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DOE b(3)

b. [redacted] The stepped ranges desired were presented since it was Motorola's contention that this would allow the design of a simpler, more reliable ranging device.

10. Test Equipment. The test equipment should be available when Abee is ready. The delay timer will not be tested on the Abee tester. If a larger size will expedite the tester, this can be done, although it is general Sandia philosophy to keep the test equipment as compact as possible."

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As a result of the October 6 conference, Motorola considered every possible means for accelerating the Abee program. Additional engineering personnel were needed to complete the design of the specialized circuits. The procurement of specialized laboratory equipment and components was progressing as quickly as technical developments and manufacturer's delivery would permit. Because of the relaxation of specifications and the availability of unlimited funds, it was now more nearly possible to establish a time schedule. The schedule, established during a conference at Phoenix, was forwarded to Mr. P. J. Larsen of Sandia on October 14th:

"As a result of the October 6 meeting, the Motorola engineers considered every possible means for the speeding of the ABEE project. Because of the relaxation of specifications and the availability of unlimited funds for the project, it now becomes possible to set schedules for the development of the research ptototype, the production ptototype, and for the release of first production of the ABEE device. With rigid specifications, there was little room for the exercise of judgment and intelligent compromise in setting the final system design, but with the specifications relaxed it now becomes possible to approach the project with the goal set for the production of the best possible equipment in the period of time available for the work. It is expected that many of the original important specifications will be met, and relaxed specifications will be reverted to only where necessary.

The following optimistic schedule has been established as the goal and every effort will be made to meet the schedule given below. Re-evaluation of the schedule will be made at three significant stages inthe program (1) The schedule will be re-evaluated at the time the first research prototype or bread-board model is completed. (2) The second re-evaluation will be made at the time the packaged unit is completed. (3) The last and most accurate re-evaluation will be completed at the time the production pilot run is started.

1. First Proposed Schedule:

A. Completion of research prototype or breadboard model November 15 to December 1, 1949.

1. It is anticipated that this prototype will incorporate all circuitry to be included in the production prototype; however, it probably will not conform to the production ABEE in size, form factor, and basic circuit and mechanical components, such as condensers, resistors, terminal boards, etc. Every effort shall be

2. made to incorporate in this unit such features as remote step selection of eight range positions and an overall range accuracy of ± 5%, requirements which were relaxed by the contractor in the interests of early delivery, at the conference of October 6.

B. Production prototype package shall be completed on or about January 1, 1950.

1. This prototype will enable Motorola production personnel to initiate the tooling program required for the mass application of the unit. During the period from December 1 to January 1, developmental changes shall continue.

C. Production Pilot Run.

1. Preparation for the production pilot run shall be completed on or about April 1, 1950.

a. At this time, the first handmade production sample shall be delivered to Sandia Laboratory. During the period January 1 to April 1, the production prototype shall be subject to further change and improvement; such changes may be determined as necessary by the Motorola development group, even though changing of the tooling commitments are required.

The above schedule is optomistic, but not impossible. It is pointed out that the first schedule of reasonable accuracy can be established at the time the first production prototype or ABEE package is completed. While the Sandia Laboratory group must recognize the optimism in the above proposal, the Motorola group will approach the problem with the full intention of meeting the schedule as written.

The exploration of the many requirements of the ABEE unit by the Motorola engineers has given rise to a number of new ideas for the design of a new unit. Sometime before April 1, 1950, Motorola proposes to submit to the Sandia Laboratory recommendations for a new design of a simplified ABEE, which may incorporate such desirable features as smaller size, lower power drain, slot off the nose antenna or slot off the fin antenna, automatic frequency control, lower receiver gain, elimination of TR box, the use of sub-miniature components, and the introduction of possible anti-jamming features. In the meantime, you have my personal assurance that we shall devote our full attention and all of our facilities to the problem of producing an acceptable ABEE unit in the minimum amount of time."

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The laboratory facilities at Phoenix were expanded quickly to accommodate the growing organization. Steps were taken to obtain AEC security clearance for a larger laboratory area. Additional engineering personnel were routed to Phoenix. Henry Magnuski and Dr. Kurt Slesinger worked approximately one week. Their recommendations appreciably guided and accelerated the circuit and system progress. Security clearance requests were being processed for the following additional engineers:

R. L. Knight	~~Business Agent~~ Executive Assistant
C. J. Russnak	Senior Mechanical Engineer
M. R. Winkler	Senior Engineer
J. W. Dunifon	Senior Engineer
A. S. Hume	Senior Engineer
C. F. Meyer	Senior Engineer
C. A. Debel	Engineer
D. B. Lee	Engineer
A. C. Fabris	Engineer

During October, other contract developments were effected. Sandia engineering had approved the use of a 400 c.p.s. filament supply. This was included as a specification to the Carter Company, manufacturer of the ABEE dynamotor.

The subject of instruction books was raised. This was not a part of the contract and was made a matter of record in the Motorola letter dated October 12 to the New York AEC.

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During the month of October, the following persons received emergency clearance:

R. W. Elsner	Senior Engineer
H. E. Brannoch	Building and Grounds
J. E. Bartling	Draftsman
R. O. Blackert	Draftsman
K. A. Hale	Tool and Die maker
J. Soriano	Laboratory Assistant
B. G. Bartee	Stock Clerk
R. S. Bailey	Senior Engineer
J. M. Hagen	Detail Draftsman
W. T. Shawler	Tool and Die maker
J. C. Gundry	Assistant Engineer
P. Brennan	Guard

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First Cost Estimate - Changed Sandia Management - Motorola Laboratory Model - Sandia Recommendations - Tester Discussions.

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By November 15, 1949, sufficient information had been collected to enable Motorola to prepare the first cost estimate. The estimate was based upon the letter contract, elaboration through correspondence, and the several conferences held prior to November 15. The scope of the contract was interpreted by Motorola to include:

"1. The design and development of ABEE units and the required associated test equipment. The complete ABEE system to be designed by Motorola following specifications, with the exception of the antenna which is to be designed by the Sandia Laboratory.

2. The production on a pilot-run basis of A) 200 ABEE units, complete systems including the main unit, the dynamotor, the antenna and cable, junction box, control head and other required accessories; B) 12 test equipment units.

3. The preparing for production by establishing a complete production set-up for quantity production of the ABEE at 35 to 75 systems per week, and of the test equipment, 15 to 30 units per month. The preparation will consist primarily of A) plant rearrangement, production jigs and fixtures, and production test equipment; B) special production machinery for the fabrication of various component elements; C) tooling for parts manufacture (purchased components).

Our program is based on following the target specifications established at the Phoenix conference September 6th and 7th and covered in notes of the conference dated September 7th, of which your office has a copy. These target specifications were amended by the conference held at Albuquerque, October 6th, which is covered in complete detail in the letter of D.E. Noble to P.J. Larson, dated October 14th, 1949.

At the October 6th conference it was emphasized and re-emphasized that "time is of the essence", and that every effort should be made to begin delivery as quickly as possible and that any retarding factors must be anticipated and overcome. We believe that we have a full cognizance of the importance of the program, as already illustrated by the accelerated effort at Phoenix, and have planned the entire program on a basis of "parallel operations", a term which was developed in Motorola during the war to designate such a schedule where the speed of project elements is increased and many phases done at the same time which normally would be done in sequence. Such an approach is effective, but does require increased effort and overtime, and does result in a higher cost than under normal operations.

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The time schedule anticipated follows that covered in the target schedule in Mr. Noble's letter of October 14th to Mr. Larsen which indicated dates for prototype models, release of tooling and finally the beginning of the production pilot run. It is understood that the beginning of pilot production of the antenna will be dependent on the completion of the antenna design by the Sandia Laboratory in sufficient time.

We have estimated the contract cost on the basis that there is to be a cost plus fixed fee contract. Based on the information known at this time, we have arrived at a total estimated cost of $1,563,000. for which we propose a fixed fee of seven and one-half percent or $117,000. You will understand that with the "parallel operations", the many factors remaining unknown and the flexibility that is required, that our estimate represents the best cost figure that we can establish at this time. We quote the fixed fee as indicated but do not believe that a contract ceiling price should be established.

Our estimated cost is outlined on the attached breakdown and includes the items delineated above under contract objective to which has been added the special costs that will be incurred, such as security and travel. In addition, the design costs are based on the continuation of development even after the beginning of the 200 units, so that a continuing effort can be made to meet fully the target specifications. We anticipate the continuing of development until February 1st, 1951, but the extent of the continuing development and the time schedule is, of course, subject to the desire of the Commission, The cost of 12 test equipment units is included in the development cost and is, therefore, not shown separately.

In the letter contract, there are two paragraphs that we wish to call to your attention, which we believe should be considered further. Paragraph 6C states that the contractor will insert in its sub-contracts provisions to paragraphs A and B of paragraph 6. Paragraph 7C requires the obtaining of patent agreements from certain employees of sub-contractors. The Security branch of the A.E.C. has pointed out that in many cases the association of components with Motorola and in turn with the A. E. C. would reveal classified information. For this reason, we suggest that there would be a definite security problem in following out these two requirements, and believe they should be reconsidered.

We are ready to begin the negotiation of a definitive contract at your convenience and suggest that such negotiations be undertaken with a view to executing the contract prior to the expiration of the present letter of intent, December 31st."

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The above was included in a letter by Motorola to the New York Atomic Energy Commission dated November 15, 1949. Attached to the letter was the cost estimate which follows:

ESTIMATED COST - ABEE CONTRACT AT(30-1)-677

"I. DEVELOPMENT			
Abee: Material	$35,000.		
Labor	250,000.		
Overhead-@30%	75,000.	$360,000.	
Test Equipment			
Material	30,000.		
Labor	150,000.		
Overhead-@ 30%	45,000.	225,000.	
Special Laboratory Test Equip.		30,000.	
Total Development Cost			615,000
II. PILOT RUN PRODUCTION			
Abee: Unit Cost			
Material	2,250.		
Labor	200.		
Overhead- @ 125%	250.		
Factory Unit Cost	2,700.		
Factory Cost - 200 Units			540,000
Test Equipment - 12 Units Included in Development Cost			
III. PRODUCTION PREPARATION			
Plant rearrangement	10,000.		
Production jigs & fixtures	10,000.		
Production test equipment	35,000.	55,000.	
Special Production Machinery:			
Antenna	10,000.		
RF Unit	15,000.		
Plating	5,000.		
Fungiciding	1,000.		
Pulse Transformer	2,000.		
Miscellaneous	5,000.	38,000.	
Total Plant Preparation		93,000.	
Tools for Abee		65,000.	
Tools for tester		10,000.	
Total Production Preparation			168,000.
IV. SPECIAL COSTS			
Security - Guard's Salaries	32,000.		
Physical changes	10,000.	42,000.	
Travel	35,000		
Moving expenses-15 men	15,000	50,000.	
Total special costs			92,000

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Sub-total	$1,415,000.
Administration - 2%	31,000.
Fixed Fee 7.5%	117,000.
CONTRACT TOTAL	$1,563,000.

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For several months, the management of the Sandia Corporation had been scheduled to change from the University of California to the Western Electric Company. The change, November 1, primarily affected the Top management of the Corporation. Changes within the organization were likely to develop according to the management policies. However, contact with Motorola remained essentially as it was prior to the change of management.

During the latter portion of November, the laboratory development work included an intensive effort on the part of three senior engineers, four assistant engineers, two junior engineers, a laboratory assistant, and one machinist, to complete by December 1, the laboratory model of Abee. The activity was in preparation for an inspection by officials from Sandia.

The technical progress was according to the schedule established during the Motorola conference, October 12. The following components had been completed by mid-November:

1. Pulse width discriminator
2. Blocking oscillator for range operation
3. Integrating and firing relay
4. Blocking oscillator for system operation
5. TR tube
6. Dynamotor
7. Hermetically sealed firing relay
8. Hermetically sealed range relay for the remote selection of two operating ranges
9. Transmitter tuning
10. Crystal mixer

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Fabrication of the i-f strip had been completed by the Chicago facilities. A voltage regulated range multivibrator had been completed which provided operation with the ±10% accuracy specification. An alternative range circuit, proposed by Dr. Schlesinger of Chicago, was under investigation. The coincidence circuits were being developed. An eight position range selector switch was undergoing fabrication. The housing and pressure seal were complete and ready for test. The problems associated with the delay timer and antenna quick disconnect coupling were not receiving attention; personnel were not available.

Drift studies were conducted to evaluate operation of the 2C40 lighthouse tube local oscillator. The frequency change during the first few seconds of operation was found to be ± 5 mc/s. Because the 2C39A showed little tendency toward this type of frequency instability, tests were conducted to determine the suitability of this tube.

The Sandia laboratory had completed the first antenna model. Future plans provided that Motorola personnel at Sandia would conduct the necessary performance tests.

While the laboratory model was being fabricated, other development work was in process. Frequent discussions were held with Sandia and Motorola personnel participating. Close contact was maintained with the Sandia Laboratory of Engineering which was responsible for the prosecution of efforts toward realization of an Abee production prototype. Other contacts were maintained with the Sandia Laboratory of Applied Physics. Continued circuit development was an activity paralleling the prototype fabrication which, guided according to flexible planning, which was to include improvement as new circuit techniques were formulated. During a visit to Motorola, Phoenix on November 18, 1949, several members of SLA discussed various technical aspects of Abee development. The data and recommendations were recorded December 12, 1949, by letter report which was prepared by T. L. Allen, Jr., H.H. Patterson, and W. A. Janvrin:

"This trip was made by Mr. Newhouse, of Whippeny Laboratories, and Messrs. Allen and Patterson, of SLA-2, in order to note the progress being made by Motorola on ABEE and to convey to them certain data and ideas concerning ABEE.

By copy of this report, Motorola is invited to comment on or supplement any information contained herein.

The main part of this report is in outline form for clarity and ease of reference. The material given under any particular topic or subtopic in this report was not derived from any one formal conference, but rather from several informal discussions.

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I. R.F. SYSTEM — Allen, Newhouse, Patterson, Sturm

A. The transmitter tube is expected to be a Machlett type 2C39A. Investigation of capacitance tuning by means of a plunger approaching the grid cylinder is being continued. A range of approximately 300 mcps has been obtained; however, the power obtained at the lower frequency is limited to a value considerably below 3 kw by arcing which necessitates lowering the pulse voltage.

A bellows arrangement surrounding the grid cylinder has been proposed as a tuning device and is being fabricated.

B. The 2C39 is being considered for the local oscillator, although at present no extensive tests have been made as to its stability as a C.W. oscillator at low plate voltage. Mr. Doolittle of Machlett Laboratories is being consulted concerning these problems.

Mr. Rutz, of ALS-2, is presently concerning himself with the problem of tuning the 2C39 over a range of 300 mcps as a C.W. oscillator. Some success has been achieved by using a tapered grid cylinder and tuning by choke alone.

C. The IF strip is expected to be similar to the one used in the APG-5 but will be opened to 10 mcps between half-power points. One is on hand at present. The AGC circuit had not been decided upon and time was given to a discussion of desirable characteristics.

II. MODULATOR

A. No radical changes from that proposed by SLA-2 are contemplated. A small forming line is to be designed to replace the capacitance being used at present by SLA-2 and this is considered an improvement.

III. RANGE UNIT

A. General — Noble, Newhouse, Elsner, Patterson, Allen, Pomeroy, Shepard, Sturm

1. Range circuit is partially frozen.
2. Pre-triggering of Range Unit was suggested in order that all voltages would be stable prior to arming. The advisability of this is to be determined by future tests.
3. Motorola feels that voltage regulation in the power supply is necessary in order to insure realization of "target" specifications.

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4. 12AT7's are being used for the most part in the Range Circuit breadboards. It was pointed out that vibration should be considered in choosing the proper tubes.
5. Some desirable anti-jam features were discussed.

B. Gate Generator — Allen, Elsner, Newhouse, Pomeroy

1. This circuit is very similar to that originally submitted to Motorola by SLA-2 except that the plate load impedance of the normally off section of the multivibrator was reduced to something less than 500 ohms, and a negative gate is taken at this point.

2. Motorola indicated that the stability of this circuit was satisfactory as far as variations in plate and bias voltage were concerned. However, no mention was made of the relation of stability and heater voltage. This relation becomes more critical when the load impedance becomes small compared to the plate impedance.

C. Pulse Width Discriminator — Allen, Elsner, Newhouse, Pomeroy

1. This circuit consists of a 6AS6 with the video pulse being applied directly to the control grid and to the suppressor grid via a 1000 ohm delay line. This circuit gives a negative output.

2. It was noted that the input and output coupling of this circuit should be carefully considered so that any of the various types of jamming signals would not render the circuit inoperative.

3. The output of this circuit has a considerably sharper front edge (fall time in order of .1 microsecond) than does the pulse width discriminator originally submitted by SLA-2.

4. A new pulse width discriminator (positive output) developed by SLA-2 was suggested for possible consideration. The rise time of this discriminator is comparable to the fall time of the above mentioned discriminator. Use of this discriminator could lead to the elimination of a complete tube from the Range Unit.

D. Coincidence Circuit — Allen, Elsner, Newhouse, Pomeroy

1. This circuit consists of two triodes running normally at zero bias and with a common plate impedance. A positive going staircase type output signal is obtained at coincidence. The first step is clipped off by applying

proper bias to the following inverter triode. The negative output of this inverter triode triggers the blocking oscillator in the integrator circuit.

2. Since the common load impedance of the coincidence tube is necessarily small compared to the plate impedance of each triode, the output may vary considerably with filament voltage.

3. A coincidence circuit developed by SLA-2 using two triodes, receiving gate and video signals and having a negative output was suggested for possible future use.

E. Integrating (or counting) and Firing Circuit — Allen, Elsner, Newhouse, Shepard

1. In this circuit pulses are taken from the resistor loaded cathode of the blocking oscillator and are applied to an integrating condenser through a diode. Since the discharge resistor is large compared to the impedance of the pulse source, a voltage is built up on the condenser in steps. This voltage, after about 20 pulses builds up to the point where it neutralizes the bias on the triode following. The firing relay in the plate circuit of this triode operates as a consequence.

2. An error of about 3 counts, plus or minus, out of 20 was observed with supply voltages varying between the specified limits.

3. An error of not over 1 count, plus or minus, was observed from tube to tube (holding supply voltage constant and using the same relay.)

4. Subsequent tests are to determine the effect of relay tolerances on counting accuracy.

5. A new integrating and firing circuit developed by SLA-2 was suggested for possible future use. This circuit consists of a triode operating normally at zero bias, followed by an integrating resistor-condenser combination. This is followed by a single neon bulb, a firing triode and relay. Integrating action is started when pulses from the blocking oscillator supply cut off bias for the first triode.

F. Automatic Gain Control. — Allen, Elsner, Morgan

1. No changes at present from that originally submitted by SLA-2.

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2. The theory of operation of this circuit was reviewed.

3. The operating characteristics were discussed and these two tentative requirements were set forth.

   a. The AGC voltage is to be determined by the width of the saturated portion of the video signal.

   b. The AGC is to be limited to a value which does not reduce the sensitivity of the receiver below a certain minimum computible with the minimum earth return to be expected.

IV. PHYSICAL LAYOUT — Kirk, Newhouse, Patterson, Sturm

A. The case is about ten inches in diameter and shorter than the APG-5 case. The inside space is divided into four longitudinal sections of equal dimensions. Some thought on shielding and the selection of suitable materials were given by Mr. Newhouse. Steel is the material being used at present.

V. TEST EQUIPMENT — Bailey, Patterson, Sturm, Trigedga

A. The problem of testing Abee under operating conditions and in the presence of near targets was discussed. The problem of near returns appears to be the main concern at present. Several solutions were mentioned including, blanking of the receiver for a period longer than normla, the use of a near perfect absorber, and the use of a reflector to reflect the energy in an unobstructed direction. The last of these met with the most approval by the Motorola representatives.

B. The propagation data supplied by SLA-2 was discussed and the question was raised as to the meaning of the columns headed, "Minimum Return" and "Signal Generator". The propagation group points out that these are to be refered to the pictures that have been supplied to Mr. Sturm of Motorola. Reading from the transmitted pulse outward, the first return is from the earth and the next is the signal generator. The setting of the signal generator at the time the picture was taken is indicated in the "Signal Generator" column and the minimum amplitude return among those in the earth return is recorded in the "minimum return" column. The numbers on the left hand column correspond to the pictures. Voltage presentation was used. (Half power corresponds to 0.707 amplitude.)

The members of Motorola's Research Division are to be commended for their cooperative spirit, their enthusiasm for thorough investigation, and their optimism for the ultimate success of the project."

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The laboratory model of ABEE was completed according to schedule and was inspected by Sandia representative T. F. Marker, SLE(Engineering), D. R. Cotter, SLPE (Production Engineering), F. C. Irwin, Military Liaison, E. C. Pace, SLCL (Contract Liaison). A report ~~of the visit~~ dated December 12 by P.J. Sturm summarized the visit:

" A brief conference regarding the status of ABEE was held immediately upon the arrival of the party to acquaint the various members with the background of the program and its concomitant problems. Subsequent to this conference a rack-mounted operating ABEE system was demonstrated which incorporated such current designs as the new dynamotor prototype, presently forzen ranging circuits, square wage modulator, 8-step position range selection, broad band I.F. strip and the 2C37 rocket tube local oscillator. While a tunable transmitter oscillator was still uncompleted, designs for this device which have been experimentally proved as working units were available for inspection on the drafting board. Overall system sensitivity of this breadboard was approximately 135 db.

The general reaction of the visitng personnel was favorable, and it was pointed out that progress on the project was wholly compatible with their expectations. Since the development prototype had utilized one week of December, or 25 percent of the time alloted to the fabrication of the production prototype, the project officially requested at that time that the due date for the production unit be advanced to one or about January 15. This was officially approved by the Sandia representatives, with the further explanation that Sandia interest was mainly centered about the first deliveries of ABEE off production tooling and therefore any date for the delivery of the prototype that was compatible with our existing schedule for production tooling would be satisfactory."

