| AD NUMBER |
| --- |
| **AD148378** |
| LIMITATION CHANGES |
| TO:<br>**Approved for public release; distribution is unlimited.** |
| FROM:<br>**Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 30 SEP 1957. Other requests shall be referred to Office of Naval Research, Arlington, VA 22203.** |
| AUTHORITY |
| **ONR ltr 28 Jul 1977** |

# CHABA

## MEMORANDUM REPORT No. 4

SEPTEMBER 1957

# INSTRUMENTATION FOR THE MEASUREMENT AND GENERATION OF HIGH INTENSITY SOUND

Technical Report No. 1[illegible]
to the Office of Naval Research
from the Central Institute for the Deaf
Contract No. Nonr 1151 (01), NR 140-[illegible]

CHABA

MEMORANDUM REPORT NO. 4

# INSTRUMENTATION FOR THE MEASUREMENT AND GENERATION OF HIGH INTENSITY SOUND

Prepared by Working Group No. 29

L. L. Beranek, Chairman
J. K. Hilliard
E. Klein
I. Rudnick
V. Salmon
H. E. von Gierke (Alternate)
G. W. Kamperman (Technical Aide)

September, 1957

ARMED FORCES-NATIONAL RESEARCH COUNCIL
COMMITTEE ON HEARING AND BIO-ACOUSTICS

Office of the Executive Secretary
Central Institute for the Deaf
818 South Kingshighway
St. Louis 10, Missouri

Technical Report No. 14
to the Office of Naval Research
Contract No. Nonr-1151 (01), NR 140-069

## FOREWORD

There have been many recurring questions about the capabilities and the availability of instruments for measurement and for generation of noise at sound pressure levels in excess of 130 db. Considerable information exists, but it is scattered through the scientific literature and special commercial and military reports. This Memorandum Report attempts to compile some of this information.

This report does not attempt to recommend particular instruments for each of the many uses that are possible. The combinations of requirements which must be met for many measurement tasks are too complex for simple tabulation. The report does include the specifications and performance data which the user generally needs in order to select the most suitable instrument. The user must first know the requirements for his particular task and then choose accordingly.

Since this field of instrumentation is developing rapidly, a report of this kind is soon obsolete or incomplete and it should be revised or supplemented from time to time. Also, there may remain inadvertent omissions in spite of the many organizations solicited by the Working Group. CHABA members and other interested readers are invited to inform the Executive Secretary of any omissions or new developments.

The appended contributions by vendors have greatly simplified the task of preparing this report and they are gratefully acknowledged. However, CHABA is not responsible for the accuracy of the information thus supplied.

D. H. Eldredge
Technical Advisor,
CHABA

## Distribution

This report has been distributed to members of CHABA, to contributors to the report, and to a list of addressees supplied by the ONR Scientific Officer for this Contract. Others desiring facsimile copies of the report should address their requests to:

Office of Technical Services
Technical Information Branch
Department of Commerce
Washington, D. C.

Qualified requesters may obtain copies from:

ASTIA Document Service Center
Knott Building
Dayton 2, Ohio

# THE PROBLEM

The CHABA Council at its meeting on 31 October 1956 voted to establish Working Group No. 29 to survey the present state of instrumentation for the measurement and generation of high intensity sound.

There are many research and development groups in the Armed Forces, government laboratories, universities and industry using instruments to measure and to generate high intensity sound (above 130 db). The sources being measured include all forms of jet propulsion, recoilless weapons, machine guns, artillery, and shock waves from nuclear weapons. Conventional sound level meters are usually not adequate for these purposes and special instrumentation is necessary. In some instances the instrumentation is being used carefully; in others, sound levels of 200 db are being reported without further qualification.

It is the purpose of this report to give detailed specifications describing the performance characteristics of commercially available microphones designed to measure high intensity sound. High intensity sound generators are also included in this report since they are used to calibrate special microphones, to investigate fatigue of materials, to study human reactions, etc.

The Council requested that this report include:

(a) A list of commercially available microphones suitable for the measurement of high intensity sound, with an indication of the performance specifications and limitations of each instrument.

(b) A similar list of high intensity sound sources.

(c) A list of needs for additional instrumentation for the measurement and generation of high intensity sound.

(d) A list of special devices that may exist but which are not commercially available.

It was emphasized that the Working Group should operate rapidly and should submit a report, even though it might be incomplete. Early availability of the information was deemed more important than detailed completeness. It was emphasized that omissions in or corrections to the report could be made at a later time.

THE REPORT

INSTRUMENTATION FOR

THE MEASUREMENT AND GENERATION OF

HIGH INTENSITY SOUND

15 September 1957

1. Method of Soliciting Information

Letters were addressed to about 70 institutions and companies known by members of the Working Group to be interested or active in the field of high intensity sound. A list of 48 organizations that replied to these letters of solicitation, including the names and addresses of the organizations and the person signing the letter, is given in Appendix A.

2. Microphones for the Measurement of High Intensity Sound

The nature of the instrumentation necessary for the measurement of high intensity sound depends upon the particular problem being studied. This Section does not attempt to discuss complete sound analyzing systems. Its scope is limited to the characteristics of high intensity microphones. Generally speaking, it is not necessary to expose the sound analyzing system to environments as adverse as those to which the microphone must be exposed. On the other hand, the microphone is always exposed to the environments present in the areas where measurements are performed. Not infrequently these environments may involve wide fluctuations or high levels, or both, in temperature, wind velocity, vibration, moisture and static pressure.

A list of the high intensity microphones, as compiled from the replies to the circular letter, is given in Table I. This table presents two kinds of information:

(a) a summary of the pertinent data supplied by the manufacturers of the various microphones; and

(b) data taken in the laboratories of Bolt, Beranek and Newman, Inc. by the Technical Aide to this Working Group for the purpose of rounding out the total information.