The following significant changes in design were incorporated in the development breadboard and are presently planned to be included in the production prototype:

1. Range circuitry which exhibits approximately ± .75% accuracy for a ± 10% supply voltage change. Temperature compensation of this circuitry is presently underway.

2. 2C37 Rocket Tube local oscillator with tunable cavity. This oscillator exhibits satisfactory drift characteristics and lends itself to tuning in a minimum of space. Efforts toward utilizing the 2C39A as a local oscillator at the low plate voltage available were abandoned after exhaustive investigation.

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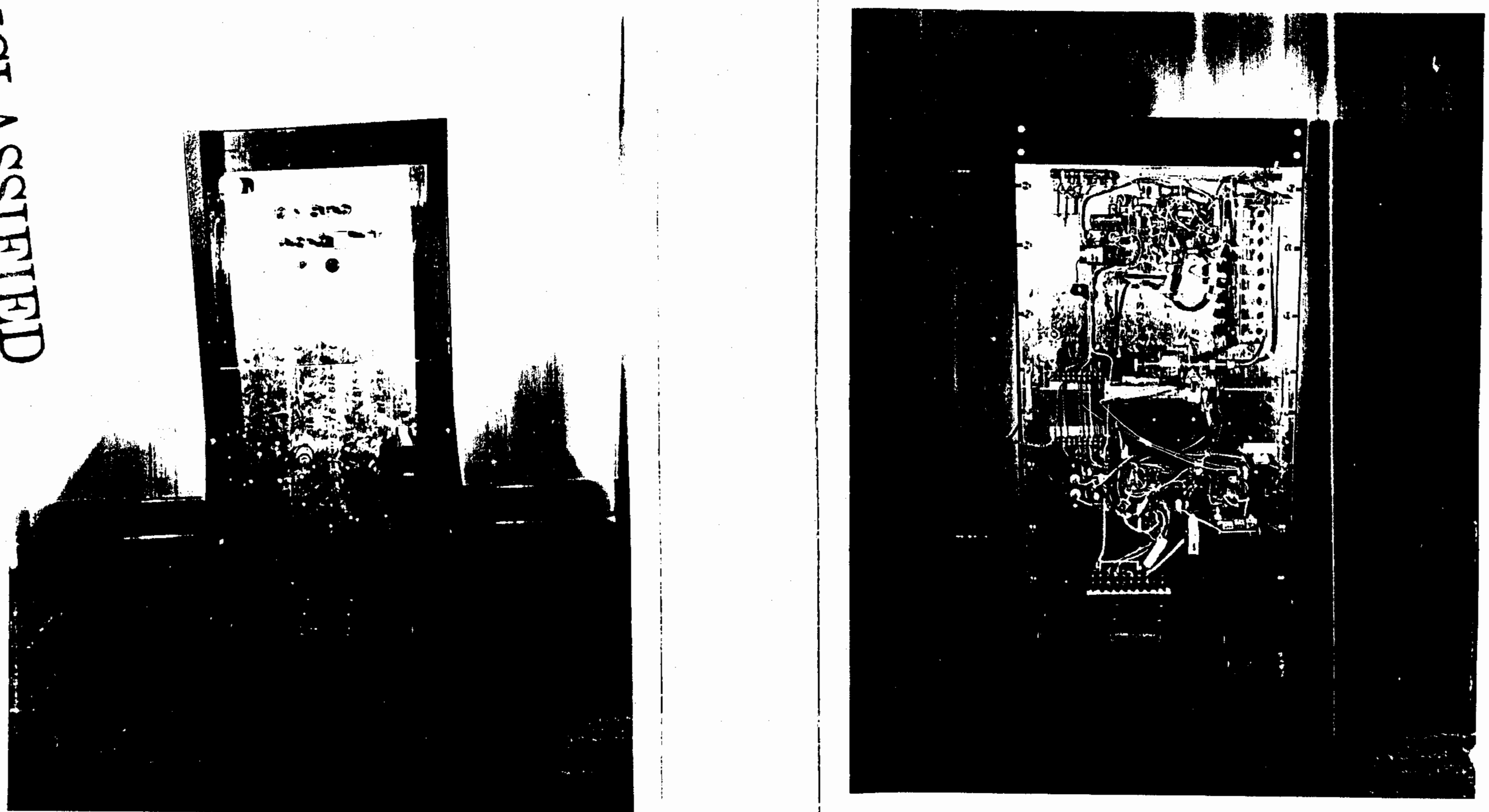

a. Front View

b. Back view

4a,b. Motorola Laboratory Model of ABEE.

3. Square wave network modulator for improving the rise time and pulse shape of the R.F. envelope. This was considered essential to lead to a system commensurate with accuracy requirements."

Fig. 4a and b present the laboratory model of ABEE which was completed the early part of December. The former presents the top side of the chassis showing some of the tubes, etc. The latter presents the wiring and other components. The r-f and modulator components are on the bottom half while the i-f and video circuits occupy the upper half of the model. The dynamotor is in the foreground.

The Tester program during October and November comprised (1) an evaluation of the system which would satisfactorily indicate the operational reliability of ABEE and (2) laboratory circuit development to achieve the system requirements. This activity was to be followed during December, January, and February by the refinement of circuit techniques for system operation and fabrication of the first laboratory model of the ABEE Tester.

The quantity of Testers to be made was originally six. This figure was raised to 12 during the conference September 6-7. The emergency conference of October 6 revised not only the ABEE schedules but also the ABEE Tester plans. Because the Tester design was dependent upon the final ABEE equipment, the Tester development was to follow the ABEE program. The revised time schedule prescribed simultaneous completion of ABEE and its Tester. Effectively, the ABEE paralleled operations were paralleled by an additional program which also would necessarily become a parallel oprration to assume that the desired delivery schedules could be approached with optimum acceleration. It is interesting to look back upon these activities to observe that continually satisfactory progress was made during these complex operations while the development of technical specifications and contract definition were an important parallel.

The delay timer had been the object of some discussion and originally a function of the Tester was to evaluate its operation. This requirement was deleted from the Sept. 6-7 target specifications during the October 6th conference. Additional information was obtained November 15th. The Sandia Laboratory prescribed that Motorola should evalue production plans based upon the manufacture of from 15 to 30 ABEE Testers per month. Another discussion on November 18 was pertinent to the philosophy of testing. The required transmitter output power for ABEE, the signal loss upon incidence and reflection, and the necessary receiver sensitivity had not been accurately determined or specified by instructions from Sandia. The most significant unknowns pertinent to this problem, later referred to as "loop gain", were the propagation attenuation and the effects of terrestrial reflection. This problem was discussed in relation to ABEE during operation as well as during test. With respect to testing, the effect of ground clutter or "near returns", was discussed. It was later determined that operational evaluation could not utilize a standard reflector placed on the ground a suitable distance from ABEE, the tester evaluating the ABEE response. The most feasible evaluation was later determined to be the measurement of transmitter power output and receiver sensitivity. Empirical data obtained from operational use of ABEE could be used to establish the operational reliability specifications. Initially the Tester was to be designed to evaluate the operation of ABEE. Later, January 5, 1950, an added requirement specified that this test device was to incorporate designs capable to test ALBERT (by another manufacturer) as well.

The progress report for the ABEE Tester to December 1, 1949,

was prepared by Dr. A. C. Tregidga:

"1. General Factual Data

a. Work on this unit to date has been subdivided into two main divisions, namely, R.F. components and delay producing devices, each of which will be discussed separately below.

A great deal of throught has been given to the overall nature of this device and the conditions under which it willprobably be used so are as we can predict with the information at our disposal. According to the tentative specifications so far submitted to us, the tester will be used only as a means for determining whether a given ABEE unit meets certain specifications or not and is not to be considered as a test instrument for repairing defective units.

b. As the range accuracy required is very high, being in fact beyond that achieved in any comparable equipment to date, it is felt that the measurement of range must be accomplished by measuring the time difference between the rectified outgoing R.F. pulse from the ABEE unit and the rectified R.F. pulse from the ABEE tester. Any method using the ABEE trigger pulse and/or the delayed video pulse used to fire the ABEE tester unit would suffer from large inaccuracy due to oscillator starting time variation. In the same way, since the I.F. strip delay is an unknown quantity, it is not permissible to use a delayed video pulse fed into the I.F. strip output connection to measure range setting.

c. In the testing of the ABEE unit it would be most desirable to use a reflector to direct all the radiant energy from the ABEE antenna straight up into the air and thus avoid troubles due to echoes from nearby objects. However, we are informed that these tests will probably be conducted, in all-metal buildings, which would prevent the use of this method. So far as we have been able to discover, there is no material available at the present time which will serve as a sufficiently absorbing surface to be used to prevent echoes from such a metal building from reaching theantenna. It will probably be necessary, therefore, to detune the local oscillator by 100 mc or so during test and conduct the range setting procedure at this different radio frequency. Sensitivity and output measurements would, of course be conducted at the correct ABEE frequency with the aid of an oscilloscope connected to the ABEE video output. It is felt that the ABEE local oscillator can be easily adjusted against an echo, regardless of whether or not a steel building is used, so that no very precise frequency measuring equipment is required. A cavity which will determine the ABEE transmitter frequency within $\pm$ 5 mc is far more precise than actually needed in view of the spacing between assigned transmitter frequencies.

The progress of the separate groups to date will now be outlined.

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2. Detail Factual Data

a. R. F. Section Progress

(1) 52 ohm Termination

In view of the possible use of directional couplers, etc., it was felt desirable to have available a small, reasonably flat termination for a Type N connector. After considerable experimentation, a termination comprising specially shaped pieces of Teflon and Polyiron was produced which would reproducibly hold a V.S.W.R. better than 1.1 over a 20% bandwidth. However, it is not felt that this item is ready for production because of the known variability of supposedly similar samples of Polyiron. The termination is useful for laboratory use, however, and since the present design of Tester does not appear to need such a termination, further work on it was abandoned.

(2) Reaction Cavity

A coaxial cavity with a dial-type drive for panel mounting has been designed and built. Ten turns of the dial are needed to cover the required bandwidth. The unit has not been tested yet, but design parameters are for an accuracy of ± 5 mc with a loaded Q of 600 or so.

(3) Klystron Cavity

Sandia suggested the use of a Sylvania SD-1103 Klystron as the R.F. source for the ABEE Tester, and we accordingly procured two such tubes and designed and built a cavity to work with them.

Numerous checks on this tube have been conducted, and although they are by no means complete, certain things have become clear. The approved mode for our frequency band is the 1-3/4 mode as this has the greatest power output. However, while the tube works well as a c.w. oscillator in this mode, it does not work at all well as a pulsed oscillator. The rise time was such as to make the production of short pulses not feasible. The minimum pulse width obtainable varied with tuning between the limits of .3 us and 1 us. The pulse-to-pulse jitter was at times as great as .2 us and always greater than .05 us. Both of these figures are intolerable in view of the accuracy required. In the 2-3/4 mode, a .3 us pulse could be obtained at all frequencies of interest, and the jitter was between .01 and .03 us. However, the power obtainable in this mode seems to be of the order of 40 milliwatts peak, which will probably be toosmall for the requirements of the Tester.

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(4) Cutoff Attenuator

A cutoff attenuator has been designed and built which should produce a maximum attenuation of 125 db. This unit has not yet been tested.

b. Delayed Pulse Section

(1) The initial approach in this work was to try to initiate a pulse at some predetermined time after a triggering impulse. In this method a circuit whose half period was the desired spacing, was rung by the initial trigger. This pulse was then amplified and squared and its trailing edge used to ring another circuit whose half period was the desired pulse width. This circuit was made to work, but had two basic defects. The first was that the initiating gate was by no means square but had a finite rise time. Thus the first half cycle of the ringing circuit was not a pure sine wave but was distorted to a small but finite and unknown extent. This prevented accurate knowledge of the length of this half cycle. The other defect, which would operate even in the case of zero rise time, is that the Q of the ringing circuit is not infinite and so there is a small phase shift in the starting of the cycle which once again precluded accurate knowledge of the length of the first half cycle.

(2) The next approach to the problem looked very good on paper also. This involved the use of a cathode ray tube as a storage tube. A circular sweep was used whose cyclic frequency was to be the desired pip spacing. The incoming trigger was then allowed to intensity modulate the beam, thus putting an extra charge on the face of the tube at this point. Now each time thereafter that the beam was swept over this point, a partial discharge would occur and thus a train of pips with the proper spacing was produced for each trigger impulse. These pips were taken from a small metal collector plate fastened to the screen and amplified in a special anti-capacity emplifier. This method worked after a fashion, but once again had a basic defect. The capacity of the plate and attached amplifier circuit could not be reduced below a certain minimum, and it was found that the internal resistance of the beam was such as to prevent the charge or discharge of this capacitance in less than a microsecond or so, so that the rise times of the pulses obtained were too large by orders of magnitude.

(3) Even if the two preceding methods had worked, there would still have been a defect, and the method to be described now was designed to remove this fault also. This method is to produce a pulse delayed afterthe rectified ABEE pulse by some variable amount, to use this delayed pulse to fire the ABEE Tester transmitter and to rectify this R.F. pulse and display it, together with the ABEE pulse on a cathode ray oscilloscope screen. A continuous train of pulses of spacing equal to the desired separation is gated into he input circuit of the oscilloscope in the interval between successive R.F. pulses and the oscilloscope arranged to synchronize alternately on r.f. pulse and c.w. pulse. Thus the display of the two

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recovered r.f. pips is superposed on that of two pips of the train, and the delay gate can be readily adjusted to make the coincidence the same between each pair of pips. This method has been tried and shows good promise of success.

(4) Other methods have been considered and some of these will be tried in order to discover the simplest and most accurate method."

6

The Motorola Production Model - Pilot Production Planning - Specifications Conferences - Antenna Status - Technical Development - ABEE and ABEE Tester Personnel Organization.

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As work toward the completion of the production prototype followed logically the completion of the laboratory model, so logically followed the necessary development of optimum ABEE specifications, definitive contract preparation, and plant facilities which would aid rather than handicap the ABEE program. As the work progressed it became appraent that visits and conferences were increasing in frequency. In addition, plans and discussions centered about proposed production of an indeterminate number of ABEE's. Estimates were given between 1000 and 10,000 units. The number of ABEE Testers would also vary directly as the ABEE quantities. While immediate delivery requirements included 200 ABEE units, it was understood that plans for fabrication should anticipate large total quantity production. This in effect prescribed patterns, dies, jigs and fixtures capable of producing many thousand parts before replacement would be necessary. Daily production rates had been discussed which varied from two to fifteen per week. The production rate was an important consideration since it would form the basis for the number and type of production machines required. Because the project objectives had evolved from the fabrication of a few pre-production prototypes to include a pilot production, it was necessary that Motorola anticipate the machinery and plant facility requirements.

The machinery requirements were surveyed in greater detail than usual because many parts used were normally fabricated and delivered to Motorola by relatively small independent industrial

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organizations. Because many of the parts were classified, it was soon to become apparent that fabrication of these parts would necessarily be produced within the Motorola plant facilities which had received proper security approval from the AEC.

The course of events which rapidly lead the program toward pilot production required careful planning. Previously a few complete ABEE systems and the associated test equipments were to be produced which would incorporate components and construction which could readily be reduced to production techniques. Further planning required definition and elaboration of the significance of the concept, pilot production.

Pilot production is a development activity. The objective is the production of a few units to organize the efficient flow of materials and services to complete, at a predetermined rate, a suitable product. In the course of the development, the electrical and mechanical as well as organizational problems are eliminated. The resulting system is capable to produce items of consistent quality and workmanship based upon the organizational, technical, and plant facility specifications developed through research, development, design, and pilot production

The project requirements had outgrown the Phoenix Laboratory facilities as well as the intended space at 1327 Washington Boulevard, Chicago. Motorola immediately made plans for an expanded Phoenix Laboratory. The details were conveyed to the New York Atomic Energy Commission by letter dated December 12, 1949:

"Wewere originally advised that it was the intention for the production under our present contract to be carried out in our Chicago factory. As we first viewed the program, which was then the assembly of a few samples only, we agreed that this was the logical manufacturing location. However, since our first conception of the project, the entire scope has been expanded, and we now find that new thinking is required.

It has been repeatedly emphasized that time is of the essence and that deliveries are urgently needed as quickly as possible. With this need clearly in mind, there are three significant elements that must be considered in making plans for production:

1. "Parellel Operations" are required which means that many phases are done at the same time which normally would be done in sequence. There will therefore be engineering continuing up to the beginning of the 200 units and even continuing beyond.

2. To move theproject into the "pilot run" stage with most efficiency will require that the same engineering personnel now doing design work will be able to move with the project into the production phase to be able to give engineering control to production.

3. Engineering control of production is required in order to supervise properly testing and inspection of this highly technical device. Anticipated production of approximately 10 units per day is not considered mass production, and the engineering control of production is not only feasible, but necessary. Motorola regularly carries this out in our Specialty Production Department in Chicago, and we have found it to be highly successful.

As we analyze the critical delivery requirements under your contract, and the elements outlined above, we have reached a conclusion that there will be a delay of two or three months, unless the units can be produced in Phoenix. We are sure that moving the project to Chicago for manufacture, which will require the transfer of people and information, would entail serious loss of time.

Believing that the solution rests in manufacture in Phoenix, we have therefore accelerated the schedule for the completion of the new building, since our present space at 1100 N. Central Avenue is not sufficient. The new building at Phoenix which will be fully equipped, has been planned as a definite part of our facilities, but it had not been planned that it be completed so quickly. You will be interested to know that Mr. Newhouse, in visiting our Phoenix Laboratories in November, discussed this matter with Mr. Noble and concurred in the conclusion that Phoenix should be selected to avoid delay.

We are convinced that there will be a delay of two or three months if the project is to move to Chicago for production, and we are sure that you wish to avoid such a condition. We believe that the delay can be avoided by manufacturing in Phoenix, and we are, therefore, requesting your immediate consideration of this proposal so that we may consolidate our detailed production planning in this direction."

The alternatives presented to the Sandia Corporation included (1) repackaging the Sandia design. and (2) complete circuit and system re-design and development over a long period of time (approx. 2 years). Because the latter was not practicable considering the Sandia delivery schedule, the following modification was presented for consideration:

a.) design correction and additional development to provide equipment performance prescribed in the target specifications which were completed and summarized in the report of the September 6-7 conference.

Engineering development to continue to July 1, 1950. Sandia conditional release on or before Dec. 15, 1950. No.1 prototype model completed Jan. 15 plus or minus 15 days (not subject to type acceptance test).

Sandia test to begin January 15 plus or minus 15 days.

Sandia final release on or before Feb. 1, 1950. Tool design release March 1. July 1: tooling completed, begin delivery of production units, complete engineering design and development.

Sandia tests to end July 15.

July 15 completed 25 units.

August 15 ten more completed.

August 22, begin production at rate of 25/week to deliver another 175.

With approval for pilot production at Phoenix the new construction was started with completion scheduled during the latter part of March. The Abee fabrication would be established during the period March 1 to April 15. The latter date was scheduled to include the completion and delivery to Sandia of the first Abee. The remainder of the compressed delivery schedule, as determined during the early October emergency conference, included the completion of (1) 24 equipments by April 22 and (2) 175 units by May 22, 1950.

Technical discussions to establish specifications continued during December 14 and 15. Mechanical design factors were discussed at the Sandia Base; Messrs. Radin, Eiffert, Smith, Marker, Hoffman of Sandia and C.J. Russnak of Motorola participated. The ABEE and Albert shock mount problems were discussed; it was agreed that the two systems would require deparate mounting designs. It was specified that the same method of attachment to the cartridge was required. Because the ABEE in operation would be subjected to high vibration frequencies to 300 c.p.s., the necessity for a high frequency vibration mount was discussed. Because the lower frequency vibrations, 10 to 60 c.p.s., during transportation would not be absorbed by the mount under discussion, Motorola suggested a shipping clamp or block be employed during transit. Additional specifications were included in the conference report by C. J. Russnak, December 15, 1949:

"The leakage rate of the pressurized ABEE must not be greater than 1/2 psi in 24 hours at 15 psi gauge.

The ABEE unit will be vibration tested without vibration mounts from 10-55 cps. This test is to discover possible weaknesses and to determine at what frequency they occur.

The ABEE unit will be vibration tested from 10-300 cps with vibration mounts.

There is still some question on the number of pins and size of AN plug to be used for connecting power. Messrs. Marker and Smith are to study that problem further.

The problem of bringing tuning controls out the cover is still to be studied.

The conditions of storage are that the units may be stored for three weeks at 8000 ft. with a maximum flight time of 14 hours."

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The antenna program was re-examined during the first days of December. A technical report was prepared by A.S. Hume, Motorola, on December 6, 1949. The contents are included on the following pages:

" ANTENNA REQUIREMENTS

Beam: 26 to 30 H-plane, 26° min. E- plane
VSWR: 1.6 max
Side Lobes: at least 13 db down
Gain: 12-15 db

Former antenna specs required a beam of 20° E-plane, 30° H-plane, 15 db gain. The values were changed by SLA on 12/5/49 to those above. It was felt by them that the larger beam width was necessary to insure a long enough ground return.

Transmitter pulling figures used in establishing a maximum VSWR were $\pm$ 3 mc for 1.5 VSWR and $\pm$ 1.5 mc for 1.3 VSWR. It is hoped by SLA that the attenuation of 12 feet of RG-8/U (1.8 db) will afford an appreciable reduction in VSWR as seen by the oscillator. No measurements of this effect have been made.

WAVEGUIDE FEED PLUS REFLECTOR

1.

Description: This antenna is being developed by SLA. The waveguide chosen has a width to height ratio of approximately 17 to 1 in order to conserve space. The antenna assembly is arranged so a waveguide choke joint occurs at the outer edge. When the entire assembly is fitted into place the two halves of the joint will be automatically aligned and no time need be wasted fastening connectors together. As of Dec. 6 the antenna may be broken down as follows:

a. Coax-to-waveguide transition. VSWR 1.18 max into a load of 1.08 VSWR.
b. Choke VSWR 1.25 max into 1.08 load. This figure is for a combination of 1/16 inch displacements from nominal in all three planes. VSWR for optimum alignment is 1.2 max. Broadbanding is limited by the low impedance of the main guide.
c. Antenna feed. VSWR 1.16 max into air. Effect of reflector undetermined but SLA claims it to be small.
d. Reflector. Shape undetermined since change of beam-width requirements.
e. Dielectric sheet or sandwich. SLA is assuming that a nearly reflectionless sandwich can be fabricated. Several samples of various thickness have been ordered from Northrup and should arrive about Dec. 9th.

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2. Overall VSWR: Not yet measured. Estimated at 1.8 for experiemtnal model as of Dec. 6. The following unknowns are apparent:
   a. effect of sandwich
   b. effect of reflector
   c. choke and transition measurements subject to about ≁ - 0.10 error due to unmatched load.
   d. It may be possible to space choke and transition for some degree of cancellation.

3. Remaining Development Work:
   a. Space choke and transition for optimum VSWR.
   b. Investigate possibility of improving transition with matching iris.
   c. Use mitered bend rather than cut-off corner on antenna feed. Production tolerances on the former item are much looser and the VSWR should be less.
   d. Produce well made feed using mitered bend to give same VSWR as, or better VSWR then, present lab model.
   e. Find suitable dielectric sandwich.
   f. Design reflector.
   g. Attempt to improve choke VSWR, possibly by using circular rather than rectangular choke.

4. Estimated Finish Date (Production prototype). Feb. 1, soonest; probably March 1. It is believed that this prototype could meet at VSWR of 1.6 max but that it would be difficult, if not virtually impossible, to hold production models to this figure. There are several factors contributing to delay:
   a. slow delivery from model shop.
   b. lack of "push" on part of development engineers. The fact that time is important does not seem to have filtered down to the lower echelons.
   c. Some of the development engineers, although apparently competent in general, are new at waveguide work.

5. Production
   a. The size waveguide chosen is not commercially available. To have the guide drawn would involve time and clearance difficulties. The best bet appears to be fabrication. Tolerances on inside width and height are, according to SLA, ≁ - .005 inch. It is possible that the tolerance on height may have to be held closer than this figure.
   b. The antenna feed will be difficult to fabricate because of its complex shape and close tolerances.
   c. The choke and transition should not be more difficult to make than the usual run of microwave devices at this frequency.
   d. If a dielectric sandwich is used it can probably be fabricated by Northrup in ample time for our needs. The problem has been discussed with a representative of Northrup.

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DISCONE FEED PLUS REFLECTOR ~~SECRET~~ ~~RESTRICTED DATA~~

1. Description Engineers of SLE have developed a discone antenna with a VSWR of less than 1.3 over a 1.5 to 1 frequency range. With a parabola giving a beam width of 20 by 30 degrees the VSWR was less than 1.3 over both ABEE 1 and ABEE 2 bands. The only apparent disadvantage would be the use of coax disconnects, involving some extra time in replacing the antenna assembly.

2. Remaining Development Work.
   a. Design reflector
   b. Find suitable dielectric cover
   c. A small amount of mechanical design is necessary on the discone and adjoining connector.

3. Estimated Finish Date. Jan. 15 for production prototype, assuming that Motorola assumes responsibility, work closely with SLE.

4. Production. No production difficulties are envisioned. The only critical dimensions of the discone is the distance from throat to disc. The tolerance is + - .005 inch. The reflector and dielectric cover would be essentially the same with this and the waveguide fed antenna.

OTHER POSSIBLE ANTENNAS

1. Slot Array. Work at SLA on slot arrays has progressed to the point of determining resonant slot lengths for several width slots at ABEE 1 midband. A broadwide array of seven slots has been fabricated with adjustable slot position from the middle of the guide. No measurements on the array have been made. It appears from the literature that broadbanding possibilities are poor.

2. Horns. The presently allotted antenna space would accommodate two horns of 12 db gain and approximately 35° beamwidth. The guide at the horn base would accommodate at coax-to-waveguide transition. It would be necessary to use a thin dielectric sheet as a cover in order to fit the horns into the available space. No work has been done along these lines.

IT IS RECOMMENDED THAT:

1. The discone plus reflector be adopted as the logical antenna choice. This unit would be much easier to produce, would necessitate no change in going from ABEE 1 to ABEE 2 band, and offers a better match electrically than does the waveguide-fed antenna. It is estimated that a discone production prototype would be available approximately six weeks sooner than the waveguide-fed antenna.

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2. Motorola assumes responsibility for the antenna. It is believed that this would assure a prototype antenna at the earliest possible date. The reflector and dielectric cover could be designed and tested at Sandia, working closely with SLE. They assure me that shop priorities can easily be obtained for this job. This information should enable a complete antenna to be designed and made at Phoenix. Impedance measurements could be made at Phoenix and the antenna then flown to Sandia for pattern measurements and gain measurements."

On December 7, the antenna was discussed with SLE, SLA, and SLTAD. The conference report by A.S. Hume dated December 8th recorded: (1) That the disk-cone radiator and parabolic reflector would be used because it would be a more simple mechanical structure with a wider bandwidth, and possibly a lower VSWR than the waveguide-fed antenna; and (2) that Motorola would immediately assume responsibility for the antenna development.

The cooperation of all Sandia facilities was assured. The existing Type C quick disconnect would be used. It was agreed that Motorola would subcontract the front plate, parabolic reflectors, and the clamping ring. Sandia determined at a later date that the reflectors were classified parts and that fabrication by Motorola would become an element of the slowly forming definitive contract. It was also specified that the antenna beam width was required to be not more than 35° and not less than 26° in both E and H planes. The side lobe attenuation was specified to be not less than 10 db. It was further agreed that the VSWR was required to be sufficiently low to permit operation of ABEE as a septem. The previously specified value (1.6) was considered untenable during production.

A later conference at Sandia, December 14, with SLA-2 effected revised antanna specifications. The revised requirements were philosophically determined in the hope that an antenna could be devised which would have a band width sufficient to operate within the MC-1 and MC-2 frequency bands. The revised specifications were:

Beam width, one plane	20° to 30°
Beam width, other plane	20° minimum
Gain, MC-1 band	13 db above isotropic radiator

No limits were established for side lobe attenuation.

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Negotiations continued during December toward the formation of a definitive contract. It was agreed on December 14 during a meeting in the New York Atomic Energy Commission offices that a fixed fee of $80,000. would accrue to Motorola. During the conference it was also agreed that the terms of the letter contract would include on a pilot run basis, the production 200 ABEE equipments. The production quantity was to be reduced to 100 at a later date.

Approximately two months' time was required before the emergency program could be fully underway. The time required for the security clearance of additional engineers, was a good example of speed and efficiency on the part of the AEC and the FBI. It must be mentioned, however, that completion of development and the pilot production of 200 equipments were merely 6 months away. The activity to be completed with 6 months had been variously estimated to be equivalent to normal activity over a period of approximately 1 1/2 years.

The following technical developments were reported during the month of December.

The Sandia prototype utilized a fixed frequency circuit, see Fig. 4. A separate grid cylinder was required for each frequency of operation. Proper feedback relationships within the oscillator circuit were obtained by adjusting the length of the coaxial transmission line in the cathode circuit of the 2C39 tube. Because a tunable transmitter was needed, several tuning methods were investigated, see Fig. 5.

The transmitter oscillator of the Sandia prototype was modified. A capacitive probe was introduced between the grid cylinder and cavity wall, see Fig. 5A. The oscillator was operated continuously with 400 volts applied to the plate circuit. Weak oscillations were obtained within the desired frequency range. A model was then constructed while a pulse modulator was fabricated. The pulsed model provided the proper operating frequency range with power output varying from 1.0 KW at the low frequency to 2.0 KW at the high frequency. Frequent voltage break down occurred between the grid cylinder and tuning probe, especially at the low frequencies which required that the tuning probe be closely coupled to the grid cylinder. A smaller probe, to capacitively load the end of the grid cylinder, was tried, see Fig. 5B. The frequency range was satisfactory and the minimum power output was increased to 1.5 KW. Excessive voltage breakdown proved the design impracticable. Fig. 5C describes the use of a circular ring designed to slide along the inner wall of the cavity. This was another method by which the frequency determining coaxial transmission line capacitance could be varied. The power output was not less than 2 KW peak pulse power and the tuning range was satisfactory. Again excessive arcing was obtained. The successful operating design, see Fig. 5D, obtained frequency control by varying the distance between the grid cylinder and plate end of the cavity. The variation required to change the frequency was small indicating the practicability of the design. There was no tendency toward arc-over throughout the desired frequency range with plate voltages 150% greater than previously applied.

Frequency control of the Sandia prototype transmitter was effected by changing the length of the grid cylinder. Optimum feedback and power output were obtained by varying the length of the cathode line. The feedback was adjustable by means of a moveable end plate in the shape of a cup. In later discussions this will be referred to as a cathode choke because the electrical design is such that the coaxial transmission line type mode of oscillation is prevented from entering the space between the end of the tuned line and the end of the cylinder. It may then be stated that optimum feedback relations were obtained by adjusting the position of the cathode choke.

The prototype oscillator utilized a cathode choke which was an integral part of the center conductor or line connecting the tube cathode to the end of the cavity. A sliding connection near the tube permitted a change of the cathode line length. A design of this type was judged to be undesirable because of strains imposed upon the tube. The recent design employed a cathode connection which was fixed in position. The cathode choke was designed to slide along the cathode line or more precisely, the center conductor of the coaxial transmission line (cathode tuned circuit).

Additionally, the cathode choke was changed from a simple cup shape to a half wave choke to more effectively prevent energy from appearing between the cathode choke and the end of the cylinder.

The tube type 2C39 manufactured by the General Electric Company had pr viously been used in the transmitter. Later transmitters utilized the same tube manufactured by Machlett. The choice was established because (1) G. E. was not currently manufacturing these tubes, (2) the Machlett tube exhibited greater mechanical strength and tube elements of higher quality and mechanical rigidity, and (3) Machlett offered to cooperate with Motorola with respect to modification of the tubes to meet the stringent requirements.

The first modification requested was a threaded section soldered to the annular grid contact. By this method the frequency was varied by the position of a threaded grid cylinder. With a given grid cylinder the frequency variation obtainable was in excess of 100 megacycles. A filament current regulator tube was used to reduce frequency changes caused by variation of filament emission. Prior to filament regulation, a 20% change of filament voltage caused a 3 to 4 mc. change of oscillator frequency.

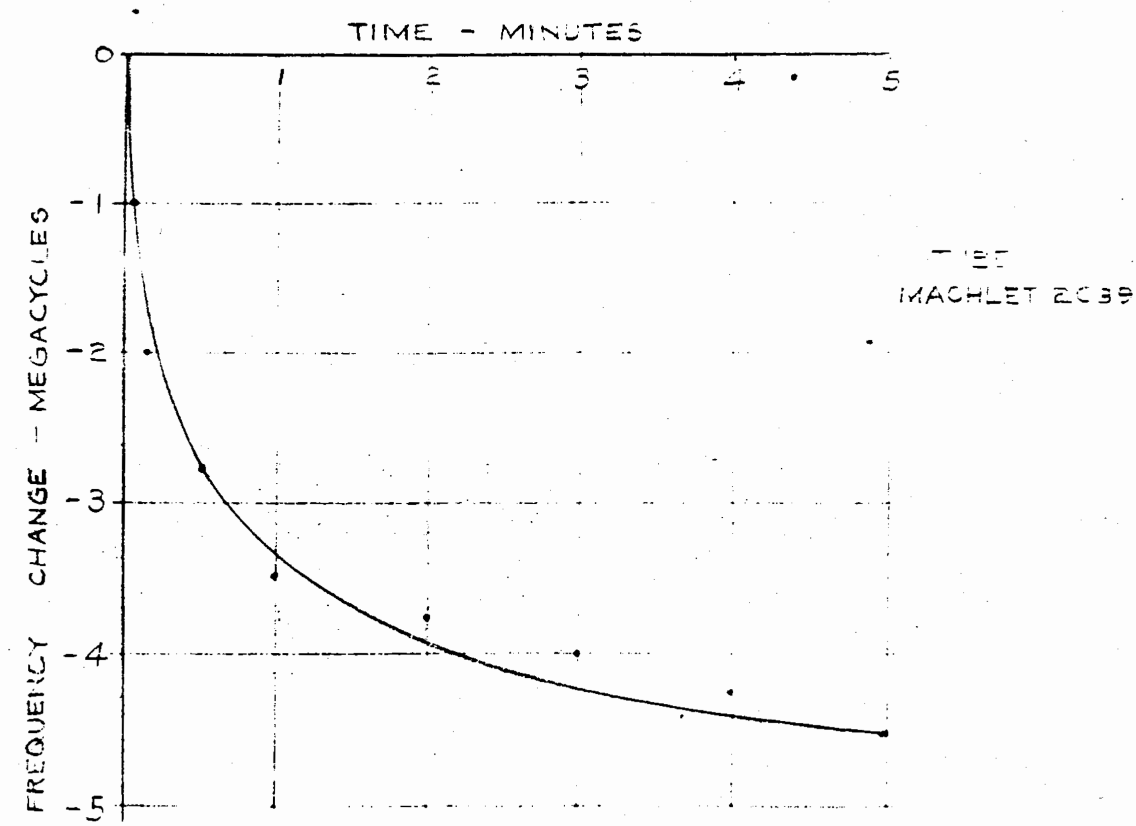

FIG. 7

TRANSMITTER FREQUENCY DRIFT AS A FUNCTION OF TIME.

The transmitter frequency change as a function of time was recorded for one 2C39 Machlett tube. Prior to the test the frequency was adjusted to the high end of the band. The transmitter plate supply was adjusted to 1050 volts and the power output recorded, 2.5 KW peak pulse power. The transmitter was turned off for one hour to allow the components to cool after which the transmitter was turned on and the frequency was measured by means of a calibrated spectrum analyser from zero time to 5 minutes. The frequency drift, 4.5 mu/s, is presented in Fig. 7. It was also observed that a 10% increase of plate supply voltage caused a 1 megacycle increase of the operating frequency. This change was observed during the early part of a 15 minute operating period. After 15 minutes, a 10% voltage change effected an undetectable frequency change.

Another stability characteristic, frequency pull, was observed. Frequency pull was defined as the transmitter frequency change which occurred as the load impedance was varied. The apparatus employed for the frequency pull tests, Fig. 8, included a double slug line which was used to simulate the degree of mismatch (proportional to the voltage standing wave ratio) as well as the extreme conditions of capacitance and inductive reactance which would likely be encountered in operation. The apparatus was terminated with a 50 ohm coaxial load. The small portion of the output power extracted from the system by means of

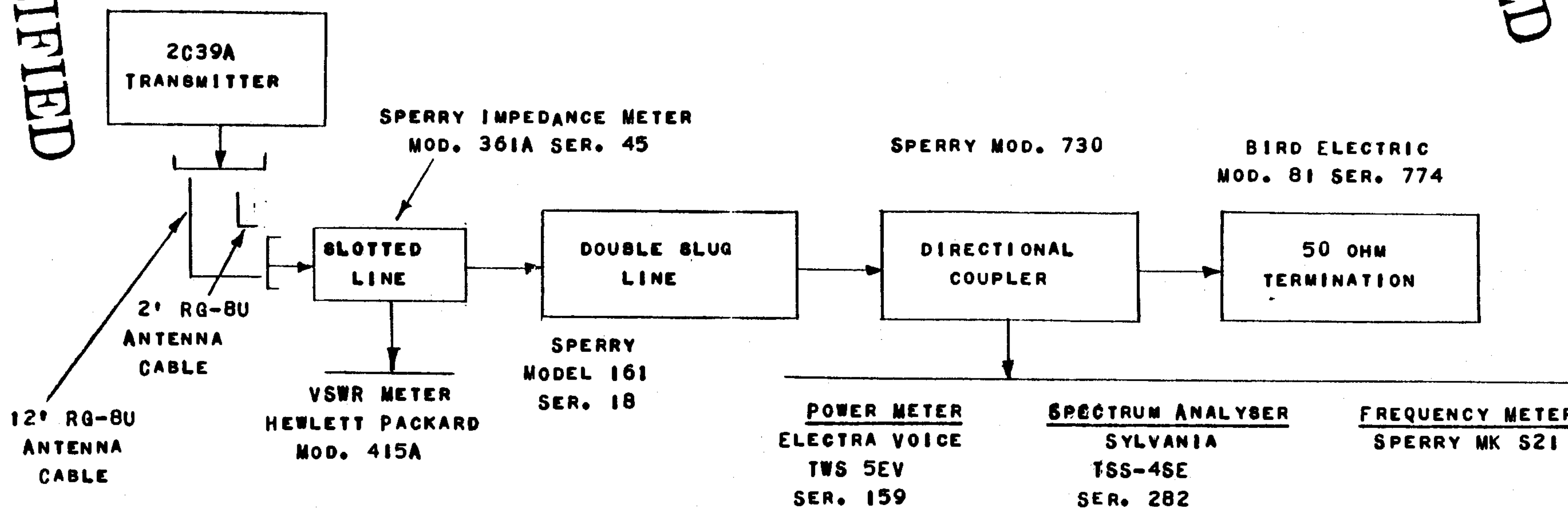

FIG. 8

EQUIPMENT AND CONNECTIONS FOR MEASUREMENT OF TRANSMITTER FREQUENCY PULL

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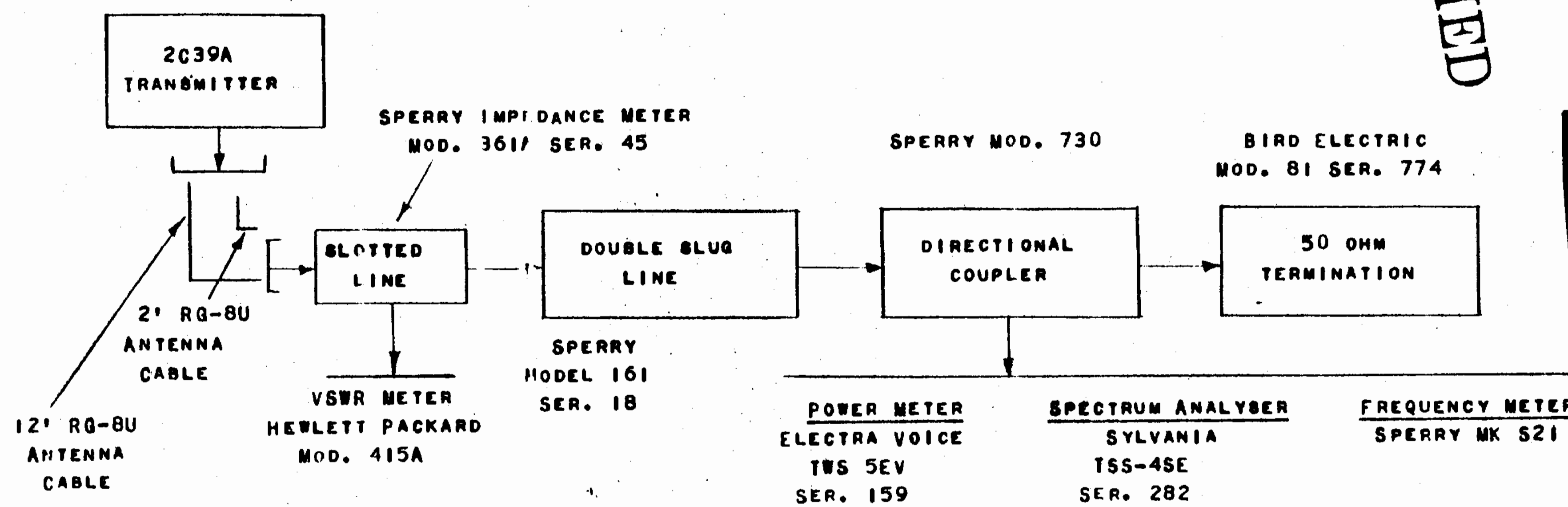

FIG. 8

EQUIPMENT AND CONNECTIONS FOR MEASUREMENT OF
TRANSMITTER FREQUENCY PULL

a directional coupler (27 db attenuation) was used to measure the frequency pull. The voltage standing wave ratio was measured with a VSWR meter connected to a slotted line. The results, Table 2,

Plate Supply Volts	Max. Power Output	VSWR	Frequency	Frequency Pull 2	Frequency Pull 12	Transmitter output Coupling
1150	2 KW	1.25	f_o + 150 mc/s	7 mc	6	maximum
1150	2.0	1.50	+ 150	13	6	power
1150	1.6	2.00	+ 150	23	10	output
1150	1.7	1.25	+ 150	3	1	80% maximum
1150	1.6	1.50	+ 150	7	3	power
1150	1.5	2.00	+ 150	10	4.5	output

TABLE 2

Frequency pull as a function of mismatch (VSWR) and Load Reactance, length of antenna cable, and transmitter output coupling.

present the results obtained with the transmitter operating 150 mc. above the center of the band. Excessive frequency pull was observed with the coupling adjusted to give maximum power output. Particular attention is directed to the results obtained with the transmitter adjusted to effect 80% maximum power output and a VSWR of 1.5, indicative of the degree of mismatch likely to be encountered in the completed ABEE and ABEE antanna system. The frequency pull was 3 mc. with a 12 foot length of RG-8U antanna cable (the length to be used during actual operation of ABEE). The recorded power values were the power extracted from the transmitter.

The transmitter tube impedance became the object of close study in December, 1949. The information was required in order that a properly designed modulation transformer could be designed.