It is believed by the Working Group that the data in this table are typical of the behavior of a given type of microphone. The characteristics of each particular microphone of any one type may vary from the data shown in Table I. The amounts of these variations are not indicated. The Working Group wishes to warn the users of this table that the characteristics of any microphone must be checked from time to time to ascertain its long term stability.

With some instruments, it is necessary to check the sensitivity and frequency response of the microphones before and after each use. If the microphone is to be used within 20 db of its rated maximum linearity range, it is advised that its linearity be examined. Some of the sound sources described in the last section of this report may be used for checking the linearity range of microphones. In addition, a small standing wave tube and pistonphone are currently being used by several laboratories to measure linearity. Microphones that are exposed to wide variations in temperature during a measuring program should be tested to determine their stability over that temperature range. Unfortunately because of the difficulties of making the measurement, very little field experience or laboratory data have been reported in regard to microphone stability as a function of temperature.

Appendix B of this report contains literature supplied by the manufacturers of some of the microphones shown in Table I.

A recent report prepared by J. K. Hilliard and presented at the General Electric Industrial Acoustics Symposium, 7 February 1957, is included in Appendix C of this report. It is entitled, Part I, "Condenser Microphones for Measurements of High Sound Pressures," and Part II, "Generation of High Intensity Sound Using Loudspeakers." Copies of this report were supplied by Altec Lansing Corporation.

## 3. Sources for the Generation of High Intensity Sound

The malfunction of structures and electronic components in high intensity sound has motivated many groups to devise methods for generating high intensity sound in the laboratory. Some of the pertinent information describing these various test facilities is outlined in Table II. Both broad band and pure tone sound sources are available. The sound is generated by a wide variety of mechanisms. The highest sound pressure levels (between 170 and 180 db) are obtained with sirens. Broad band noise with a maximum sound pressure level between 160 and 170 db can be found in the near field of large jet and rocket engines. Loudspeaker systems are currently being used to generate lower sound pressure levels.

A recent report presented by K. R. Jackman of Convair at the IAS National Summer Meeting, June 17-20, 1957, describes several of the high intensity sound generating sources that are listed in Table II. It is entitled "New Sonic Test Environments and Facilities." Convair, Pomona Division, has made this report available to the Working Group, and a copy is appended herewith in full without editing or detailed review. It illustrates many, if not all, of the new sonic test facilities and the manner of use of many of the specific microphones and sound sources considered in the body of the present report.

## 4. Instrumentation for the Measurement and Generation of High Intensity Sound

Very little information on the need for improved instrumentation was obtained from those participating in this survey. A brief list of the nature of these responses is given in Table III.

## 5. Acknowledgment

The Working Group wishes to acknowledge the assistance of all of those who supplied information contained in this report. It especially wishes to thank George W. Kamperman, the Technical Aide, for compiling the information and for obtaining additional data as indicated in Table I.

# TABLE I - MICROPHONES

| MANUFACTURER | MODEL NUMBER | TYPE OF TRANSDUCER | OPEN CIRCUIT SENSITIVITY in decibels re 1 volt re 1 µbar | MAXIMUM POSITIVE PRESSURE LEVEL in db re .0002 µbar for LINEAR RESPONSE | MAXIMUM POSITIVE PRESSURE LEVEL in db re .0002 µbar WITHOUT DAMAGE | OPERATIN[G] TEMPERAT[URE] RANGE in degrees |
|---|---|---|---|---|---|---|
| Altec Lansing Corp. | 21BR150 | Condenser | - 60 | 160* | 175 | * The micr[o]phone wi[ll] operate <-50° to Max. Temp. fo[r] Pre-Amp. |
| Altec Lansing Corp. | 21BR180 | Condenser | - 70 | 170* | 185 | |
| Altec Lansing Corp. | 21BR200 | Condenser | - 90 | 190* | 205 | |
| Altec Lansing Corp. | 21BR220 | Condenser | -110 | 210* | 225 | |
| Altec Lansing Corp. | 6117 Probe | Condenser | - 75 | 170* | 185 | |
| Altec Lansing Corp. | 21BR180 Pin Hole | Condenser | - 70 | 170* | 185 | |
| Altec Lansing Corp. | 21BR180-5 Flush Mount | Condenser | - 70 | 170* | 185 | |
| Atlantic Research Corp. | BC-10 | Barium Titanate Cylinder | -117 | 230 | 250 | 0 to + |
| Atlantic Research Corp. | BC-30 | | -111 | 230 | 250 | 0 to + |
| Atlantic Research Corp. | LC-60 | Zirconate | -112 | 230 | 250 | -40 to + |
| Atlantic Research Corp. | LC-33 | Zirconate | -105 | 225 | 230 | -40 to + |
| Atlantic Research Corp. | BD-10 | Barium Titanate Discs | -111 | 230 | 250 | 0 to + |
| Atlantic Research Corp. | BD-30 | | -111 | 230 | 250 | 0 to + |
| C.E.C. | 4-340 | Electrokinetic | -107 | 211 | | -10 to + |
| Endevco Corp. | 2503 | Piezo-Electric | -125 | 191 | 230 | -30 to + |
| Gulton Industries Inc. | P600 | Ceramic Sphere | -106 | >168 | | <160 |
| Gulton Industries Inc. | KTP900 | Ceramic Disc | -101 | >180 | 186 | -65 to + |
| Massa Laboratories | M-141 | ADP Crystal | -106 | >200 | 230 | -40 to |
| Massa Laboratories | M-125 | | - 93 | | 230 | |
| Massa Laboratories | M-213 | | -102 | | 244 | |
| Massa Laboratories | M-214, M-215 | | - 98 | | 244 | |
| Photocon Research Products | 320 | Condenser Microphone Plus Carrier System | - 88 | 190 | 220 | -50 to |
| Photocon Research Products | 374 | | - 77 | 180 | 200 | |
| Photocon Research Products | 364 | | - 57 | 160 | 180 | |
| Photocon Research Products | 354 | | - 37 | 140 | 160 | |
| Statham Laboratories Inc. | PG132TC-15-350 | Straingage | -154 | 194 | 200 | -65 to |
| Western Electric | 640AA | Condenser | - 50 | 155* | | <-40 to> |