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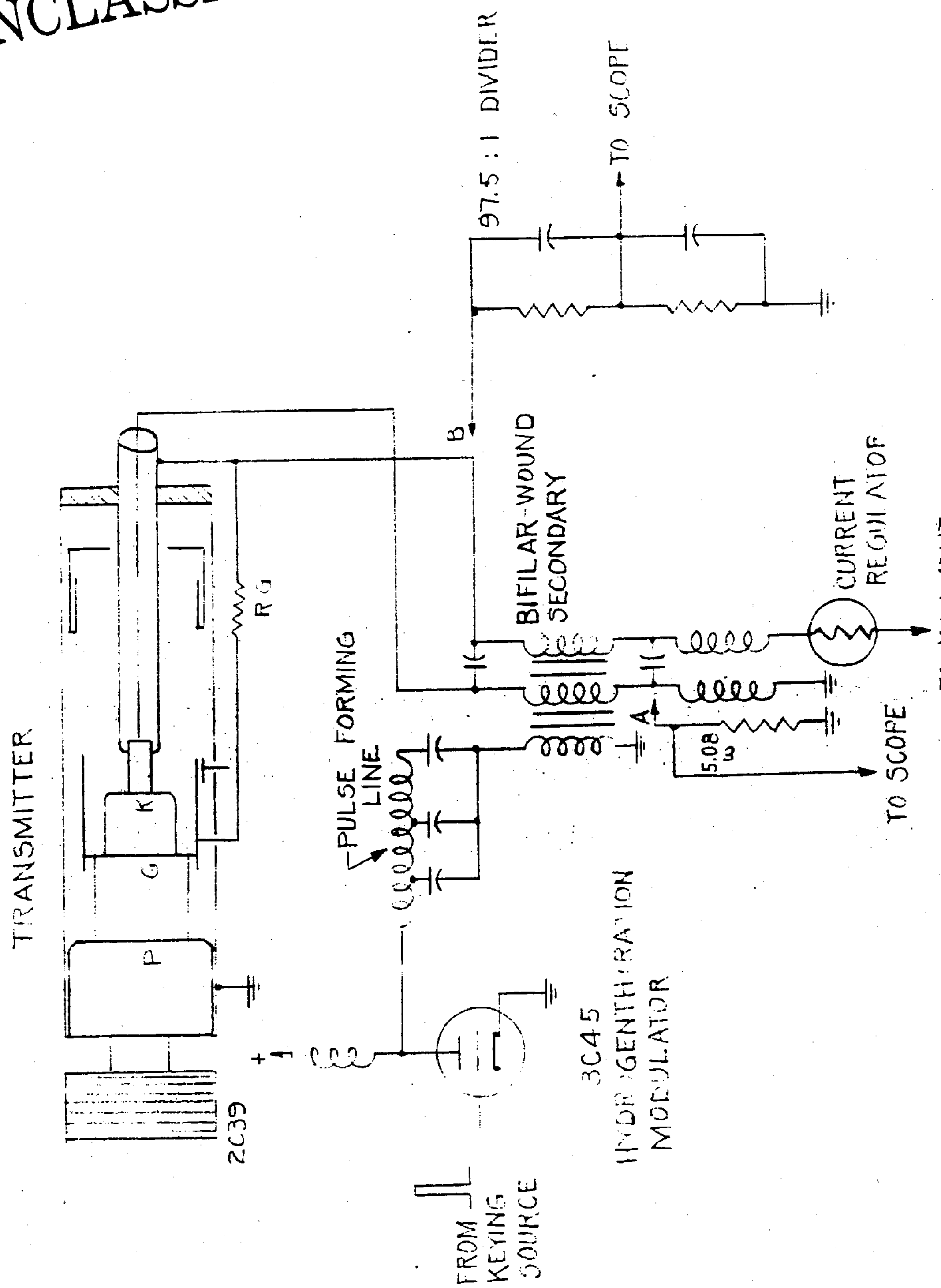

FIG. 9
TRANSMITTER - MODULATOR
WITH CONNECTIONS FOR MEASUREMENT
OF TUBE IMPEDANCE

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Fig. 9 presents the transmitter-modulator schematic with connections for the measurement of tube impedance. The impedance was determined by the relation $R = E/I$ where E was the amplitude of the modulation pulse and I was the amplitude of the current through the 2C39. The modulation pulse applied to the cathode was measured at B. A divider was used to reduce the voltage to a value which would not damage the calibrated oscilloscope used for the measurements. The 2C39 plate current was determined indirectly by measuring the voltage amplitude across 5.08 ohms in the cathode circuit. Other miscellaneous information included the calculation of peak input power and oscillator efficiency. The results obtained are presented in Table 3.

Pulse Modulation Amplitude E_B	Cathode Voltage E_A	$R_{tube} = \frac{5.08\,E_B}{E_A}$
3250 VOLTS	19 VOLTS	870 OHMS
3500	22	808
3280	22	757
3050	47	647

Table 3
2C39 impedance measurements

A Machlett 2C39 Serial 18PF was used. The tube input power was calculated

$$\frac{E_A^2}{R_{tube}} = \frac{(3050)^2}{647} = 14.4 \text{ KW peak input power}$$

The transmitter power output was measured so that the efficiency could be calculated:

$$\text{efficiency} = \frac{1.58}{14.2} \times 100 = 11\%$$

The operation was at the high end of the band. The tube impedance was measured at the low end of the band with a serial 29PB tube.

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The following data were obtained:

E_B	E_A	R_{TUBE}
3200	27.4	593
3100	27.0	583

Under similar conditions, the efficiency was again determined. A higher value, 19.5%, was obtained at the low end of the band. A higher efficiency was expected because the output power at the lower frequency was nearly double that at the high end of the band.

The tube impedance was found to be proportional to the value of grid resistance as well as the degree of output coupling and VSWR; the latter effects upon tube impedance were negligible.

The local oscillator development had continued toward the design which would permit the receiver to be tuned over the desired 300 megacycle range by means of a single control. In order to "gang" the two necessary controls, grid cylinder length and cathode choke position, it was necessary to know the change of cathode choke position with respect to a predetermined change of the grid cylinder length. To facilitate the adjustment of grid cylinder length, a grid cylinder extension was made to slide over a fixed cylinder which was tightly fitted to the grid of the 2C37 oscillator tube. By extending or telescoping the adjustable grid cylinder, a change of operating frequency was obtained.

The change of dimensions which were obtained indicated that a 2:1 tuning ratio would be suitable, the cathode choke moving twice as far as the grid cylinder extension, and both moved in the same direction. The dimensioned changes are not included for security reasons. Sufficient information had been obtained so that a single control oscillator could be fabricated, although other problems were encountered which required solution.

The local oscillator in the Sandia prototype employed a 2C40 lighthouse tube. This tube was found to exhibit excessive frequency drift after application of plate voltage. Also, the tube and circuit were frequency sensitive to changes of plate and filament voltages. The 2C39 was considered for the local oscillator. The type circuit employed was similar to that presented in Fig. 5A. The capacitive probe type did not tune the oscillator over the required 300 mc range. A maximum range of 150 mc was obtained. The use of the 2C39 as a local oscillator was discontinued at this stage of development. The use of a telescopic grid cylinder as the frequency determining element had not been investigated until after development attention was focused upon the new 2C37 planar element "Rocket" tube.

The 2C37 local oscillator which was first constructed did not incorporate ganged tuning. The following characteristics were noted: A tuning range of 60 mc was obtained by varying the length of the cathode line. Frequency stability was superior to the 2C40. The operating efficiency was 10% with a plate supply of 150 volts. Plate voltage and filament current stabilization provided frequency stability in the presence of varying input power.

Because the local oscillator development had not been completed, comprehensive operating characteristics are not presented. However, some of the factual information may be of interest. Ganged tuning across the desired frequency band $f_o \pm 150$ mc. (f_o was the center frequency) was obtained with the polystyrene coupling. The 2C37 plate voltage was 150 volts. The plate current varied from approximately 25 to 30 ma. This plate current was higher than the normal value of 15 ma. The additional current did not result in operation exceeding the recommended plate dissipation for the tube. Normally, an efficient oscillator with optimum design would operate with low plate current. The plate current in this case was higher than normal because (1) the tube efficiency was low at the operating frequency and (2) the materials within the r-f field (necessary to ~~afford~~ effect ganged tuning) reduced the oscillator efficiency. With the early attempts toward frequency change by a single control, the power output varied across the band from a minimum of 5 ma to 15 ma on one occasion. With another adjustment, smaller grid resistor, and maximum output coupling the power varied within the frequency range from 30 milliwatts to 70 milliwatts. The latter data represent local oscillator powers greatly in excess of that required for receiver operation.

Optimum receiver operation was detected, among several possible methods, by noting the receiver crystal current. The optimum crystal current, 0.6 to 1.0 milliamperes, was effected with power output in the order of 1.0 milliwatt. The current may also be calculated knowing the impedance of the crystal mixer circuit which is approximately 1000 ohms.

The optimum location for the grid return connection may be opened to question. The contact location is critical and is dependent upon the impedance distribution within the oscillator as well as by the value of grid resistance. The procedure to determine the optimum location was merely to experimentally locate the connection which effected maximum power output after all other design features had been established - including the average degree of cavity penetration by the output coupling probe. Once established in the manner prescribed above, the position was not "critical" within the operating frequency range. This comment applied also to the design of the transmitter.

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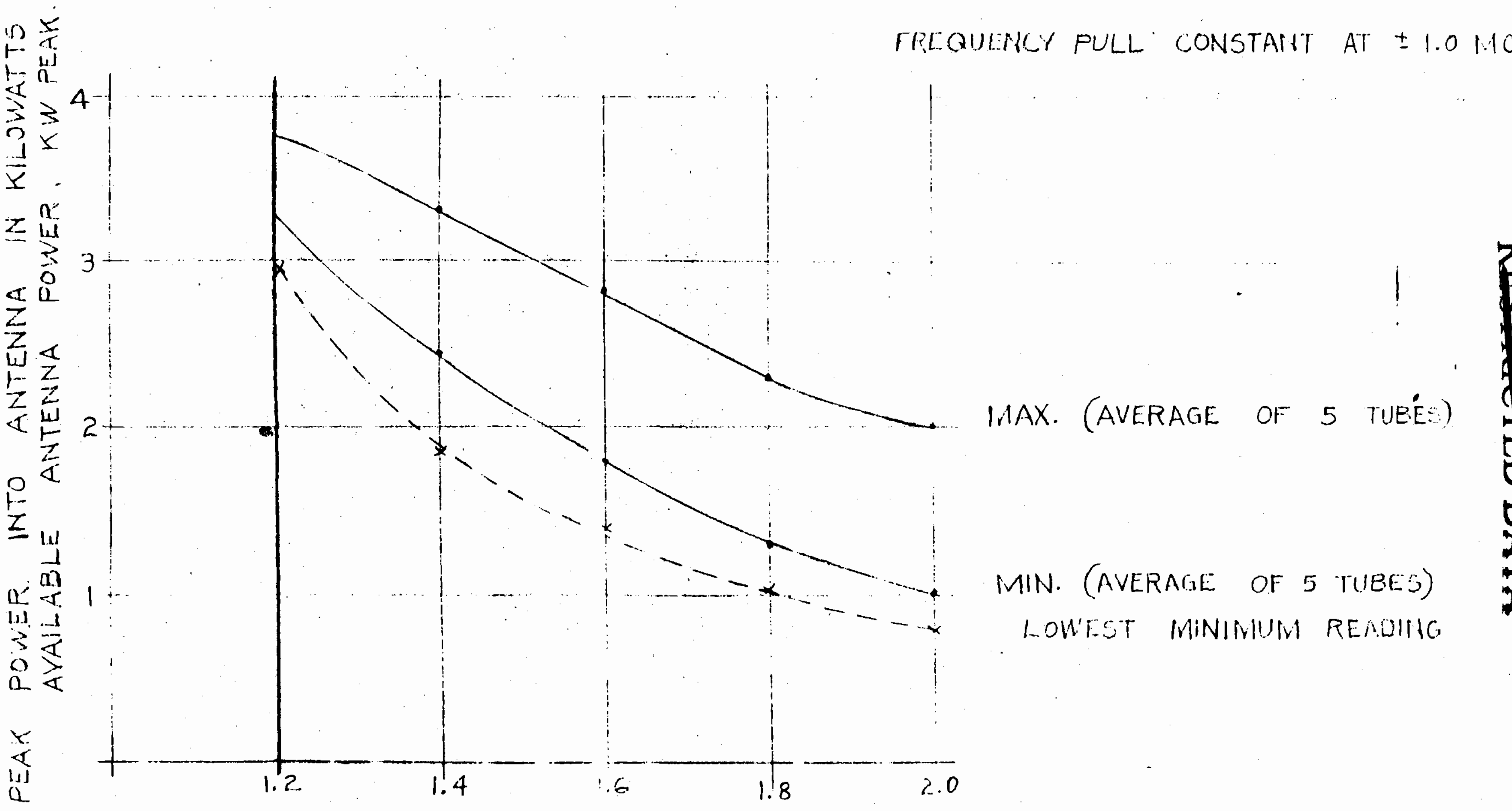

FIG. 10

MAXIMUM AND MINIMUM TRANSMITTER POWER OUTPUT AS A FUNCTION OF MISMATCH (VSWR) AND LOAD REACTANCE.

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Additional tests were conducted to determine the peak power output of the transmitter and 12 foot length of RG-8u antenna cable. The power output as a function of VSWR was determined. For each VSWR two power output figures were determined corresponding to the extremes of capacitive and inductive load conditions which could be simulated by the double slug line. Five tubes were tested, the minimum and maximum power output determined, and the average powers for each value of VSWR plotted (see Fig.10) The minimum power output obtained with five type 2C39 Machlett tubes was also plotted for each VSWR to present the extreme condition encountered.

The frequency drift characteristics of one tube was investigated. Plate voltage was applied after the filament voltage had stabilized. The frequency drift during the first two seconds was 2 mc. The frequency had stabilized during the following 13 seconds during which time the frequency changed 1.0 mc.

Redesign of the high voltage power supply for the TR tube was determined, after investigation of the prototype characteristics. The time constants of the power supply prevented effective voltage from being supplied to the tube until after the transmitter had operated many times. The r-f voltages applied to the 1N21 crystal were excessive. It was judged that this condition would require correction to improve operational reliability of ABEE.

The master oscillator which determined the pulse recurrance frequency was a conventional blocking oscillator circuit. The Motorola circuit was essentially similar with only minor modifications. The Sandia prototype employed the 2C51 tube which previous analysis indicated was unsuitable for pulse applications. The type 12AT7 was substituted and satisfactory performance obtained. The tube transconductance did not deteriorate with use, the observed malfunction of the 2C51 in pulse operation. The pulse recurrance frequency stability with input power variations was judged to be satisfactory. A 40% variation of either the plate or filament voltage effected a frequency change of only 8 cycles per second. Other minor circuit modifications were made as required by the system development. For example, one output connection was omitted with a decision that the high voltage power supply would not be keyed "on" simultaneously with the modulator, range, and i-f blanking circuits.

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The modulator supply was studied. It was noted that the rise time of the modulator pulse was approximately 0.4 microseconds. The modulation transformer had a 10:1 ratio which was not capable of reproducing in its output the voltage rise time applied to the input. Later development, ~~described later~~, effected operation of the transmitter within 0.1 microsecond from the time the modulator began to operate. This measurement included the video response and delays introduced by (1) the modulator circuit including the transformer, (2) the transmitter, (3) the transmission line to an r-f diode detecter cavity, (4) the output circuits to an oscilloscope, and (5) the delay inherent in the oscilloscope operation. The improvement was reflected in redesign of the pulse forming circuit and the modulation transformer. The primary power for the modulator was changed from the 300 volts used in the prototype to 1000 volts. The higher voltage was obtained by the use of a step-up transformer connected to 400 cycle filament supply.

The T.R. cavity became the subject of an investigation to determine the required bandwidth. A recommended bandwidth of 21 megacycles was determined theoretically according to the following analysis by P. W. Sokoloff:

"I. Band-Pass Transmission

The selectivity of any resonant circuit is a function of the equivalent reactances and equivalent resistances, coupled and internal, of which it is comprised. The cavity used at high frequencies is a special form of resonant circuit in which distributed constants replace lumped constants, so that values of L and C cannot be measured separately, but can be measured with relationship to loss components of the circuit.

A. Insertion Loss Factors

Figure 11a. shows a resonant circuit without coupling to any

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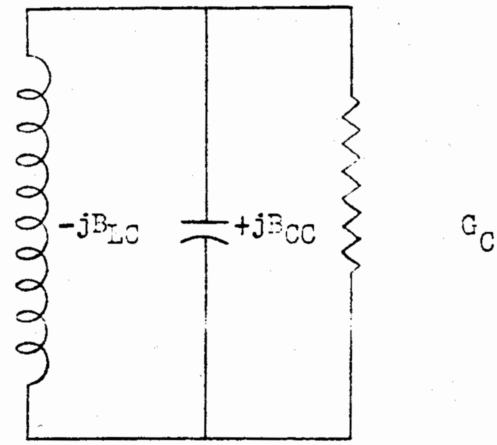
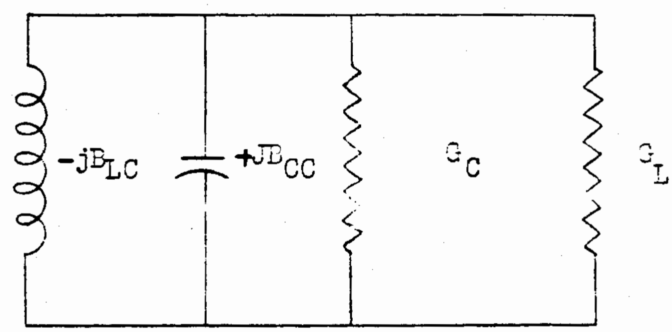
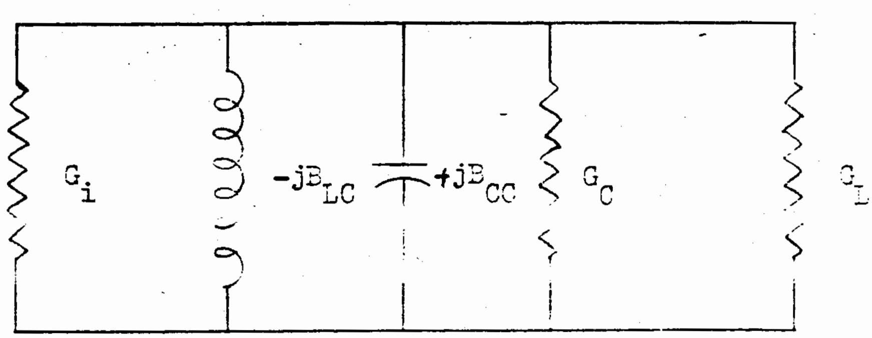
a. Unloaded TR cavity



b. Cavity and output load



c. Cavity with output and input loads



d. Loaded cavity, normalized to input line conductance, G_o

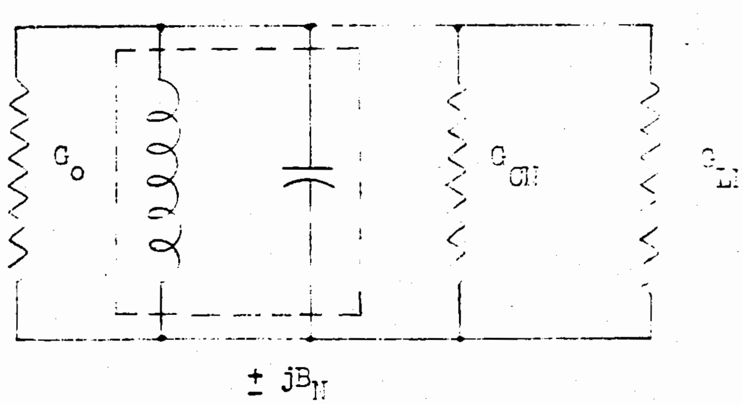


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Fig. 11
TR Cavity Equivalent circuits

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input or output circuits. The only lossy element is G_c, and all real power is dissipated here. At resonance,

$$+ j\,Bcc - j\,BLc = 0 \qquad (1)$$

and the input admittance is real and equal to conductance G_c.

Figure 11 b. is the original resonant circuit with additional loading of a coupled output circuit to give an equivalent shunt conductance, GL. The energy coming into the circuit is dissipated into internal loss and output in the proportion to G_c and G_L, respectively, so that the efficiency of the circuit is

$$\frac{G_L}{G_L + G_c} \qquad (2)$$

The proportional loss is

$$\frac{G_c}{G_L + G_c} \qquad (3)$$

$$\mathrm{Log}_{10} \frac{(G_L + G_c)}{G_L} \quad \text{is the insertion loss in decibels.} \qquad (4)$$

Figure 11 c. shows the cavity loaded by output and input lines. G_L is the loading of the input transmission line across the cavity with a constant current generator.

Figure 11 d. is the same as Figure 11 c. with all values of admittance normalized to the input transmission line admittance, G_o. The combination of $-j$ BLc and $+j$ Bcc is reduced to a single susceptance with a normalized value $+ j$ Bn. With the constant current generator, it is readily seen that .707 of resonant voltage across the cavity is obtained when /Bn/ is equal to Go $+$ Gcn $+$ GLn. It is also seen that maximum power at resonance is obtained when the cavity matches the input line, that is, Go $=$ Gcn $+$ GLn. (5)

Knowing the off-resonance frequencies at which power is 3 db down from resonance for any condition of loading and the insertion loss under any given loading condition, one can determine the band width and insertion loss for any other condition of loading.

B. Minimum Bandwidth Possible

The minimum bandwidth possible, obtainable only with extremely large insertion loss, and light coupling to the input line, is fo/Qo, where Qo is the Q of the cavity loaded only by its internal losses. The minimum bandwidth with cavity matched to the input line and extremely large insertion loss is 2fo/Qo.

II. ABEE T-R Cavity

A. Unloaded Pass-Band of Cavity

The T-R cavity chosen for ABEE is that used in the APG-5 equipment with only one mechanical change in spring finger and tube contact design to give better shock characteristics. Test data for the APG-5 T-R tube is given in Northwestern Reports #F549-60.

A typical T-R box had an insertion loss of 1.35 to 1.56 db and a bandwidth of 20 Mc/sec. From this information, we can determine the unloaded pass-band of the cavity and characteristics for any form of loading as follows:

Referring the numbers above to Figure 11d. and equation (4)

$$\frac{1.35}{10} = \text{Log}_{10} \frac{G_L + G_c}{G_L} = \text{Log}^{-1}_{10}\, 1.36$$

If the cavity input is matched to the line, $G_{Ln} + G_{cn} = 1$ and

$$G_{Ln} = .735.$$

$$G_{cn} = 1 - .735 = .265$$

Since the total normalized shunt conductance of Figure 11d. is 2 and the bandwidth is 20 Mc/sec, the bandwidth of the cavity alone is

$$20 \times \frac{.265}{2} = 2.65 \text{ mc.}$$

If the cavity is matched to the input line, with virtually no output coupling, the shunt conductance across the cavity is doubled, and band-width is

$$2.65 \times 2 = 5.3 \text{ mc}$$

B. Calculation of Pass-Band Versus Insertion Loss

If, in turn, the output load is matched to the cavity as well, the insertion loss is 3 db and the bandwidth is 2 x 5.3 = 10.6 Mc/sec. This bandwidth is of the order of the I.F. bandwidth of ABEE and is

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the usable spectrum of the pulses employed.

By cranking in a number of values for G_{Ln} for Equation (5), and matching the resultant resonant load to the line, a cavity with a limiting bandwidth of 2.65 Mc/sec gives the following table:

G_{Ln}	G_{cn}	Insertion Loss in DB	Half-Power Pass-Band Mc/sec
0	1	0	5.4 Mc
.1	.9	10	6.0
.2	.8	7	6.75
.4	.6	4.0	9.00
.5	.5	3.0	10.8
.7	.3	1.54	18.00
.8	.2	1.0	27.00
.9	.1	0.5	54.00

C. Bandwidth Allowance for Drift

1. Frequency Pulling of Transmitter Due to Antenna

Drift of the transmitter oscillator may be caused by pulling of the antenna load. Measurements for the 2C39 tube indicate that an antenna of 1.5 VSWR, connected to the oscillator through 12-foot length of RG-8/U cable and with a coupling coefficient to the transmitter cavity of 0.8 maximum, gives a pulling figure of 3 Mc/sec. This figure checks with that obtained by SLA. The allowance for this effect should be $\pm$ 3 Mc/sec or 6 Mc/sec.

2. Other Drift of Transmitter Oscillator

The pulsed 2C39 oscillator has a frequency change with pulse voltage reulation of $\pm \frac{1}{2}$ Mc, for a total change of 1 Mc/sec.

3. Drift of T-R Cavity

Northwestern Report #F549 covering the drift of T-R box with temperature, shows a drift of 20 Mc from -50° C to + 80° C, or 0.154 Mc/sec/C°. It is expected that heater units will hold the ABEE within 25° C, $\pm$ 10 C°, with a variation of frequency of $\pm$ 1.54 Mc/sec.

4. The total drift guard range should be the sum of the three variations shown above. These are

(a) 6 Mc
(b) 1 Mc
(c) 3 Mc
10 Mc

Total bandwidth is 10 Mc plus a useful 10.8 Mc for a total band width 21 Mc/sec. The resulting insertion loss at resonance is about 1.4 db."

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The efforts to devise a suitable local oscillator with a single control for the adjustment of frequency were started during the latter part of December. Many of the tests and investigations were undertaken to establish the proper mechanical design which would permit optimum operation. It had previously been determined that the tuning ratio was 2:1.

The nature and placement of the grid return circuit was studied: previous cavity oscillators employed a wire either soldered to or pressed tightly against the grid cylinder. The free end of the wire was connected to a grid resistor which completed the circuit from grid to ground. A new technique was tried: the grid resistor was connected from grid to cathode with the grid resistor adjacent to the tube envelope. Satisfactory electrical operation followed although the output power was halved by the introduction of the grid resistor in the radio frequency field of the oscillator. Because solder connections were required, the operating temperatures were of interest. The cavity was operated at ambient room temperature and two temperatures were measured: (1) 43° C near the plate of the 2C37 tube and (2) 60° C at the grid of the tube. The tube and cavity assembly procedure was complicated. The use of solder at high operating temperatures was considered impracticable. Consequently this type grid return was abandoned.

Graphite, connecting the grid to the cathode was used for a grid return resistor. Satisfactory operation was obtained with slightly reduced oscillator power output. This technique was judged impracticable for production because of anticipated difficulty with production quality control. The technique was also abandoned because many rejects would be necessary in the event that tube selection were required.

The first local oscillator with a single control to change the operating frequency was tested the last week in December. The mechanical coupling between the grid cylinder extension and cathode choke was similar to that depicted in Fig.21a. Three tuning shafts (spaced 120 degrees around the wall of the cavity) were used to support and adjust the grid extension and cathode choke. Two couplings each with three radically extended arms connected the tuning elements to three external shafts. The coupling material for both tuning elements was polystyrene. The polystyrene material was thermoplastic and had low tensil strength. The material was not suited to this application. Teflon, not tried would have been a more suitable material. Mycalex would have been the ideal coupling with the best dielectric properties. However its tensil strength was low; and this material could not be used for machine manufacture of small parts. Molded Mycalex was considered. Further investigation revealed that the costs would be prohibitive. Additionally, the dimensions were classified information which would hinder progress and endanger the security of this component.

By a suitable cathode choke design, a brass coupling was used which performed very satisfactorily.

The three tuning shafts with a set of gears to couple the action of the tuning shafts, would not function easily in unison. The alignment of the several parts, threads, and gears was difficult, and alignment could be obtained only by threaded parts held to impractically small tolerances in production. The tuning mechanism was simplified by using one shaft and one coupling arm for each of the two timing elements. The revised structure, described later, is presented in Fig. 21 a.

A question was raised during this development concerning the necessity for cathode bias (resistor). It had been suggested that greater oscillator stability would result by obtaining bias in the cathode circuit. Thus plate current fluctuations would be stabilized by a corresponding

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fluctuation of the bias voltage between the grid and cathode. Facts were not available to ascertain the reasoning behind the statement. Logic dictates that the above statement is true. It is believed that the recommendation was made before the plate voltage was regulated with a voltage regulator tube. Experience has proved that adequate local oscillator frequency stability could not be obtained without plate and filament regulation.

There remains one argument in favor of the cathode bias. The grid-to-plate spacing would vary with plate current and tube heating. This would be referred to as a deformation or buckling of the wire mesh grid structure. The frequency change would result from a change of the grid to cathode capacitance. Past experience has demonstrated that the cathode impedance change caused a frequency change one half as great as the same change of plate to grid impedance. This then is an argument in favor of cathode bias. It is believed that laboratory tests would verify the statements.

The above reference to high frequency oscillator stability is written after a few months' experience with the problem. It will be recorded later in this account, that the above reasoning effectively solved a very serious transmitter frequency-stability problem.

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The first two special pulse transformers were fabricated during December. The input impedance was designed to be 50 ohms. Because the transmitter impedance had not been definitely established, one transformer was designed to match a 1000 ohm load while the other was designed to operate into an 1800 ohm load. A 0.3 microsecond pulse forming delay line with a 50 ohm characteristic impedance was designed and connected as shown in Fig. 9. The pulse forming line, chokes and, pulse transformers were designed and fabricated for laboratory test, to determine the optimum design as well as a suitable size for the final prototype ABEE. As soon as an acceptable electrical and mechanical design had been provided, the required quantities were to be procured from a subcontracting manufacturer.

For the high voltage power supply he CK5517/CK1613 was suitable; a power transformer to transform the 6.3 volts, 400 cycles, to 1000 volts would be designed. Other power requirements for the dynamotor were established. The power supply requirements were 300 volts d.c. at 200 ma and 6.3 volts at 500 to 600 cp.s. The requirements were established on the basis that the transmitter and local oscillator filament power would be supplied by the primary power, nominally 26.5 volts d.c. at 1.5 amperes. The total primary current to ABEE and the dynamotor was determined, 11.5 amperes.

The power requirements for the component sections of ABEE were calculated:

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	VOLTAGE	CURRENT
I-F filaments	6.3	1.75 amps
Range "	6.3	1.98 "
3C45 "	6.3	2.38 "
High voltage Power Transformer	6.3	3.65
		9.76 amps @ 500-600 cps.

Thedynamotor output characteristics were measured. The results are presented in Table 4. The test procedure comprised (1) adjusting the current output of the 600 cycle supply to effect an output of 6.3 volts, (2) adjusting the plate supply current to 200 ma, and (3) maintaining the primary input at 26.5 volts. The primary voltage was then varied from 24 to 28 volts. The data were recorded with the plate supply current at full load and no load; the dummy filament load was 0.346 ohm.

Dynamotor voltage	Input Current	Plate supply voltage	Plate supply current	Filament Supply Voltage	Filament Supply Current	Frequency
28V	14.5 A.	320 V	200 ma.	6.75 V	19.5 A.	600 c.p.s.
26.5	13.55	300	200	6.3	18.2	575
24	12.5	275	200	5.9	17.0	560
28	11.55	360	0	6.85	19.8	640
26.5	11.30	345	0	6.45	18.6	610
24.0	10.30	313	0	6.00	17.3	590

Table 4

Dynamotor Characteristics

Similar data were obtained with a dummy filament load of 1.113 ohms, See table 5.

Dynamotor Input Volts	Plate Supply Current	Filament Voltage	Filament current	Filament frequency
28 V	200 ma	12.7	11.4 A	600 c.p.s.
26.5	200 ma	12.25	11.0	575
24	200 ma	10.5	9.4	550
28	0	13.4	12	620
26.5	0	12.4	11	610
24	0	11	10	575

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Table 5

Dynamotor Characteristics

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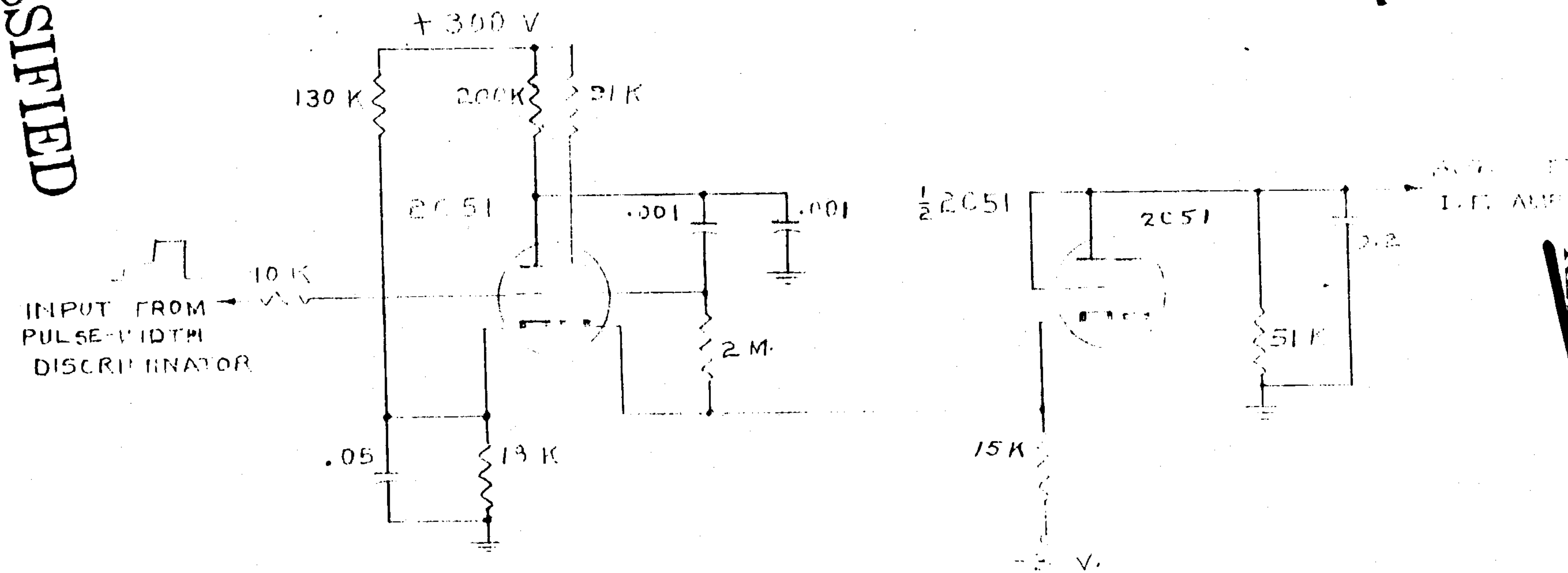

FIG. 13-A

A.G.C. CIRCUIT WITH
THE SANDIA PROTOTYPE.

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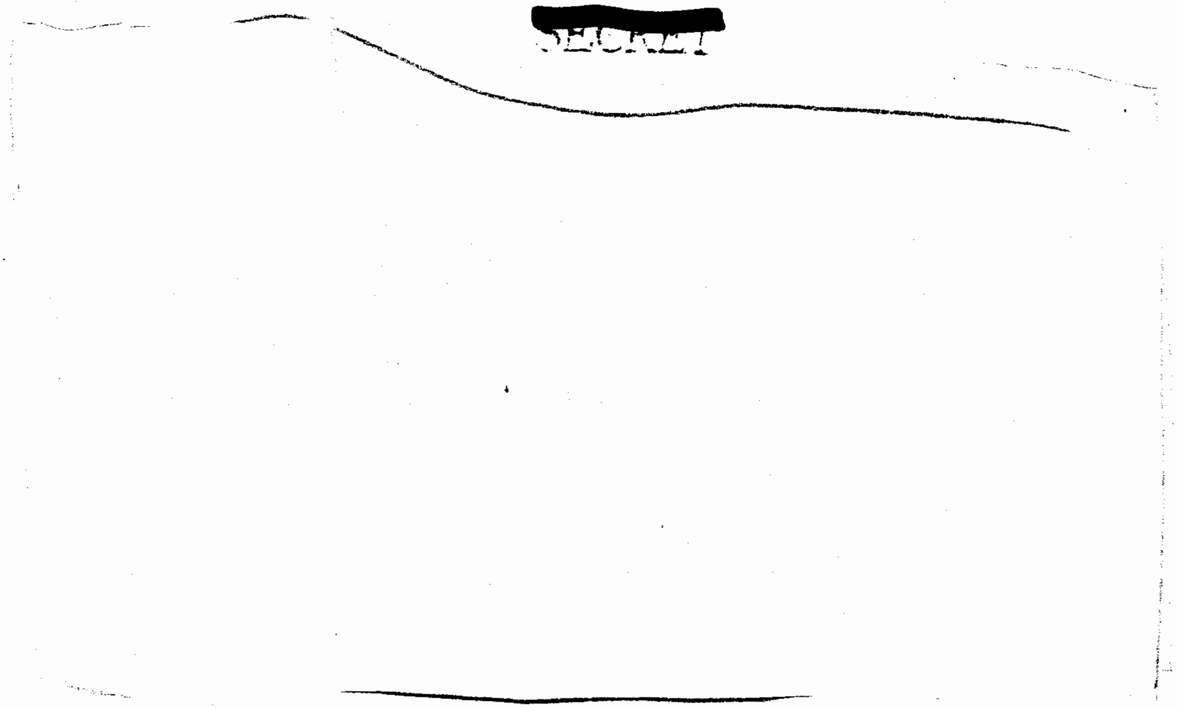
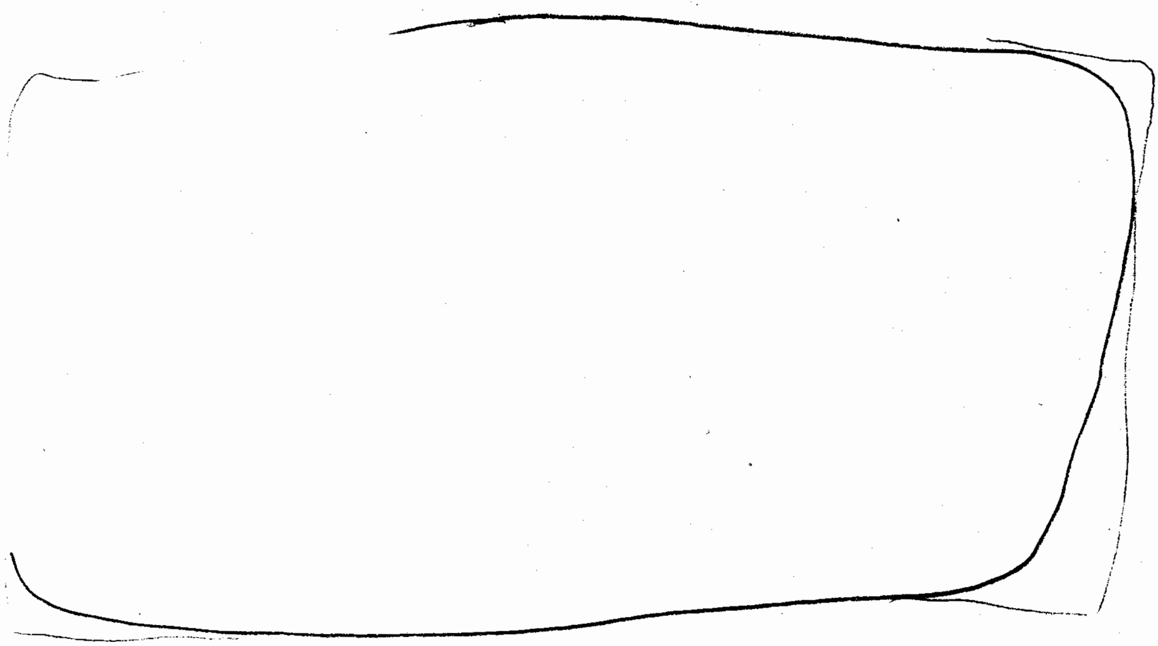
[redacted]



DoE b(3)

a. PROTOTYPE PULSE WIDTH DISCRIMINATOR



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b. MOTOROLA PULSE WIDTH DISCRIMINATOR

FIG. 12

PULSE WIDTH DISCRIMINATOR CIRCUITS

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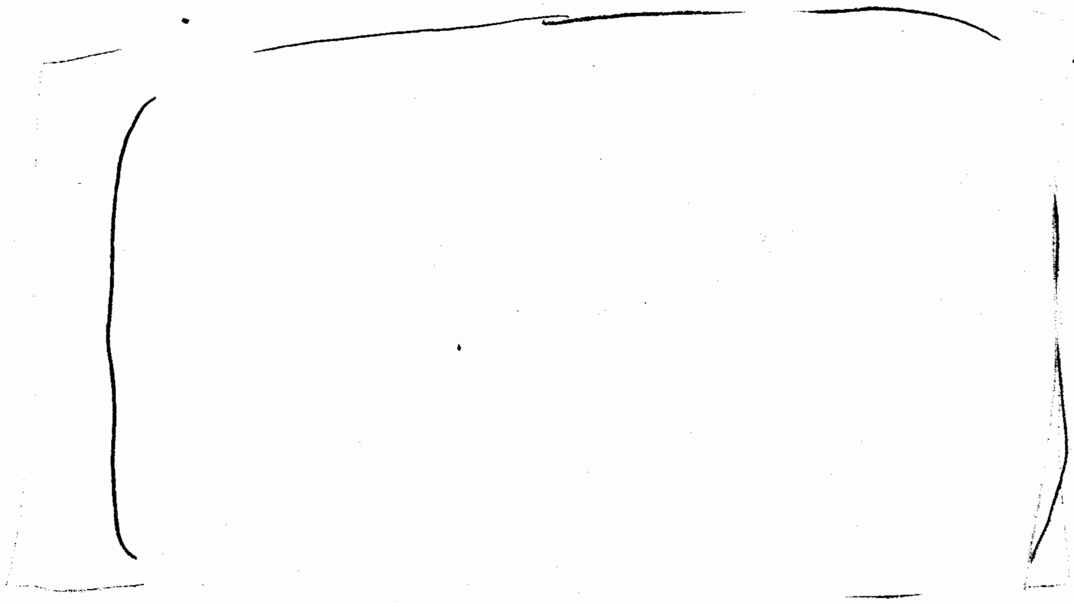

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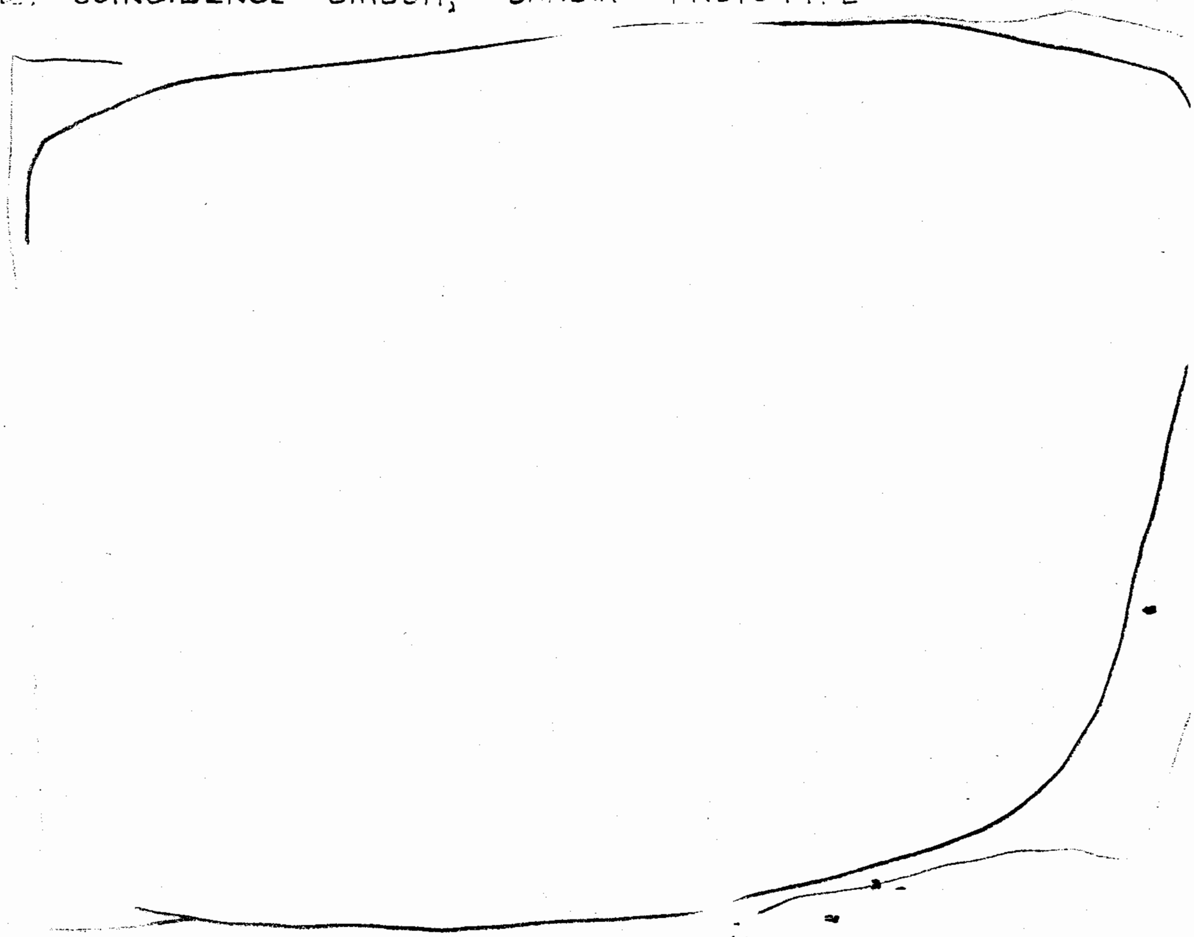
a. COINCIDENCE CIRCUIT, SANDIA PROTOTYPE



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b. COINCIDENCE CIRCUIT, MOTOROLA LABORATORY MODEL.