# TABLE I MICROPHONES FOR THE MEASUREMENT OF HIGH INTENSITY SOUND

| F CER | OPEN CIRCUIT SENSITIVITY in decibels re 1 volt re 1 μbar | MAXIMUM POSITIVE PRESSURE LEVEL in db re .0002 μbar for LINEAR RESPONSE | MAXIMUM POSITIVE PRESSURE LEVEL in db re .0002 μbar WITHOUT DAMAGE | OPERATING TEMPERATURE RANGE in degrees F | FREQUENCY RESPONSE RANGE in CPS Free Field Random Incidence Response ± 3 db | FREQUENCY RESPONSE RANGE in CPS Pressure Response ± 3 db | ACCELERATION RESPONSE in Equivalent Sound Pressure LEVEL for 1 g Excitation | STABILITY of SENSITIVITY over Specified Temperature Range | MICROPHONE With FLUSH MOUNTED SENSING ELEMENT | OPERAT in the PRESEN of HIGH HUMIDI |
|---|---|---|---|---|---|---|---|---|---|---|
| er | - 60 | 160* | 175 | * The micro- | 10-12,000 | 10-12,000 | 100 ** | ± 5 db** | No | |
| er | - 70 | 170* | 185 | phone will | 10-14,000 | 10-14,000 | 107 ** | | No | |
| er | - 90 | 190* | 205 | operate | 10-16,000 | 10-16,000 | 105 ** | ±1 db** | No | No |
| er | -110 | 210* | 225 | <-50° to 500° | 10-16,000 | 10-16,000 | 109 ** | | No | |
| er | - 75 | 170* | 185 | Max. | 10-10,000 | 10-10,000 | 107 ** | | Yes | |
| er | - 70 | 170* | 185 | Temp. for | 10- 8,000 | 10- 8,000 | 107 ** | | Yes | |
| er | - 70 | 170* | 185 | Pre-Amp. 150° | 10- 8,000 | 10- 8,000 | 107 ** | | Yes | |
| Titanate | -117 | 230 | 250 | 0 to +194 | 1- 5,000 | 1-75,000 | 130 ** | ± 3 db | No | |
| nder | -111 | 230 | 250 | 0 to +194 | 1- 2,500 | 1-40,000 | 145 ** | ± 3 db | No | |
| te | -112 | 230 | 250 | -40 to +210 | 1-15,000 | 1-50,000 | 134 ** | ± 0.5 db to | Yes | Yes |
| te | -105 | 225 | 230 | -40 to +210 | 1-10,000 | 1-80,000 | | 175° F | No | |
| Titanate | -111 | 230 | 250 | 0 to +194 | 1-20,000 | 1-20,000 | 138 ** | ± 3 db | Yes | |
| scs | -111 | 230 | 250 | 0 to +194 | 1-10,000 | 1-15,000 | | ± 3 db | Yes | |
| okinetic | -107 | 211 | | -10 to +140 | 3- 2,000 | 3-25,000 | 130 | ± 0.5 db | No | Yes |
| Electric | -125 | 191 | 230 | -30 to +230 | 2-10,000 | 2-10,000 | 125 | ± 1 db | Yes | Yes |
| c Sphere | -106 | >168 | | <160 | 10- 6,000** | | 140 | | No | Yes |
| c Disc | -101 | >180 | 186 | -65 to +350 | 30-10,000 | 30->10,000 | 144 | ± 1 db | Yes | |
| | -106 | >200 | 230 | -40 to +160 | 20-15,000 | 20-35,000 | 138 ** | ± 0.25 db | Yes | |
| ystal | - 93 | | 230 | | 20-15,000 | 20-35,000 | | ± 0.25 db | Yes | |
| | -102 | | 244 | | 20-40,000 | 20-125,000 | 140 ** | ± 0.25 db | Yes | Yes |
| | - 98 | | 244 | | 20-30,000 | 20-80,000 | 140 ** | ± 0.25 db | Yes | |
| | - 88 | 190 | 220 | -50 to +400 | 0-12,000 | 0-12,000 | 135 ** | Very stable | Yes | |
| ser | - 77 | 180 | 200 | | 0-12,000 | 0-12,000 | | if water | No | Yes |
| hone | - 57 | 160 | 180 | | 0-10,000 | 0-10,000 | 84 ** | cooling | No | |
| arrier tem | - 37 | 140 | 160 | | 0- 2,500 | 0- 2,500 | 96 ** | feature used | No | |
| gage | -154 | 194 | 200 | -65 to +400 | 0- 6,000 | 0- 6,000 | 124 | ± 0.5 db | Yes | Yes |
| ser | - 50 | 155* | | <-40 to >200 | 1-10,000 | 1-15,000 | 92 ** | ± 1.5 db | No | No |

** Data from Bolt, Beranek and Newman, Inc.

***We
Ty

## PHONES FOR THE MEASUREMENT OF HIGH INTENSITY SOUND

| OPERATING TEMPERATURE RANGE in degrees F | FREQUENCY RESPONSE RANGE in CPS Free Field Random Incidence Response ± 3 db | FREQUENCY RESPONSE RANGE in CPS Pressure Response ± 3 db | ACCELERATION RESPONSE in Equivalent Sound Pressure LEVEL for 1 g Excitation | STABILITY of SENSITIVITY over Specified Temperature Range | MICROPHONE With FLUSH MOUNTED SENSING ELEMENT | OPERATION in the PRESENSE of HIGH HUMIDITY | INTERNAL IMPEDANCE | MODEL NUMBER of MICROPHONE PRE-AMPLIFIER |
|---|---|---|---|---|---|---|---|---|
| * The micro- | 10-12,000 | 10-12,000 | 100 ** | ± 5 db** | No | | | M-14 |
| phone will | 10-14,000 | 10-14,000 | 107 ** | | No | | | System |
| operate | 10-16,000 | 10-16,000 | 105 ** | ±1 db** | No | No | | Pre-Amp |
| <-50° to 500° | 10-16,000 | 10-16,000 | 109 ** | | No | | 6 μμf. | and |
| Max. | 10-10,000 | 10-10,000 | 107 ** | | Yes | | | Power |
| Temp. for | 10- 8,000 | 10- 8,000 | 107 ** | | Yes | | | Supply |
| Pre-Amp. 150° | 10- 8,000 | 10- 8,000 | 107 ** | | Yes | | | |
| 0 to +194 | 1- 5,000 | 1-75,000 | 130 ** | ± 3 db | No | | 6,000 μμf. | |
| 0 to +194 | 1- 2,500 | 1-40,000 | 145 ** | ± 3 db | No | | 8,000 μμf. | |
| -40 to +210 | 1-15,000 | 1-50,000 | 134 ** | ± 0.5 db to | Yes | Yes | 2,000 μμf. | 104 |
| -40 to +210 | 1-10,000 | 1-80,000 | | 175° F | No | | 2,500 μμf. | |
| 0 to +194 | 1-20,000 | 1-20,000 | 138 ** | ± 3 db | Yes | | 500 μμf. | |
| 0 to +194 | 1-10,000 | 1-15,000 | | ± 3 db | Yes | | 3,000 μμf. | |
| -10 to +140 | 3- 2,000 | 3-25,000 | 130 | ± 0.5 db | No | Yes | 100K Ohm | |
| -30 to +230 | 2-10,000 | 2-10,000 | 125 | ± 1 db | Yes | Yes | 400 μμf. | 2608 |
| <160 | 10- 6,000** | | 140 | | No | Yes | 400 μμf. | |
| -65 to +350 | 30-10,000 | 30-10,000 | 144 | ± 1 db | Yes | | Pre-Amp out | KTP 900 |
| -40 to +160 | 20-15,000 | 20-35,000 | 138 ** | ± 0.25 db | Yes | | 500 μμf. | |
| | 20-15,000 | 20-35,000 | | ± 0.25 db | Yes | | 120 μμf. | |
| | 20-40,000 | 20-125,000 | 140 ** | ± 0.25 db | Yes | Yes | 12 μμf. | M- 114B |
| | 20-30,000 | 20-80,000 | 140 ** | ± 0.25 db | Yes | | 18 μμf. | |
| | 0-12,000 | 0-12,000 | 135 ** | Very stable | Yes | | 3,500 Ohm | DG -400 |
| -50 to +400 | 0-12,000 | 0-12,000 | | if water | No | Yes | Out of | DG -500 |
| | 0-10,000 | 0-10,000 | 84 ** | cooling | No | | DG-400 | DG -600 |
| | 0- 2,500 | 0- 2,500 | 96 ** | feature used | No | | | Dynage |
| -65 to +400 | 0- 6,000 | 0- 6,000 | 124 | ± 0.5 db | Yes | Yes | 350 Ohm | |
| <-40 to >200 | 1-10,000 | 1-15,000 | 92 ** | ± 1.5 db | No | No | 50 μμf. | *** |

** Data from Bolt, Beranek and Newman, Inc.

***Western Electro-Acoustic Laboratory Type 130A, 120A, 100D

3

TABLE II SOURCES FOR THE

| LABORATORY OR MANUFACTURER Using or Producing Sound Source | TITLE OF SOUND SOURCE | TYPE OF TRANSDUCER | MAXIMUM SOUND PRESSURE LEVEL in db re .0002 μbar | ACOUSTIC POWER in WATTS | INP POW in WAT |
|---|---|---|---|---|---|
| Altec Lansing Corp. | Unsymmetrical Chamber | Loudspeakers | 156 at 1KC | | 80 |
| Altec Lansing Corp. | Plane Wave Tubes | Loudspeakers | 160 at 1KC | | 25 |
| Bell Aircraft-Buffalo | Resonant Sound Chambers | Loudspeakers | 160 | | |
| Convair-Fort Worth | Random Noise | Jet Engine | 168 | | |
| Convair-Fort Worth | Random Noise | Air Jet | 154 | | |
| Convair-Fort Worth | Siren | Siren | 153 | | |
| Convair-Fort Worth | Siren | Siren | 170 | | |
| Convair-Pomona | Plane Wave Tube | Loudspeakers | 140 | 30 | 260 |
| Convair-San Diego | Siren | Siren | 171 | | |
| Douglas Aircraft Co. | Santa Monica Siren | Siren | 162 | | |
| General Electric | Random Noise Chamber | Loudspeakers | 135 | | 100 |
| General Electric | Dyna-Jet | Toy Pulse Jet | | 200 | |
| Gulton Industries Inc. | RB Whistle | Air Whistle | 140 | | |
| Martin Co. | Siren on 30" Exponential Horn | Siren | 150-160 | 1,600 | |
| NACA-Langley Field | Siren | Siren | 160 | | |
| NACA-Langley Field | Air Jet | Air Jet | 155 | | |
| Northrop Aircraft Co. | 130db Interim Chamber | Loudspeakers | 130 | | |
| Penn State | Siren | Siren | 178 | 2,500 | |
| RCA-Camden | Large Chamber | Loudspeakers | 145 | | 4,000 |
| RCA-Camden | Small Chamber | Loudspeakers | 145 | | 350 |
| Rotatest Laboratory | Inverse Exponential Horn | Loudspeakers | 150 | 40 | 400 |
| Stanford Research Inst. | Air Modulated Horn | Air Modulated Horn | 165 | 100 | 10 ; |
| Soundrive Engine Company | High Energy Siren | Siren | 180 | | |
| Soundrive Engine Company | Turbojet Engine | J-34 | | | |
| Western Electro-Acoustic Lab. | High Intensity Sound System | Loudspeakers | 130 | | |