FIG. 13

COINCIDENCE CIRCUITS.

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a. PROTOTYPE [illegible]

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b. RANGE MULTIVIBRATOR, LABORATORY MODEL

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C. CATHODE COUPLED MULTIVIBRATOR

FIG. 14
RANGE GATE GENERATORS ~~SECRET~~

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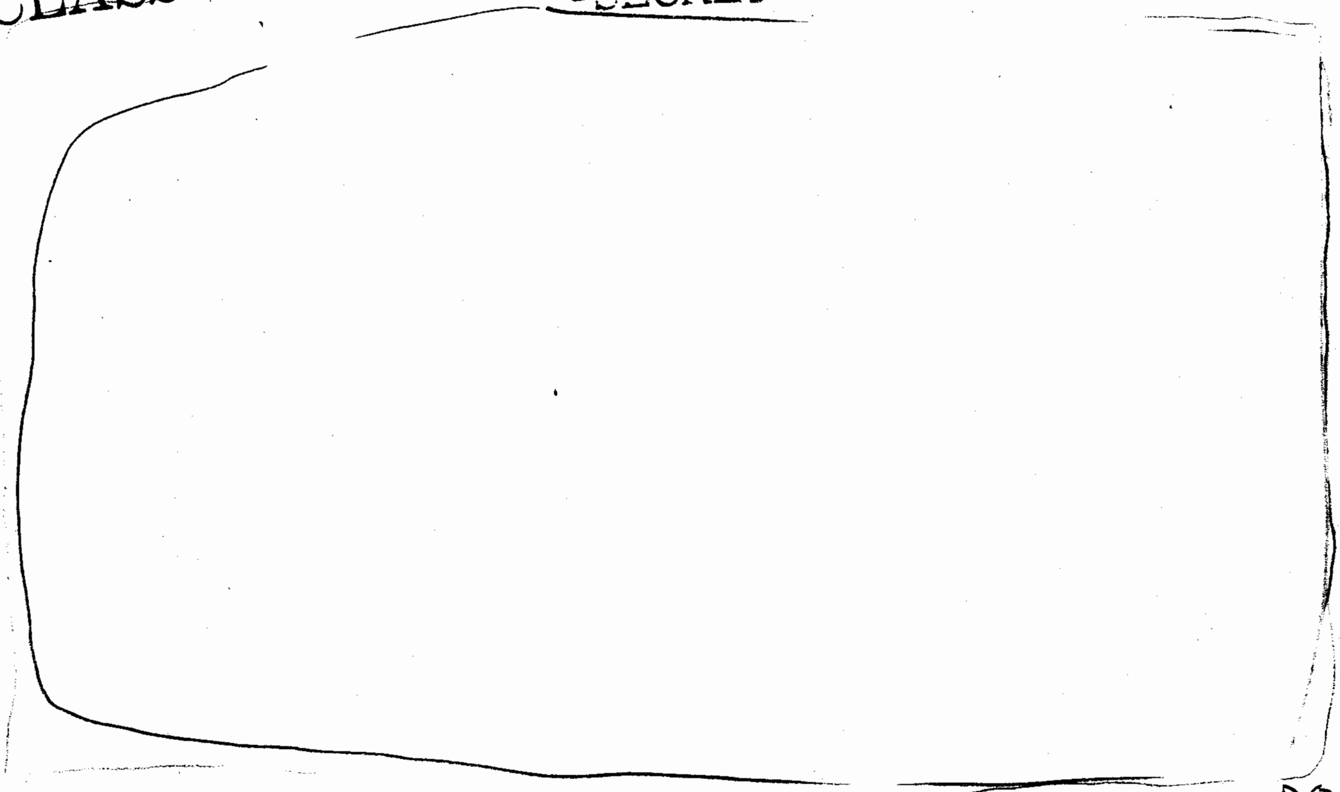

a. PROTOTYPE CIRCUITS

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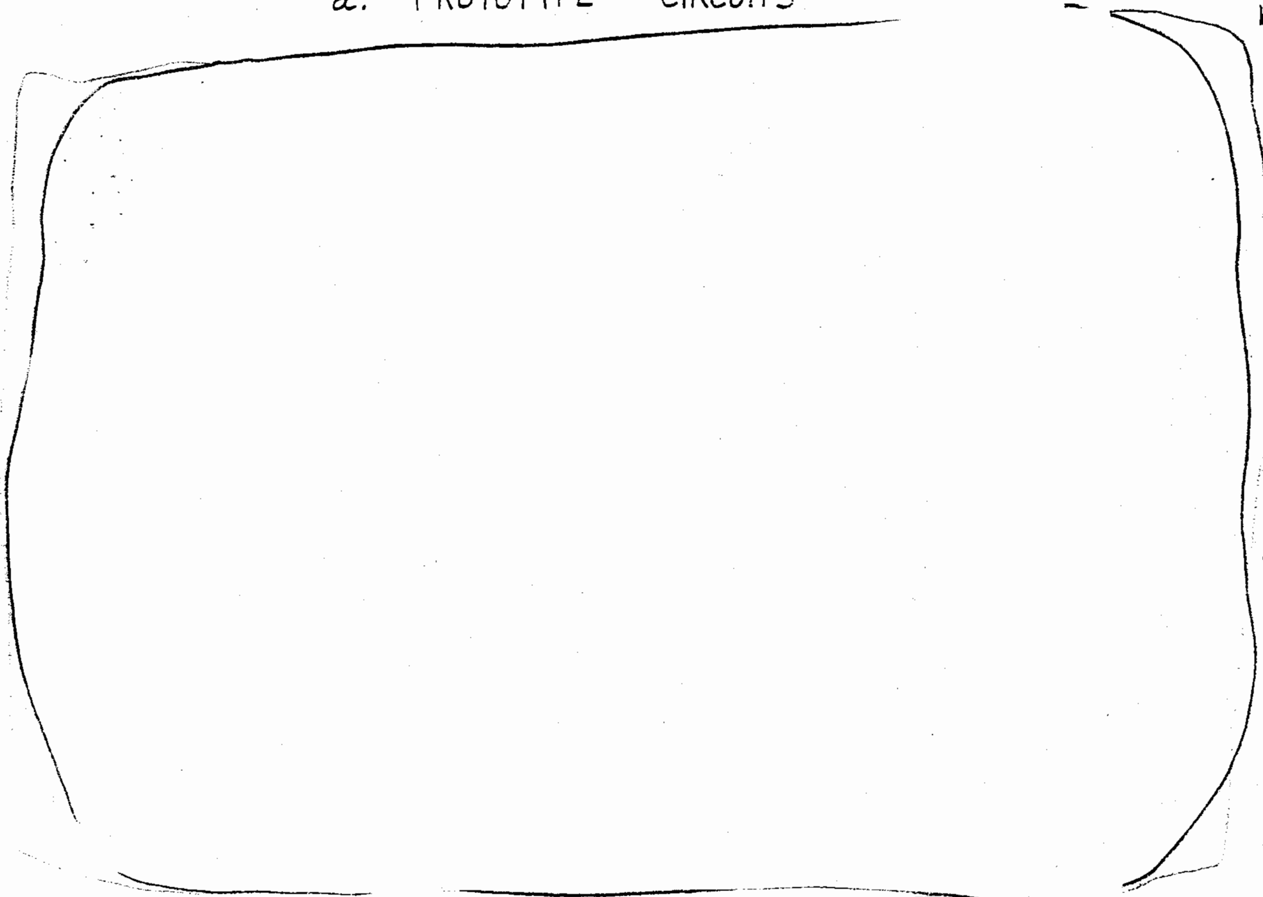

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b. MOTOROLA CIRCUITS

FIG. 15

COUNTING AND FIRING CIRCUITS.

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Miscellaneous Laboratory Equipment

1. Pulse Generator. The laboratory development of the video and range circuits required utilization of a versatile pulse generator. The signal generator was required to produce output pulses with exceptionally fast rise and fall times. Time difference measurements of approximately 0.01 microseconds was the objective. Commercially available pulse generators did not produce pulses with the needed rapid transition times. Consequently, a development program was initiated to design and construct a suitable pulse generator. This activity paralleled the ABEE and ABEE Tester circuit and system development. On several occasions a suitable generator, much needed, was not available. Time was required to successfully complete the development. It was during April and May, 1950, that the work was carried to a successful conclusion. The output pulse of either positive or negative polarity was characterized by transition times of .025 usec. Versatility was achieved; the output amplitude was constant with a pulse width which was continuously variable from 0.05 to 15 microseconds. Other refinements included (1) a variable pulse recurrence frequency (200 to 4000 c.p.s.), (2) a "course" delay control, (3) a "fine" delay control, (4) a "course" pulse recurrence frequency control, (5) a "fine" pulse recurrence frequency control, (6) an output pulse of positive or negative polarity with an amplitude continuously variable from 0 to 50 volts, and

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(7) an output synchronizing signal of positive or negative polarity with an amplitude continuously variable from 0 to 100 volts.

The results obtained comprise a detailed account of the objective. Further elaboration reveals that the pulse time modulation was required to be negligible so that time intervals of 0.01 microseconds could be accurately measured. The desired short time statability would then be approximately 0.001 microseconds. An additional requirement was long time stability. The pulse position was required to accurately maintain its time position for long periods of time, approximately 8 hours. To achieve this, the final equipment employed voltage regulated plate supply and bias voltages.

The first approach considered the use of standard multivibrators. Pulse width variation from 0.3 to 6 microseconds with pulse rise and decay times of 0.15 microseconds. The maximum output amplitude obtained was 50 volts.

The very short (.05 usec) pulses desired were unobtainable by the use of single multivibrators. The next approach utilized a fixed reference pulse and a pulse whose time position was variable. The two signals were applied to a mixer or coincidence circuit. Pulse width variation was obtained by changing the degree of time-coincidence of the fixed and variable position pulses. The pulse amplitude was limited by the current capabilities of tube types such as the 6BN6, 6AH6, 6AS6. Additionally, the pulse transition times were poor, a result of interelectrode and stray capacitances. Amplifiers and limiters could not be used for the same reason. An unsatisfactory attempt included the attempted improvement of video characteristics by the use of peaking coils. While the pulse generator did not meet the laboratory requirements, it was used pending an improved pulse generator development.

The next attempt employed the 6D4 thyratron tube. This tube did not perform satisfactorily. More signal power was required to "fire" the thyratron than was available from preceeding circuits. Also, grid to cathode conduction not only decreased the grid applied to the signal but produced an output signal at the cathode. This spurious signal appeared in the output prior to the thyratron ignition effecting a poor output pulse shape. A later design incorporated the type 2D21. The circuit design was completed during April , 1950, and will be described later.

2. Delay Timer. The delay timer was originally specified to be a part of Abee. The requirement was waived during the conference held at the Sandia Laboratory, October 6, 1949. The delay timer was a required development but was to be located within the cartridge rather than remain a portion of the Abee "package". The delay timer, developed during December, was to be a part of the system which would be produced by Sandia. The timer was required to operate from 0.1 to 1.0 second at 0.1 second intervals. The time adjustment was required to be accurate within the limits ± 5%.

The intended use of the timer was described by a drawing supplied to Motorola by Sandia. This drawing was reproduced and

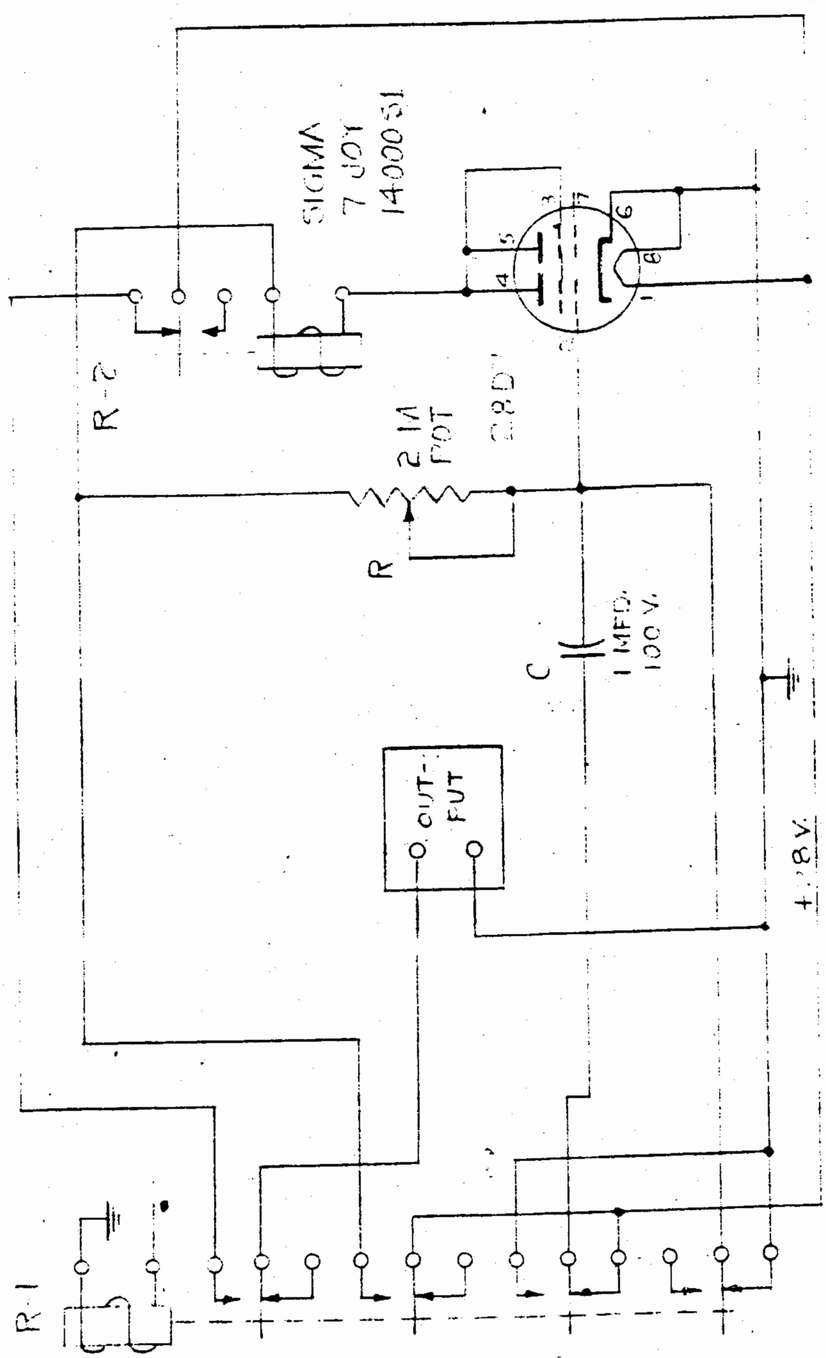

FIG. 15a
DELAY TIMER

is presented in Fig. 3. The drawing provided information concerning the intended use of the timer. The circuit was an unclassified component and therefore was assigned to the group of engineers who were awaiting AEC security clearance.

The 28D7 tube was selected because the tube filament could be operated directly from the 26.5 volt source of previous power. The twin triode tube also provided excellent gain with only 28 volts plate supply voltage.

The desired circuit function was the operation of relay R2, Fig. 15a, a predetermined time after the operation of relay R1. Initially the circuit was in the "off" condition during which the condenser C was charged negatively with respect to the grid of the tube. The grids were connected to the cathode and ground, and the plate voltage was zero. The timing operation was initiated by operation of relay R1 which connected 28 volts to the plate, connected the positive side of C to ground, and removed the ground connection to the grids and RC timing circuit. The tube was cut-off by the 28 volt bias voltage across C. After operation of the relay R1, the grid voltage increased expotentially to the 28 volt supply voltage. Timing accuracy was excellent because tube conductance occurred during the linear portion of the RC discharge characteristic. The flow of plate current closed relay R2 to operate an external circuit. The elapsed time from the operation of R1, tothe operation of R2 was variable from 0.1 to 1.0 second by proper adjustment of R. An alternative, not considered during this development, would include a number of fixed resistors and a switch toselect the desired timing intervals.

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The reset accuracy of this device was determined in the laboratory. A standard $1\frac{1}{2}$" diameter dial plate calibrated from 0 to 100 and a small 1" pointer knob were used with the timing potentiometer R. The timer was calibrated with an interval timer, Standard Electric Timer type MST-500. Using this calibrated control, the timer was adjusted visually to operate after intervals of 0.1, 0.2, ---- to 1.0 seconds. For each time interval setting, the actual operating time was measured with the standard interval timer. Five complete test runs were made. The data, Table 8, record the reset accuracy of the delay timer.

Measured Time-Seconds

Nominal Time-Seconds	1	2	3	4	5	Maximum error in seconds	Percent Error
1.0	0.996	.980	.994	.985	.990	.020	2.0%
.9	.901	.901	.901	.903	.893	.007	0.8%
.8	.800	.799	.804	.801	.800	.004	0.5
.7	.699	.702	.706	.700	.708	.008	1.1
.6	.603	.590	.600	.600	.601	.010	1.7
.5	.497	.496	.495	.495	.500	.005	1.0
.4	.395	.398	.400	.397	.405	.005	1.3
.3	.300	.298	.302	.302	.301	.002	0.7
.2	.204	.200	.200	.195	.197	.005	2.5
.1	.103	.097	.097	.098	.097	.003	3.0

Table 8

Delay Timer, Reset Accuracy

The maximum reset error obtained, 3%, was within the requirements of the target specifications, $\pm$ 5%. With a series of fixed resistors and a selector switch, the timing accuracy could be controlled by using resistors manufactured within the required tolerances. The

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contributing errors would be caused by change of resistance with age and temperature, the reset error by the operator having been eliminated.

Personnel security clearance requests for key personnel were in process during November, December, and the early part of January, 1950. Those cleared during the three month period of time included several "Key" engineers whose participation in the Abee program was to signal the completion of an efficient development organization. The addition of 28 men did not reduce the number of hours per week to be worked by the development staff. Much development work remained in either a semi-finished or incomplete status. In addition, the parallel plan was to require the services of many engineers in positions of multiple responsibility, development, design for production, and preparation for pilot production. Other needed service type responsibilities included:

1. Personnel management
2. Raw stock procurement, facilities, and records
3. Personnel security clearances, guard instructions, building security requirements, as well as classification and documentation of records
4. Procurement of production machinery, patterns, dies, jigs, and fixtures including equipment maintenance and records
5. Accounting records, charges and disbursements
6. Job schedules for model shop and drafting
7. Laboratory instruments procurement and maintenance including records, and
8. Plant facilities allocation and modification including construction. planning for the new laboratory building.