1

**TABLE II** SOURCES FOR THE GENERATION OF HIGH INTENSITY SOUND

| | TYPE OF TRANSDUCER | MAXIMUM SOUND PRESSURE LEVEL in db re .0002 μbar | ACOUSTIC POWER in WATTS | INPUT POWER in WATTS | FREQUENCY RANGE in CPS for 5 db Output | TEST ROOM VOLUME in Cubic Feet | CROSS SECTIONAL AREA of TEST SECTION in Sq. Ft. | SYSTEM MANUFACTURED FOR SALE | |
|---|---|---|---|---|---|---|---|---|---|
| amber | Loudspeakers | 156 at 1KC | | 800 | 100-5,000 | 8 | | Yes | 4 Altec 290 |
| | Loudspeakers | 160 at 1KC | | 250-500 | 100-5,000 | | | Yes | 1" to 4" di |
| hambers | Loudspeakers | 160 | | | | | | No | Resonant Tu |
| | Jet Engine | 168 | | | | | | No | J-57, J-79 |
| | Air Jet | 154 | | | | | | No | Convergent |
| | Siren | 153 | | | | | | No | |
| | Siren | 170 | | | | | | No | |
| | Loudspeakers | 140 | 30 | 260 | 100-6,000 | 50 | 3.14 | No | 16' Tube 2' |
| | Siren | 171 | | | 100- 500 | | | No | 3 PSIG Air |
| en | Siren | 162 | | | 500-1,000 | | | No | 4000 CFM at |
| mber | Loudspeakers | 135 | | 100 | 100-5,000 | 15 | | No | 5 Jim Lansi |
| | Toy Pulse Jet | | 200 | | | | | Yes | Pulse Jet b |
| | Air Whistle | 140 | | | one tone | | | Yes | 40-75 PSIG |
| onential Horn | Siren | 150-160 | 1,600 | | 100-4,000 | 610 | 40 | No | Air Supply |
| | Siren | 160 | | | 100- 500 | | | No | 2" Air Line |
| | Air Jet | 155 | | | | | | No | 100 lbs/sec |
| hamber | Loudspeakers | 130 | | | 60-3,000 | 100 | | No | 2 Universit |
| | Siren | 178 | 2,500 | | 3KC- 34KC | | | No | Required Ai |
| | Loudspeakers | 145 | | 4,000 | 30-8,500 | 27 | 4.5 | Yes | 48 Loudspea |
| | Loudspeakers | 145 | | 350 | 30-8,500 | 1 | .5 | Yes | 4 Loudspeak |
| tial Horn | Loudspeakers | 150 | 40 | 400 | 50- 10KC | 1.5 | .45 | Yes | 40"x40" Ho |
| orn | Air Modulated Horn | 165 | 100 | 10 ; 700* | 50-4,000 | 1,000 | | Yes | *Power in: |
| en | Siren | 180 | | | | | 1.0 | No | 180 db SPL |
| | J-34 | | | | | | | No | |
| Sound System | Loudspeakers | 130 | | | | 1,000 | | Yes | |

2

## THE GENERATION OF HIGH INTENSITY SOUND

| INPUT POWER in WATTS | FREQUENCY RANGE in CPS for 5 db Output | TEST ROOM VOLUME in Cubic Feet | CROSS SECTIONAL AREA of TEST SECTION in Sq. Ft. | SYSTEM MANUFACTURED FOR SALE | REMARKS |
|---|---|---|---|---|---|
| 800 | 100-5,000 | 8 | | Yes | 4 Altec 290C Drivers & 4 Altec 515 units |
| 250-500 | 100-5,000 | | | Yes | 1" to 4" diameter Tubes with 2 to 4 Altec 290C units |
| | | | | No | Resonant Tubes 2.4", 4" and 16" in diameter |
| | | | | No | J-57, J-79 Jet Engines |
| | | | | No | Convergent Air Nozzles, pres. ratio 2.5:1, Air 400 lbs/min |
| | | | | No | |
| | | | | No | |
| 260 | 100-6,000 | 50 | 3.14 | No | 16' Tube 2'diameter, Altec #515,802C,288B,290C units. |
| | 100- 500 | | | No | 3 PSIG Air |
| | 500-1,000 | | | No | 4000 CFM at 5 PSIG |
| 100 | 100-5,000 | 15 | | No | 5 Jim Lansing D123 Speakers |
| | | | | Yes | Pulse Jet by Curtis Automotive Devices Inc. |
| | one tone | | | Yes | 40-75 PSIG Air; Freq. set by Mfg. between 3KC-40KC |
| | 100-4,000 | 610 | 40 | No | Air Supply is 100 PSIG |
| | 100- 500 | | | No | 2" Air Line at 100 PSIG |
| | | | | No | 100 lbs/sec. of air through 12" nozzle |
| | 60-3,000 | 100 | | No | 2 University 315 Speakers |
| | 3KC- 34KC | | | No | Required Air Supply of 15 PSIG |
| 4,000 | 30-8,500 | 27 | 4.5 | Yes | 48 Loudspeakers |
| 350 | 30-8,500 | 1 | .5 | Yes | 4 Loudspeakers |
| 400 | 50- 10KC | 1.5 | .45 | Yes | 40"x40" Horn opening to 8"x8" opening |
| 10 ; 700* | 50-4,000 | 1,000 | | Yes | *Power in: 10 watts elect., 700 watts pneumatic. |
| | | | 1.0 | No | 180 db SPL in one $ft^2$. duct. |
| | | | | No | |
| | | 1,000 | | Yes | |