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The Motorola organization for the Abee and Abee Tester program is presented below:

__Engineering__ P. J. Sturm, Project Engineer, P7

- R. W. Elsner, Development of prototype and Production Test Equipment.
    - J. W. Dunifon
        - J. C. Gundry
        - D. B. Lee
    - P. W. Sokoloff
        - C. B. Boenning
        - D. A. Smith
        - C. A. Debel
    - R. W. Elsner
        - I. D. Pomeroy
        - E. S. Shepard
        - H. C. Morgan
        - A. L. Turner
    - Fred E. Dreste
    - Laboratory Assistant
        - E. P. Hannum
- C. F. Meyer, Production Engineer, Chicago Project Coordination; production information & facilities.
    - C. J. Russnak, Mechanical Project drafting
    - A. C. Fabris, Procurement
    - A. S. Hume, Electrical Project drafting
    - J. L. Rising, Production Engineer - Laboratory Facilities
- A. C. Tregidga, Project Engineer, P8
    - R. S. Bailey, Asst. Proj. Engr.
        - E. Conrad
            - R. O. Blackert
            - C. J. Clark
            - H. R. Dell
            - K. W. Gardiner
            - J. E. Bartling, Mechanical
        - Laboratory Assistants
            - J. Soriano
            - F. G. Posey

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__Drafting__

- W. H. Wolbrink, Chief Draftsman
- E. D. Kirk, Assistant Chief Draftsman
    - H.R. Anderson, Layout Draftsman
    - J. M. Hagen, Detail Draftsman

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Model Shop

E. W. Rafter, Foreman
K. A. Hale
W. T. Shawler
K. M. Kraus
H. C. Staudigel

Secretarial

P. S. Ferrell
J. K. Saville
H. R. Garvey

Stock Room

B. G. Bartee

Guards

J. S. Bolin
G. K. Edgar
C. R. Goforth
R. R. Roberts

Building and Grounds

H. E. Brannoch

The Motorola employees who received AEC security clearance during November, December, and January included:

E. S. Shepard	Assistant engineer
C. B. Boenning	Assistant Engineer
H. R. Dell	Assistant engineer
H. R. Anderson	Layout draftsman
C. J. Russnak	Senior mechanical engineer
C. J. Clark	Assistant engineer
K. M. Kraus	Tool and Die maker
H. L. Morgan	Assistant engineer
K. W. Gardiner	Assistant engineer
S. H. Kirby	Junior engineer
J. W. Dunifon	Senior engineer
C. F. Meyer	Senior engineer
A. C. Fabris	Engineer
A. S. Hume	Senior Engineer
D. B. Lee	Engineer
M. R. Winkler	Senior engineer
R. L. Knight	Administrative assistant
C. A. Debel	Engineer
A. L. Turner	Junior engineer
G. K. Edgar	Guard

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7

Production Model Evaluation - Manufacturing Schedule - Security Construction and Machinery - Revised Cost Estimate - Machinery Requirements - Production Quantities - Technical Progress.

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The objectives during the early months of 1950 included (1) fabrication of the production model (2) the commencement of production tooling, (3) continued development, and (4) delivery of the final production prototype. Other continuing activities included changes of target specifications and the preparation for the New York AEC of a revised cost estimate.

The first production model was scheduled to be completed by January 15. The model, completed by January 22, was fabricated primarily to resolve mechanical problems and was also capable of being operated electrically, suitable for production with modifications. Since this was the first ABEE fabricated in the size and shape anticipated for pilot production, the circuit operation was examined to determine whether or not the circuits operated satisfactorily. This was the second analysis of the system operation, the first analysis being confined to the laboratory "breadboard" model. A number of electrical troubles were noted. These included (1) insufficient current to assure optimum closure and reliability of the firing relay, (2) excessive blanking time duration, (3) operation of the firing relay by stray r-f signals appearing in the i-f amplifier, and (4) inaccurate range adjustment (the time delay between the master synchronizing pulse and the r-f pulse, not previously known, was found to be 0.2 microseconds). It had previously been determined that a change of the amplitude of the range synchronizing pulse was followed by a change of range operation. To correct this source of range inaccuracy, a limiter amplifier was connected between the range circuits and the source of synchronizing pulse. The limiter circuit provided an output pulse of constant amplitude. To obtain the added circuit, the master blocking oscillator was made to operate with 1/2 12AT7. Previously the two tube sections were operated in parallel. It may be recalled that originally the tube was a type 2C51. This tube was found to deteriorate rapidly during use, especially with subnormal filament voltages.

The production model was evaluated from a mechanical point of view. Several changes were proposed during a conference at Phoenix. Several Chicago Motorola personnel including L.P.Morris and W. Barbier examined the model and contributed many constructive suggestions. The r-f plumbing assembly could be stabilized during vibration by a clamp, the likely location being at the crystal mixer assembly and junction with the i-f input cable. A tighter swage assembly of the plumbing components was advocated. An insufficient number of threads on the TR cavity was noted. Other observations included:

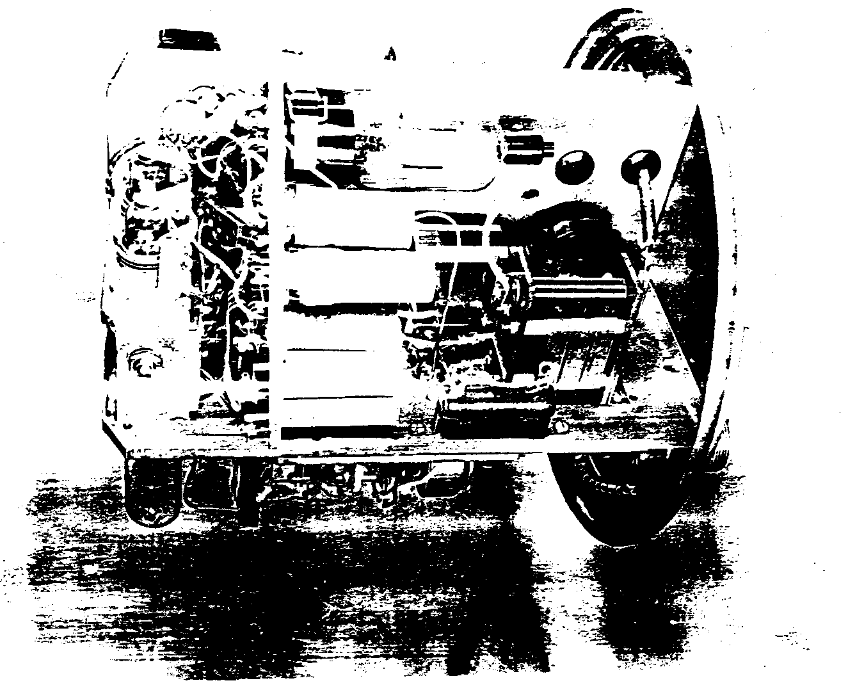
(1) improper alignment of the [illegible] clamp,

(2) use a spring to support keep-alive voltage connection to the TR tube,

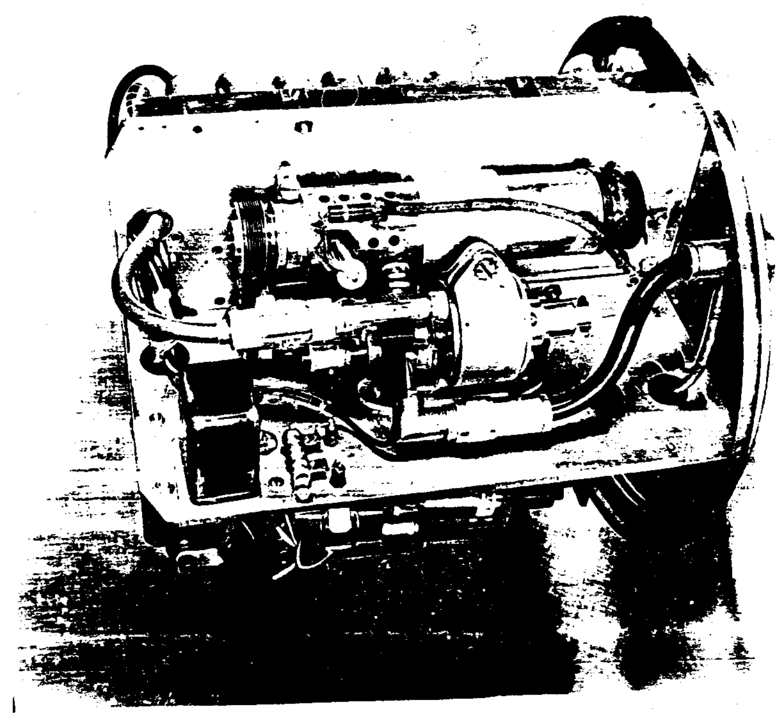
(3) include a 90 degree coupling from the mixer to the i-f input cable to avoid a 90 degree bend in the i-f cable,

(4) clamp the 3C45 near the top of the tube base,

(5) check the voltage breakdown properties of the high voltage insulation,

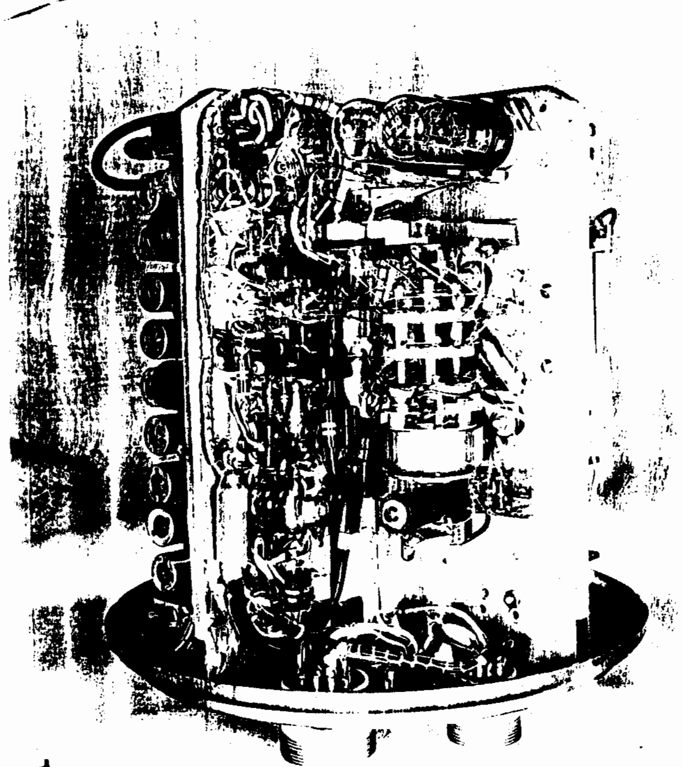


Modulator Quadrant

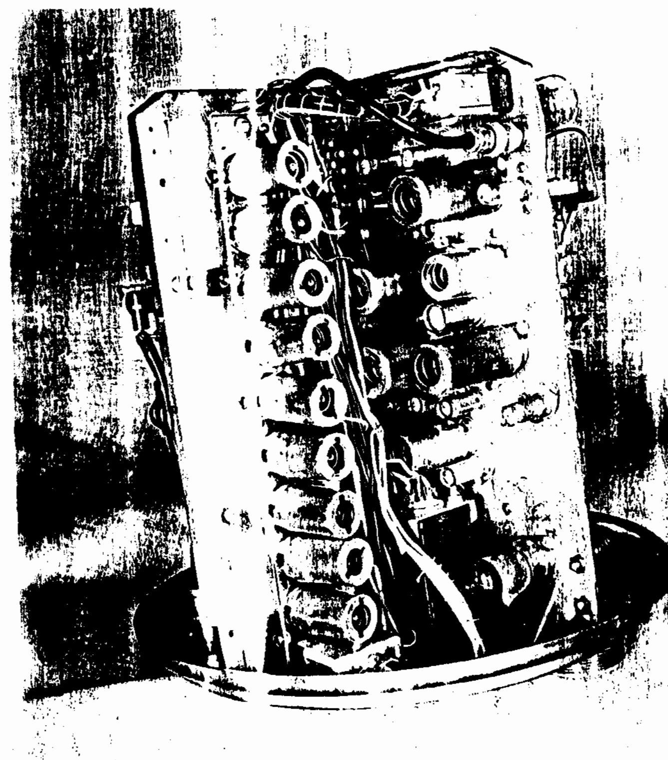


R-F Quadrant

Fig. 16. The Production Model



Range Quadrant



i-f Quadrant

Fig. 16a. The Production Model

(6) use no. 22 wire instead of no. 20 wire,

(7) move the current regulator tubes to facilitate adjustment of range condensers,

(8) use mineral oil impregnated high voltage condensers,

(9) improve mechanical support for range condensers, and

(10) use vinyl wire for i-f strip wiring.

Numerous other suggestions were offered to improve the mechanical construction, accessibility, serviceability, and appearance of ABEE. Four views of the production model are presented in Figures 16 and 16a.

To avoid possible confusion in terminology the terms laboratory model, production model, and production prototype should be defined. The laboratory model, often called breadboard model, is a combination of circuits and chassis which are interconnected to demonstrate the ability of the circuits to operate properly alone and as a system. This procedure establishes the type of circuits to be used and the required complement of tubes, relays, transformers, cables, etc. required for proper operation. The operation as a system is also intended to demonstrate that the assembly is practicable and merits continued effort toward a tactical equipment. After the laboratory model has received the required approval, executive action is required to prepare the system for production. The new phase of activity includes proper mechanical and electrical designs which are suitable (1) for production and (2) to assure that the system will operate within the conditions imposed in use.

The production model may be defined as an equipment employing model shop construction. The objective is to reduce

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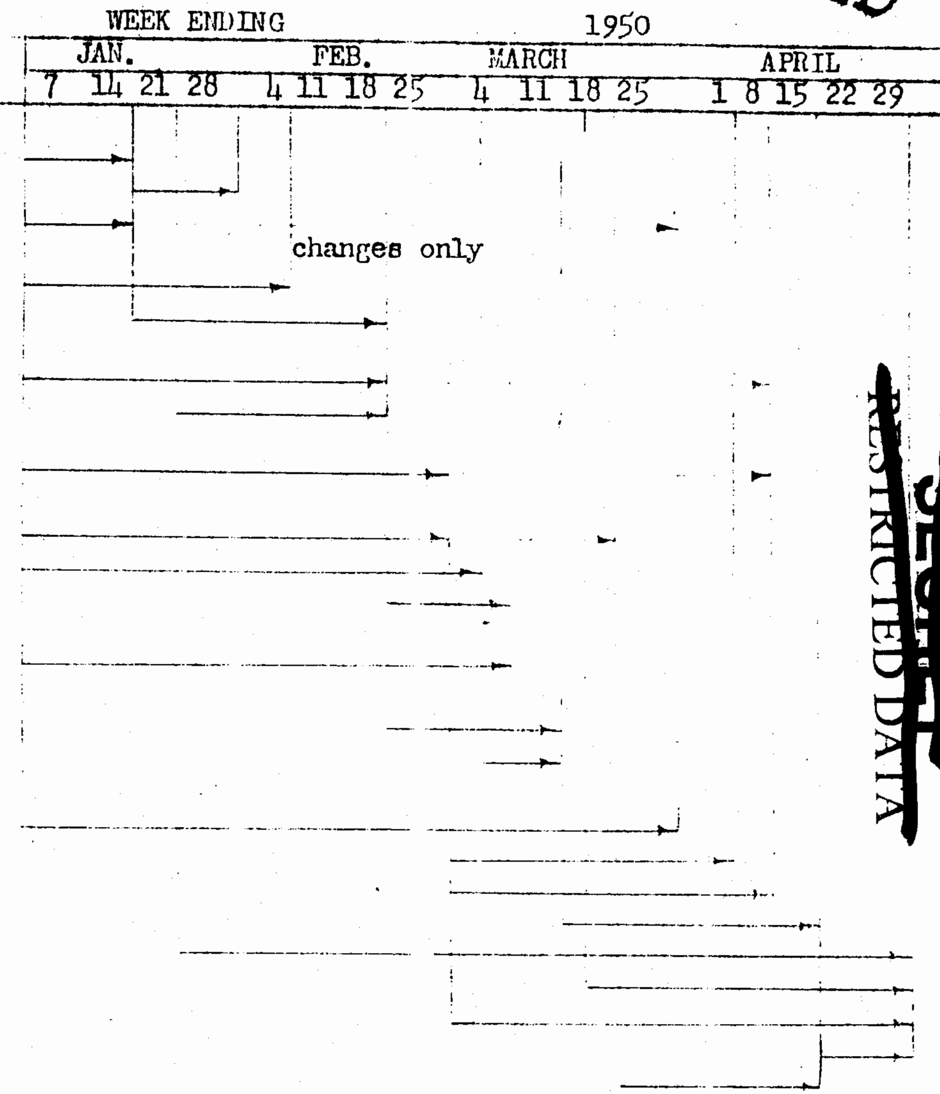

1. Production model wiring and assembly (Note 1)
2. Production model tests.
3. All electrical parts ordered (re-ordered as required)
4. Preliminary drawings, as permitted by development status (Note 2)
5. Production drawings, releasing ordering (Note 2)
6. Mechanical parts ordered, including hardware (re-ordered as required)
7. Production prototype wiring and assembly (Note 3)
8. Electrical parts received, tested and stocked, for 25 units.
9. Mechanical parts received, inspected, and stocked for 3 units.
0. All development ends
1. Assembly of 3 units (samples)
2. Drawing changes due to redesign (Production drawings must have CR, with approval of project engineer)
3. Production prototype tests, including vibration, temperature, etc.
4. Tests on one of three sample units
5. Mechanical parts received, inspected, and stocked for 25 units
6. Sub-assembly of remaining 22 units
7. Sub-assembly test
8. Final assembly of remaining 22 units
9. Drawing changes due to production requirements
). Systems test of remaining 24 units
1. Rework and retest
2. Final clean-up of drawings
3. Components for remaining 75 units

NOTES: 1. The production model is aimed primarily at resolving mechanical problems. It will be a fully operative unit, and suitable for production, if necessary, with only minor modification.

2. Preliminary drawings are to be made to distribute the drafting load. If there is a reasonable certainty that a part will be changed, drawings will be held up; if a 50-75% chance of using a part as is, drawings will be made, but not released for ordering.

3. The production prototype will represent the unit actually to be produced. Substituted parts must simulate production parts closely enough to permit full tests, including vibration, temperature, altitude etc.

Fig. 17 P-7 Schedule, Jan. 3, 1950.

the equipment to the size, shape, and weight intended in production. The proper components are selected and combined to resolve mechanical problems and electrical problems associated with a relocation of circuits.

The production prototype includes all the materials, components and circuits which have been reduced to acceptable manufacturing processes. Production planning is centered entirely about this true model. Production is followed by a pilot or trial production which has previously been defined as an activity designed to perfect the manufacturing and product inspection processes.

The criticism of the production model of ABEE was completed during the last week of January. This signaled the beginning of production activities. Because of the accelerated program, laboratory (model) development activities continued. As the laboratory model continually progressed, it was desirable to incorporate the changes in the production model. Consequently, the production model developed and changed while during the same period of time, February through June, production patterns for castings, dies and other machine tooling were designed and manufactured.

The production schedule was in fact established by January 3. This schedule, Fig. 17, anticipated the completion of 25 ABEE equipments by the end of April to be used by Sandia for acceptance tests. The results and recommendations by Sandia in addition to the contributions

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by Motorola would be incorporated in a final prototype which would include all the qualities and characteristics of the production equipments. Three equipments were to be delivered on or about March 6. The week of March 6-11 was scheduled for tests by Motorola at the Sandia Atmospherics and Vibration Division.

Production planning was started in January. The necessary production lathes, mills, and other specialized production machinery had been ordered. The production facilities included space at 1100 North Central Avenue and the new facilities under construction at 3102 North Ingleside Drive. The equipment for gold, silver, and bright alloy plating had been procured and plans were made by the Aladdin Metalcraft Company, consulting contractor, to install the equipment in the new building. The first plating was scheduled to begin March 1, 1950.

The production plans were established during conversations with various Sandia departments. The use of permanent tools was requested in order that quantity production plans would be in as advanced a state as possible. By the end of January the dies for the housing (a "deep draw" operation), main chassis, and the two wing chassis had been ordered. The first pattern for the cover plate had been completed and sample coverplates were scheduled for delivery by February 15. Approximately 10% of the required production jigs and fixtures had been completed. The assembly lines were to be established March 1 or as soon as the new building could be completed. The first 25 equipments were to be fabricated at 1100 N. Central Avenue.

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As production plans were devised during the first week of January, it became evident that approximately $34,000.00 worth of machine tools would be required in order that Motorola could comply with the security requirements of this program. The typical radio and electronic manufacturing organizations customarily procure many components from other highly specialized manufacturers. Many ABEE parts which required manufacture by machine methods were classified as secret by Sandia and the Atomic Energy Commission. This was a critical problem. The specialty machinery required would represent a substantial investment which could not be amortized on the basis of the production contract.

For Motorola to provide such equipment without sufficient production quantities to justify the acquisition, would indeed have been a poor business economy designed to frustrate any financially sound industrial organization. An additional survey of machinery requirements established the fact that the number and type of machine tools would be directly dependent upon the production quantities required by Sandia. To resolve these problems a conference was called on January 12, 1950, at Albuquerque. It was decided that Motorola would purchase the required machine tools in the event that the original contract between Motorola and the A.E.C. so provided. In the event that there was no previous agreement, Mr. P. J. Sturm would contact Mr. J. Robinson of the New York A.E.C. giving him a list of the equipment required. Mr. Robinson, in turn, would make arrangements for facilities. In the event that Mr. Robinson failed to do so by 3:00 P.M. Friday, January 13th, Motorola was authorized by Sandia to obtain the necessary facilities. It was also decided that production tools should be provided to meet a production rate of ten units per day. These decisions were confirmed in a memorandum written by W.F. Deitrich dated January 12, 1950.

The antenna design for production was nearly complete. Immediate plans included the procurement of the requisite material, machinery, dies, jigs, and fixtures for production.

The construction of the new building at Phoenix had been contemplated by Motorola for many months. Plans had been prepared for a research laboratory with maximum space allocated for the laboratory and model shop use. The building area was sufficiently large to provide for expansion as the laboratory requirements increased. The facility was particularly suited to the laboratory requirements for the ABEE contract. Because the plans were still on paper when the ABEE program assumed a role of increasing importance at the Phoenix Laboratory, modification of the plan could be effected to suit the requirements of the new work - especially the security requirements. It was merely a matter for the security officers of the AEC to specify the type of construction which would effect a class A building facility. The additional costs over and above the usual building costs would be paid by the AEC or other authorized agent. Because the security costs were a special or miscellaneous cost compared with the major items, development, pilot production, and production preparation, they were studied to ascertain that the expenditure would not have been made except for the security requirements of the ABEE program. To avoid possible later misunderstandings or misinterpretations, the New York AEC was informed of the security plans and progress. Occasional visits by security officials were assurance that the proper security measures would be included. The building construction proceeded at a very rapdi pace at the request of Motorola. The delivery schedules were sufficiently compressed that construction delays would seriously have handicapped the entire ABEE program. Perhaps it was the rapid progress that required major attention, leaving little or no time to ascertain that the myriad of details had received adequate attention. The result was that a few security expenditures were later subject to questions and correspondence concerning payment. For the greater portion of security expenditures, the personal and letter contacts effectively eliminated the element of misinterpretation. As soon as a security requirement was discussed, the solution was planned, a cost quotation obtained from a reliable source, and a letter request for authorization to purchase at the quotation price was mailed to the New York AEC. Occasionally an emergency, from the time schedule viewpoint, arose which required an immediate decision by telegram, teletype, or telephone. These business matters were later confirmed by letter or telegram. Security costs of production machinery were another item requiring careful judgement. Motorola purchased the necessary machinery which would be required in the normal course of activities at the Phoenix Laboratory. The production facilities at Chicago were considered. If similar machinery and equipment were required by the ABEE program - Motorola proceeded to procure these also. The additional machinery requirements were for the manufacture of parts which would be made by other manufacturers in the absence of security measures. In discussions with Sandia and the New York AEC, provisions were made for payment by the AEC of the costs to provide the necessary machinery.