TABLE III

AREAS SUGGESTED BY RESEARCH PERSONNEL AS NEEDING IMPROVED INSTRUMENTATION

| ORGANIZATION STATING THE NEED | PRESSURE SENSITIVE MICROPHONE for the measurement of High Intensity Noise | PRESSURE SENSITIVE MICROPHONE for the measurement of Boundary Layer Noise | MICROPHONE for measuring Sound Intensity | MEANS FOR CALIBRATING sound measuring instruments in the presence of High-Intensity Noise | HIGH-INTENSITY SOUND SOURCE: Random Noise and Pure Tones |
|---|---|---|---|---|---|
| Armour Research Foundation | | | X | | |
| Boeing Aircraft Company | X | | | | X |
| Bolt, Beranek and Newman, Inc | X | X | X | | |
| Convair-Fort Worth | | | | X | X |
| Convair-San Diego | X | | | | |
| NACA, Langley Field | X | | | | |
| New York Naval Shipyard | X | | | | |
| Stanford Research Institute | | X | | | |

## APPENDIX A

### Organizations Replying to the Letter of Inquiry

The following organizations answered the letter soliciting information on the present state of instrumentation for the generation and measurement of high intensity sound.

| Organization | Individual Answering |
| --- | --- |
| Altec Lansing Corporation<br>9356 Santa Monica Blvd.<br>Beverly Hills, California | Dr. John Hilliard |
| Armour Research Foundation<br>Technology Center<br>Chicago 6, Illinois | Dr. R. W. Benson |
| Army Medical Research Laboratory<br>Fort Knox<br>Kentucky | Capt. John L. Fletcher |
| Atlantic Research Corporation<br>901 N. Columbia Street<br>Alexandria, Virginia | Mr. George C. Pierce |
| Bell Telephone Laboratories<br>Whippany<br>New Jersey | Mr. M. D. Fagen |
| Bendix Aviation Corp.<br>Eclipse Pioneer Division<br>Teterboro, New Jersey | Mr. James E. Bevins |
| Bendix Aviation Corporation<br>Red Bank Division<br>Eatontown, New Jersey | Mr. Carroll S. Townsend |
| Boeing Aircraft Company<br>Seattle 14<br>Washington | Dr. Karl Martinez |
| Bolt Beranek and Newman<br>50 Moulton Street<br>Cambridge 38, Mass. | Mr. George W. Kamperman |
| Brush Electronics<br>3405 Perkins Avenue<br>Cleveland 14, Ohio | Mr. James Day |
| Bureau of Ships<br>Attn: Code 565<br>Navy Department<br>Washington 25, D. C. | Dr. Everitt Martin |

| Organization | Individual Answering |
|---|---|
| Consolidated Electrodynamics Corp.<br>300 N. Sierra Madre Villa<br>Pasadena, California | Mr. J. L. Higgins |
| Convair Aircraft Corporation<br>Pomona<br>California | Mr. Ken Jackman |
| Convair Aircraft Corporation<br>San Diego 12<br>California | Mr. G. L. Getline |
| Convair Aircraft Corporation<br>Fort Worth<br>Texas | Mr. E. E. Murphy |
| Endevco Corporation<br>161 E. California Street<br>Pasadena, California | Mr. Michael Caldwell |
| General Electric Company<br>General Engineering Labs.<br>1 River Road<br>Schenectady, New York | Mr. B. E. Earls |
| Guiton Manufacturing Corporation<br>212 Durham Avenue<br>Metuchen, New Jersey | Mr. Walter Welkowitz |
| Human Factors Operations Res. Lab.<br>Headquarters Command<br>Bolling Air Force Base<br>Washington, D. C. | Dr. Karl D. Kryter |
| Lockheed Aircraft Corporation<br>Burbank<br>California | Dr. Charles T. Molloy |
| The Martin Company<br>Baltimore 3<br>Maryland | Mr. E. J. Kirchman |
| Massa Laboratories<br>Fottler Road<br>Hingham, Massachusetts | Mr. Frank Massa |
| Massachusetts Institute of Technology<br>Aeronautical Engineering Dept.<br>77 Massachusetts Avenue<br>Cambridge 39, Massachusetts | Mr. Y. T. Li |
| National Advisory Committee for Aeronautics<br>Langley Aeronautical Lab.<br>Langley Field, Virginia | Dr. H. Hubbard |

| Organizations | Individual Answering |
| --- | --- |
| National Advisory Committee for Aeronautics<br>Lewis Flight Propulsion Laboratory<br>Cleveland, Ohio | Mr. Harold Mull |
| Naval Air Material Center<br>Navy Department<br>Philadelphia 12, Pennsylvania | D. L. Hignite, LCDR |
| Pennsylvania State University<br>University Park<br>Pennsylvania | Dr. Eugene Ackerman |
| Photocon Corporation<br>421 N. Altadena Blvd.<br>Pasadena, California | Mr. C. E. Grinstead |
| Pratt and Whitney, Inc.<br>East Hartford<br>Connecticut | Mr. John Tyler |
| Radio Corporation of America<br>Camden<br>New Jersey | Mr. M. L. Graham |
| Ramo-Woolridge Corporation<br>Los Angeles 45<br>California | Dr. Charles T. Morrow |
| Roth Laboratory for Physical Research<br>1240 Main Street<br>Hartford, Connecticut | Dr. Wilfred Roth |
| Sandia Corporation<br>Albuquerque<br>New Mexico | Mr. Paul Syroid |
| Soundrive Engine Company<br>3300 Cahuenga Blvd.<br>Los Angeles 28, California | Mr. A. Bodine |
| Stanford Research Institute<br>Menlo Park<br>California | Dr. Vincent Salmon |
| Statham Laboratories, Inc.<br>12401 W. Olympic Blvd.<br>Los Angeles 64, California | Mr. J. K. Story |
| Sylvania Electric Products<br>Emporium<br>Pennsylvania | Mr. John Robbins |

| Organizations | Individual Answering |
|---|---|
| Thiokol Chemical Corporation<br>780 N. Clinton Avenue<br>Trenton, New Jersey | Mr. Breitschneider |
| U. S. Naval Air Station<br>Acoustics Laboratory<br>Pensacola, Florida | Commander |
| U. S. Navy Electronics Laboratory<br>San Diego 52<br>California | Dr. R. W. Young |
| U. S. Naval Ordnance Laboratory<br>White Oak<br>Silver Spring, Maryland | Mr. J. H. Armstrong |
| U. S. Naval Proving Ground<br>Dahlgren<br>Virginia | Capt. R. D. Risser |
| University of California at Los Angeles<br>Physics Department<br>Los Angeles, California | Dr. I. Rudnick |
| Western Electro-Acoustics Lab<br>11789 San Vicente Blvd.<br>Los Angeles 49, California | Mr. Paul S. Veneklasen |
| Westinghouse Electric Corporation<br>Air Arms Division<br>Friendship Airport<br>Baltimore, Maryland | Mr. Trevor Clark |
| Westinghouse Electric Corporation<br>Westinghouse Research Labs<br>East Pittsburgh, Pennsylvania | Mr. Charles H. Smith |
| Wiancko Engineering Corporation<br>255 N. Halstead Street<br>Pasadena 8, California | Mr. Deane M. Swanton |
| Wright Air Development Center<br>Aeromedical Laboratory<br>Att: WCLDN-5<br>Wright-Patterson Air Force Base, Ohio | Dr. H. E. von Gierke |

# APPENDIX B

Appendix B contains literature from the following Vendors.

Altec Lansing Corporation
Atlantic Research Corporation
Consolidated Electrodynamics Corporation
Endevco Corporation
Gulton Manufacturing Corporation
Massa Laboratories
Photocon Research Corporation
Statham Laboratories Incorporated
Western-Electro Acoustics Laboratory

# OPERATING INSTRUCTIONS

# M-14
# HIGH INTENSITY MICROPHONE SYSTEM

## M-14 MICROPHONE SYSTEM

Frequency Range, Pressure Range and Sensitivity: See Table I.
Weight: 7 pounds packed for shipment.

### 21BR MICROPHONE

Directionality: Omnidirectional, Fig. 4.
Capacitance: 6 micro-microfarads, approx.
Dimensions: Length 13/32", Diameter 11/16", Weight 1/4 ounce.

### 165A BASE

Dimensions: Length 2 15/16", Diameter 11/16", Weight 2 ounces.
Vacuum Tube: 1 type 5840.
Cable: 15 feet Tensolite 1883-H6 with Cannon RWK-6-22-C (male) Connector.

### P-526A POWER SUPPLY

Dimensions: Width 8 5/8", Depth 7 1/2", Height 2 3/8", Weight 5 lbs. 10 oz.
Load Impedance: 50,000 ohms or higher.
Power Requirements: 117 volts, 50-400 cps, 15 watts.

## ACCESSORIES (Not Included in M-14 System)

167A Extension Cable, 25 ft. long, with Cannon RWK-6-22-C and RWK-6-21-C Connectors.
159B Probe Tube, 3 7/8" overall length, bore 2 mm (shown at bottom of illustration).
4665 Transformer (plug-in type), permits accommodation of load impedance of 30/50, 125/150, 250/300 and 500/600 ohms.

ALTEC LANSING CORPORATION
1515 S. Manchester Ave., Anaheim, Calif.
New York, Beverly Hills, Los Angeles

12196

PRINTED IN U.S.A.

## DESCRIPTION OF 21BR MICROPHONE:

The condenser microphone (Fig. 1) consists essentially of a stiff diaphragm having a conductive surface and a fixed backplate. A DC polarizing potential is applied between these electrodes. When positive sound pressure deflects the diaphragm inward, the capacitance of the condenser increases; and since the charge on the condenser tends to remain constant, the instantaneous potential across the condenser drops. Conversely, when the cycle reverses, the instantaneous potential increases. The output voltage is essentially proportional to diaphragm displacement. Because of the extremely high impedance of the condenser, the capacitance of which is approximately 6 mmf, a cathode follower tube serving as an impedance transformer is placed as close as possible to the microphone. The tube is housed in the 165A base which also mounts the microphone. The cathode follower permits transmission of the signal to remote measuring apparatus with minimum frequency discrimination and noise pickup. The tube is a 5840 pentode with a shock rating of 500 G. No physical grid resistor is employed; as a consequence, the low frequency response is extended and the noise threshold is lowered.

The condenser microphone is a refined measuring instrument. It is remarkably stable and will withstand a degree of rough handling.

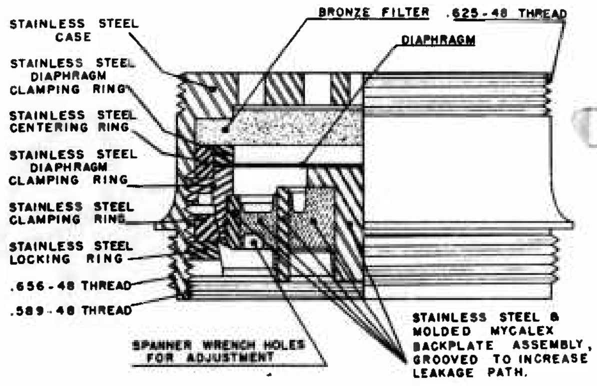


FIG. 1

## DISTORTION:

The distortion of the cathode follower when measured with a load greater than 50,000 ohms produces a second harmonic of less than 2% at 25 volts output in the frequency range up to 15,000 cps with the standard 15 foot cable supplied with the 165A base. Distortion resulting from adding a capacity of .01 mfd (200 feet of cable) is shown in Fig. 2.