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The decisions related to production machinery requirements were immediately carried out to avoid procurement delays. This activity became quite complicated. Production planning contemplated production of 200 ABEE units. This quantity was originally zero - 50 prototype equipments being the objective. So at the onset of the program the model shop requirements were compatible with the development program. Production planning commenced when an order for 200 production equipments was given to Motorola by the AEC. The quantity was later reduced to 100 units, production planning and preparation were accordingly modified. The number and types of machines was also dependent upon another factor not yet mentioned; production rate per day or week. The fact that the production rate was a consideration apart from the total quantities could easily be overlooked. Early estimates oscillated from two to ten a day. The actual quantities were not related to the desired total capacity because the present needs were for standby or stockpile use - to be available when needed. The desired total capacity of approximately ten equipments per day was the subject of many discussions which, while not specified in the AEC contract, represented the possible future requirements in the event of a National emergency.

Production pattersn, dies, jigs, and fixtures were also second with the approval of the New York AEC. While those costs in excess of $5000 required approval specified in the letter contract, the approval to purchase most of the required "tooling" was obtained through correspondence.

The above account of the authorization procedure is related in lieu of frequent elaborate references to items and prices which, it

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is believed, would add little to this account of the ABEE and ABEE Tester programs.

Other contract negotiations included the revised cost estimate dated January 27, 1950. This letter from Mr. G. R. MacDonald, vice president of Motorola, to the New York AEC, presented the current conception of the contract requirements and requested authorization to expand and obligate in excess of the existing $150,000. contract limitation. The following presents the contents of the contract letter:

"In accordance with your letter of January 23rd, which listed a change in requirements, we are submitting to you our revised estimated cost for the work to be performed under Contract No. AT(30-1)-677, for which we now have a Letter Contract, dated June 27, 1949, and Amendment No. 2, dated December 22, 1949. The letter Contract is now valid until February 28, 1950.

Our revised estimate now includes -

1. The change in Job I, Phase B from 200 to 100 units.

2. The estimated development cost for the antenna originally not included but made a Motorola responsibility as confirmed in the letter of D. E. Noble to your office, December 2, 1949.

3. Changes in machinery and tooling costs as a result of later information.

Your secret letter to contract No. AT(30-1)-677, dated June 27,1949, listed essentially two jobs to be included within the scope of the contract. Based on later elaboration through correspondence, the several conferences, and your latest letter of January 23rd, we now interpret the objective and scope of the contract as follows:

1. The design and development of ABEE units and the required associated test equipment. The complete ABEE system to be designed by Motorola following specifications, and now also including the antenna.

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2. The production on a pilot run basis of:

   a. 100 ABEE units, complete systems including the main unit, the dynamotor, the antenna and cable, junction box, control head, and other required accessories.

   b. 12 test equipment units.

3. The preparingfor production by establishing a complete production set-up for quantity production of the ABEE at 35 to 75 systems per week (latest information - 10 systems per day), and of the test equipment, 15 to 30 units per month. The preparation will consist primarily of:

   a. Plant rearrangment, production jigs and fixtures and production test equipment.
   b. Special production machinery for the fabrication of various component elements.
   c. Tooling for parts manufacture (purchased components).

A number of considerations form the basis for our cost estimate, the significant ones of which are enumerated below. Several are quoted in whole or part from our previous quotation of November 15, 1949.

1. Our program is based on following the target specifications established at the Phoenix conference, September 6th and 7th, and covered in notes of the conference, dated September 7th, of which your office has a copy. These target specifications were amended by the conference held at Albuquerque, October 6th, which is covered in complete detail in the letter of D.E. Noble to P.J. Larson, dated October 14th, 1949.

2. At the October 6th conference, it was emphasized and re-emphasized that "time is of the essence", and that every effort should be made to begin delivery as quickly as possible and that any retarding factors must be anticipated and overcome. We believe that we have a full cognizance of the importance of the program, as already illustrated by the accelerated effort at Phoenix, and have planned the entire program on a basis of "parallel operations", a term which was developed at Motorola during the war to designate such a schedule where the speed of project elements is increased and many phases done at the same time which normally would be done in sequence. Such an approach is effective, but does require increased effort and overtime, and does result in a higher cost than under normal operations.

3. The time schedule anticipated follows that covered in the target schedule in Mr. Noble's letter of October 14th to Mr. Larson, which indicated dates for prototype models, release of tooling,

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and finally the beginning of the production pilot run. It is hoped that the beginning of pilot production for the antenna can parallel the schedule for ABEE, but is must be remembered that the engineering did not become a Motorola responsibility until the last of November , and it is therefore not now possible to predict with certainty a schedule. However, every effort is being made to close the time gap. In the contract cost revision, antenna development is based on eight men for approximately six months, or 49 man-months, including engineers, draftsmen and model makers. In calculating the cost of 100 ABEE units instead of 200, we have cut the previous cost exactly in half, although there is much room for discussion, in that the cost for producing 100 would be more than 50% of the cost for 200. This and other costs have been prepared on a conservative basis, and have not been expanded in order to justify a higher fixed fee.

4. We have estimated the contract cost on the basis of a cost plus fixed fee contract. Based on the revisions and the information known at this time, we have arrived at a total estimated cost for the elements involving a fixed fee of $993,480.00, for which we propose a fixed fee of $70,000.00 making a total of $1,063,480.00. The fixed fee of $80,000.00 agreed to in the negotiation meeting, December 14th, has not been reduced exactly proportionately, because we believe that the fixed fee is intended to cover the entire project, and it is clear that engineering and development are the significant parts of this contract, and that the responsibility for executing the contract is not diminished in an amount proportional to the reduction in the quantity of the pilot run.

   You will understand, that with the parallel operations, the many factors remaining unknown, and the flexibility that is required, that our estimate represents the best cost figure that we can establish at this time. We quote the fixed fee as indicated, but do not believe that a contract ceiling price should be established.

5. In the production preparation costs, the estimated cost for plating equipment has been raised from $5,000 to $10,00 because of the new requirements which now include gold and bright alloys. In the tooling cost for ABEE, has been added $10,000 to provide for the antenna tooling, based on information now available that was not known at the time of the previous estimate.

6. The security costs have been increased by $7,000, based on the requirements covered at the conference in Phoenix, January 11th and confirmed by our letters of January 16th and 26th.

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7. Our estimated cost is outlined on the attached breakdown, including the various elements stated above, under contract objective. It will be noted that the design costs are based on the continuation of development even after the beginning of the 100 units, so that a continuing effort can be made to meet fully the target specifications.

We anticipate the continuing of development until February 1st, 1951, but the extent of the continuing development and the time schedule for it are of course subject to the desire of the Commission. The cost of 12 test equipment units is included in the development cost and is therefore not shown separately.

The production cost for the antenna is included in the production cost of ABEE, and it is not possible at this time to give a further breakdown. Until the pilot run is farther along, it will be difficult to forecast more accurately any of the production costs. As you know, our new building is being rushed to completion and production will be carried out there, approval for which has been covered by your letter of January 19th.

The letter contract in paragraph 4A established a ceiling of $150,000, beyond which we cannot expend or obligate without prior written approval of the Commission. Inasmuch as there may be some days elapse before this letter contract is converted to a definitive contract, we request your approval immediately to expend an obligate beyond the present limitation, so that we may continue the procurement of materials, machinery and tooling in readiness for the pilot run phase. With the urgent time schedule you will understand the need for relieving this present restriction.

We solicit your immediate consideration of this revised cost estimate, and with the contract negotiation already an accomplished fact, we suggest that it will be mutually desirable to convert to a definitive contract prior to the expiration of the present contract February 28, 1950."

The revised cost estimate was attached to the letter and is presented below:

"I. CONTRACT ELEMENTS INVOLVING FIXED FEE

A. Development			
1. ABEE- Material	35,000		
Labor	250,000		
Overhead - 30%	75,000	$360,000	
2. Test Equipment -			
Material	30,000		
Labor	150,000		
Overhead - 30%	45,000	225,000	
3. Antenna			
Material	10,000		
labor	22,000		
overhead - 30%	7,000	39,000	
Special Lab Test Equipment		30,000	
Total Development Cost:			$654,000

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B. Pilot Run Production			
1. ABEE - Unit Cost			
Material	2,250		
Labor	200		
Overhead - 125%	250	2,700	
Factory Cost - 100 units			270,000
C. Special Costs			
Travel		35,00	
Moving - 15 men		15,000	50,000
SUB-TOTAL			974,000
Administration - 2%			19,480
			993,480
Fixed Fee			70,000
			1,063,480

II CONTRACT ELEMENTS NOT INVOLVING FIXED FEE

A. Production Preparation			
1. Plant Rearrangement	10,000		
Production jigs-fixtures	10,000		
production test equipment	35,000	55,000	
2. Special Production Machinery			
Antenna	10,000		
RF unit	15,000		
Plating	10,000		
Fungiciding	1,000		
Pulse Transformer	2,000		
Miscellaneous	5,000	43,000	
Total Plant Preparation		98,000	
3. Tools			
ABEE and Antenna	75,000		
Tester	10,000	85,000	
Total production preparation:			183,000.
B. Security			
1. Guards' salaries	32,000		
2. Physical changes	27,000		59,000
			$242,000."

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Several conferences were initiated between the Sandia Corp. and Motorola on Jan. 11 and 12 for the approval of the expenditure of approximately $35,000 for purchase of machinery to be employed in the production of Abee in accordance with the earlier request of Mr. L. J. Biskner of the Production Engineering facility at the Sandia Corp. Motorola determined estimates of the number of man-hours the machines required and of the cost of machines which would be necessary to establish production of Abee at the rate of 3 a day and 10 a day respectively. These estimates are presented in tables 9 and 10.

On January 11, at the meeting between Mr. Biskner, Mr. Marker, and Mr. Sturm, these estimates were submitted for the consideration and approval of the Sandia Corp., and as a result were immediately brought to the attention of Mr. W. H. Pagenkopf of SLSM. Subsequent to an examination of these requirements by the various department heads of the Sandia Corp., the following proposal was submitted to Motorola as the procedure to be employed in the procurement of the necessary machinery and tools:

> Motorola would submit estimates from three vendors of the various machines and dies to the Sandia Corp. These quotations would be examined by the Sandia Corp., and approval of a specific vendor would then be forwarded to Motorola, to serve as authority to initiate purchase. Motorola would then proceed with the procurement and determine delivery such that the machines would be available in time to dove-tail with the production schedule.

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OPERATION	TIME (man hours)	MACHINES	COST
Milling, slotting etc.	16 hours (2 men)	2 hand mills	$3600.
		1 #2 B&S mill	4000.
Turning	64 hours (8 men)	4 13" S.B. lathes	7200.
		1 Hardinge high speed 2nd operation or screw mach.	1850.
		3 bench lathes	4500.
Drilling	2 hours	1 Bench drill press	150.
		1 Floor drill press	300.
Grinding	4 hours	1 Dumore grinding attachment	150.
		1 tool grinder	50.
		1 surface grinder	1500.
Sawing	4 hours (½ man)	1 power hack saw	400.
Silver Soldering	8 hours (1 man)	1 torch and rotating table	500.
	98 man hours		$24,200.

Table 9

Machinery Requirements to Produce parts manufactured by Motorola for Security Reasons only.

Production Rate: 3 ARE[illegible] equipments per day.

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OPERATION	TIME (man hours)	MACHINES	COST
Milling & slotting etc.	48 hours (6 men)	4 hand mills	7200
		2 B&S #2 mills	8000
Turning	48 hours (6 men)	3 Hardinge highspeed 2nd operation or screw mach.	4550
		1 #2 Warner Swazey turret lathe	6000
		2 13" S. Bend lathe	3600
Drilling	6 hours	1 bench drill press	150
		1 floor drill press	300
Sawing	8 hours (1 man)	power hack saw	400
Grinding	12 hours ($1\frac{1}{2}$ man)	2 Dumore grinding attachments	300
		1 tool grinder	50
		1 surface grinder	1500
Silver Soldering	16 hours (2 men)	Lindberg furnace	2000
	138 man hours		$34,050.

Table 10

Machinery Requirements to Produce Parts Manufactured by Motorola, for Security Reasons only.
Production Rate: 10 ABEE Equipments per day.

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After due consideration, the Sandia Corp. was informed by Motorola that since establishment of production facilities must necessarily adhere to the extremely rigid schedule which was established during the Oct. 1 conference, Motorola could not agree to this proposal unless it was mutually agreed that delivery dates would be relaxed. In the event of the delay in the purchase of the necessary machines, these delays would inevitably be introduced by the determination of formal quotations and the paper work involved in the submission and approval of the requirements.

A conference report was prepared by P.J. Sturm on January 14, 1950. The conference at Sandia with respect to tools, and equipment was reported by W. F. Dietrich on January 12, 1950. The following Sandia personnel were present:

H. D. Ross SLPA
W. F. Dietrich SLPB
W. H. Pagenkopf SLSM
L. J. Biskner SLPE
T. F. Marker SLE

Motorola personnel present included P.J. Sturm. The New York AEC was represented by George Bates.

Motorola representative, Mr. Sturm, had raised these problems with Sandia.

1. To comply with the security procedure they would require machine tools valued at $34,000 in their Phoenix plant.

2. Some rate of production should be established so as to determine what type of production tools would be required.

Conclusions reached were as follows:

1. If the original Motorola agreement with the AEC provided for Motorola purchasing machine tools, they would

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proceed accordingly.

2. If no previous arrangement on machine tools was made, Mr. Sturm would contact New York AEC, Mr. J. Robinson, giving him a list of equipment required. Mr. Robinson, in turn would make arrangements for facilities. In the event he fails to do so by 3 P.M. Friday, January 13, Motorola may proceed to obtain facilities.

3. Production tooling should be provided to meet a rate of 10 units per day."

Accordingly Mr. Robinson of the NY AEC was immediately informed of the agreement, and on the afternoon of January 13, a telephone conversation between Mr. J. Robinson and C. J. Russnak of Motorola brought to light that the AEC surplus pool could only provide two drill presses toward the fullfilment of the Motorola requirements. This decision was later confirmed, by telegram.

It was not possible during the conferences held on January 11 and 12 to establish the final figure for the total production quantites of Abee. Mr. Bismer of Sandia implied that production would not likely be less than 1000 and would probably be as high as 10,000. He indicated that production planning would probably be designed around the 10,000 total production figure. A production of ten equipments per day was judged to be the optimum rate which could be established at this time.

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The modulator pulse characteristics were measured to facilitate calculation of the transmitter peak power output. The average pulse width was determined by the sum of (1) the time duration of the "top" of the pulse (2) one-third of the pulse "rise" time, and (3) one-third of the pulse "fall" time. The typical measurement included 0.08 usec "rise" time, 0.175 usec duration at the "top" of the pulse, and 0.1 usec "fall" time. For this example the average pulse width was 0.235 microseconds. The scale pulse power output was then calculated from the relation:

$$Wp = \frac{Wa\ R}{T}$$

where

Wp = peak power in kilowatts

Wa = measured average power output

R = pulse recurrence frequency (1000 c.p.s.)

T = time duration of modulator pulse, microseconds (0.235).

The oscillator efficiency was determined according to the relation:

$$Eff. = \frac{Wp \times 1000}{EmIm} \times 100$$

Eff = transmitter efficiency, percent.

Em = amplitude of modulation pulse, volts

Im = amplitude of transmitter plate current during modulation, amps.

The transmitter impedance (load presented to the modulator) was determined by the relation:

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$$Z_t = \frac{E_m}{I_m}$$

Z_t = transmitter impedance, ohms

The above characteristics were determined many times during the

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course of ABEE development. During the early work, wide variations of these characteristics were observed, especially when different tubes of the same type were employed.

With the relationships presented above and other data obtained by laboratory measurements, the Table 11, Transmitter Characteristics, was recorded.

F_o, Transmitter Frequency, Mc/s	-150	-10	+170
E_b, Modulator Plate Voltage, Volts	1250	1250	1200
I_b, Modulator Plate Current, Ma.	8.5	8.5	8.5
E_m, Modulation Pulse Amplitude, Volts	5350	4500	5100
I_m, Transmitter Current Amplitude, Amps.	4.3	3.82	3.7
Z_t, Transmitter Impedance, Ohms	1240	1020	1350
W_m, Modulation Power Inputs(peak), Watts	24	19.8	18.9
W_o, Average Power Output, Ma.	1.0	0.9	1.0
W_p, Peak Power Output, KW.	4.25	3.82	4.25
E_{ff}, Efficiency, percent	17.7	19.2	22.5

Table 11

Transmitter Characteristics.

The frequencies of operation were megacycles plus or minus the mid-band frequency. The modulator input voltage was essentially constant. The transmitter output coupling was adjusted to extract approximately the maximum useful power output. The maximum available power output could not be obtained because increased coupling produced a voltage breakdown between the coupling probe and grid cylinder. The voltage applied to the transmitter was a high voltage pulse generated by the modulator. The transmitter current was a current pulse which occurred during modulation. The measurement technique is described elsewhere within these pages. The impedance, peak power output, and efficiency were calculated.

The transmitter impedance varied with frequency and power output. The tube impedance was lowest at the low frequency end of the band, a minimum with the lowest power output, and was also found to decrease as the output coupling was increased. The percent efficiency was included for information and in usual designs would be inversely poportional to frequency. The tube impedance figures were for a randomly selected Machlett type 2C39 tube. The actual impedance was a variable dependent upon (1) the manufacturer and (2) the serial number as well as by the adjustment and applied voltages. While the above impedance figures were for a constant (nearly optimum) load, it was interesting to note later that the impedance varied with the voltage standing wave ratio (a measure of degree of mismatch), the lower the VSWR the higher the tube impedance.

The transmitter impedance was measured using several Machlett 2C39 tubes. It was also desired to determine the frequency pull with a VSWR=2. The transmitter was operated at the high end of the band. Because there was a tendency for the tubes to operate at different frequencies (due to differences in interelectrode capacitances) an adjustable grid cylinder was used to adjust the operating frequency to within ± 5 mc/s for each tube tested. The cathode choke was adjusted to effect maximum power output in each case. The output coupling was constant. Table 12 presents the data obtained.

E_b	I_b	E_m	I_m	W_m	Z_t	W_o Min.	W_o Max.	Frequency Pull, mc/s	Tube Serial Number
1250	8.5	5360	3.8	20.4	1410	.765	1.19	2.0	58PI
1250	9.0	4380	4.82	21.1	910	.595	1.10	0.5	26PU
1250	8.7	4300	5.0	21.5	860	.72	1.15	0.75	16PT
1250	8.8	4600	4.8	22.0	960	1.04	1.78	1.5	41PI
1250	8.8	4400	4.64	20.4	950	.72	.98	1.5	53PP
1250	9.0	4280	4.9	20.9	875	.64	1.06	0.5	24PT
1250	8.8	4400	4.9	21.7	910	.98	1.61	1.5	43PI
1250	8.8	4350	4.94	21.5	880	.72	1.15	1.0	34PU
1250	9.0	4100	4.94	20.3	830	.64	1.27	1.0	21PT

Table 12

Transmitter Impedance and Frequency Pull for several Machlett 2C39 tubes (VSWR=2)

These facts may be recorded from the information contained in Table 12. The impedance variation was from 830 to 1410, a range of 580 ohms. The average frequency pull was approximately 1 mc/s.

The maximum frequency pull, 2 mc/s, was identical to the limits established as a desirable target specification. The power output was lower than that obtained later; the variation was attributable to the extreme values of reactance which could be encountered during operations at the test frequency.

A transmitter cavity of optimum design was tested using a Machlett 2C39 tube. The power output as a function of frequency within the 200 megacycle range was determined. The peak power output varied from a maximum of 3.25 kilowatts at the lowest frequency to 1.45 KW at the highest frequency. The output coupling was adjusted to produce optimum output with a matched load (VSWR = 1.1:1) at the low frequency. A greater output could have been obtained at the highest frequency by increasing the output coupling. The frequency change obtainable by adjusting the cathode choke position was determined between the half power points. A frequency change of 13.5 mc was obtained at the lowest frequency. A greater frequency change, 27 mc, was obtained at the high frequency end of the band.

The transmitter frequency drift after the application of modulation (filament current previously stabilized) was studied frequently throughout the transmitter development. The problem did not atfirst appear to be serious - as it was later determined to be. The reason was that attention was focused upon other factors of great importance; tube impedance, effect of stabilized or unstabilized modulation and filament power, effect of antenna and transmission line mismatch (VSWR) power output, and other factors pertinent to optimum oscillator design. Early drift measurements indicated a change of 1.0 megacycles which was excellent. There was no doubt that the tubes tested were either superior by chance selection or that in use the tubes had been aged which effected a greater than normal stability.

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The drift characteristics of a Machlett 2C39 were studied during the last part of December. The air current flow, generated by a blower, was directed against the plate end of the cavity. Within one minute after the application of modulation, the frequency had stabilized one megacycle lower than the initial frequency. The cooling effect of the blower was removed. Within 24 minutes the operating frequency had decreased 5.0 megacycles. Because the intended operation time of ATEE was short, this was not considered a serious factor. The effects of ambient temperature changes, determined later, presented a serious problem.

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