## CALIBRATION AND SENSITIVITY:

To cover the wide range of sound pressure, four interchangeable microphone types are available for use with this system. Average properties are listed in Table I for each type as part of a standard M-14 Microphone System and with [illegible] volts polarizing potential.

**TABLE I**

| Code | Open Circuit Sensitivity, db re 1 volt/dyne/cm² | Linear Limit, SPL re .0002 dyne/cm² | Average Noise Threshold, SPL | Frequency Range |
|---|---|---|---|---|
| 21BR-150 | −55 to −60 db | 150 db | 40 db | 5 cps to 17 KC |
| 21BR-180 | −65 to −75 db | 160 | 53 | 5 cps to 20 KC |
| 21BR-200 | −85 to −95 db | 180 | 73 | 5 cps to 25 KC |
| 21BR-220 | −105 to −115 db | 200 | 93 | 5 cps to 30 KC |

An individual calibration is furnished with each M-14 Microphone System.

The noise threshold is due principally to tube noise but it is expressed in Table I in terms of the Sound Pressure Level that would produce the same output. The threshold of a particular microphone system may vary ± 4 or 5 db from the average.

Fig. 3 indicates the open circuit output voltage for any sound pressure level corresponding to any value of sensitivity.

The 21BR Microphone will operate satisfactorily over a wide range of ambient barometric pressure and temperature without adversely effecting its sensitivity. The sensitivity increases with a decrease in ambient pressure: at a pressure of 180 mm of mercury (equivalent to 35,000 feet above sea level), the sensitivity increases approximately 4 db with no marked change in frequency response.

The sensitvity changes inversely with temperature 0.022 db per degree F, determined over the range 70° to 300° F.

A check of the sensitivity of the 21BR Microphone can be made by two methods:

1. Acoustic calibration as provided by the General Radio Type 1552-B Sound Level Calibrator. This method is recommended for field operation and can be accurate within 1 db. It is usually made at 400 cps.
2. Insert voltage calibrations as described in "Acoustic Measurements," Page 213, L. L. Beranek, John Wiley & Sons, Inc.

The directional characteristics (Fig 4) are identical for all types of 21BR microphones.

## OPERATION:

The 21BR Microphone is shipped in position on the 165A Base. Attachment is made by .656-48 threads on the outside of the shell of the microphone. The microphone must be screwed tightly in position. An alligator type jaw plier with tape over the jaws is an adequate tool to attach or remove the microphone. Connection between 165A Base and P-526A Power Supply is made by plugging the Cannon RWK-6-22-C cable connector into the receptacle marked "Input" on the front panel of the P-526A Power Supply.

Connect the AC cord of the power supply to any supply of 117 volts 60 cycles alternating current. Fuse protection is provided by a ½ ampere type 3 AG Littlefuse. The power supply may also be used on frequencies as low as 50 cycles and as high as 400 cycles.

The sensitivity of the microphones is directly proportional to the polarizing voltage. 21BR Microphones are calibrated at 100 volts and this voltage is provided by the P-526A Power Supply when P-1 is so adjusted that M-1 reads 10 ma. (Fig. 6.)

## OUTPUT CONNECTIONS:

The output of the M-14 System appears at the end of the two conductor shielded cable attached to the P-526A Power Supply. As shipped, the Power Supply is connected for a high impedance load and one side of the output is grounded. If a balanced line, isolation from ground, or accommodation of low load impedance are required, the 4665 plug-in transformer should be used.

## PROBE TUBE:

The 159B Probe Tube threads on the end of the microphone. It may be used where continuous high temperatures (to 700° C.) are encountered at the pickup point. It provides a point source pickup for measurements in pipes, engines, etc. The tube is constructed of stainless steel to resist corrosive action of heat and various types of liquid fuels and propellants, and the wall is of sufficient thickness to provide a wall attenuation of at least 40 db. See Table II for the effect of the probe on frequency response.

**TABLE II**

Typical Effect of 159B Probe Tube on Frequency Response of M-14 System

| Frequency | Deviation |
|---|---|
| 100 | +1 db |
| 200 | +2 |
| 300 | +3 |
| 700 | 0 |
| above 700 cps | −6 db/octave, approx. |

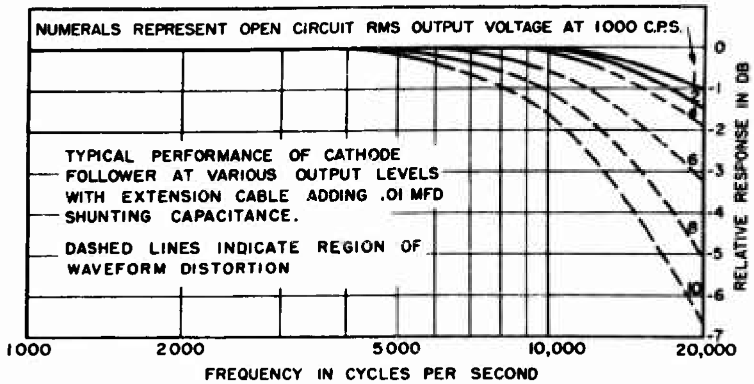



FIG. 2

21 TYPE MICROPHONES
OUTPUT VOLTAGE VS. INPUT PRESSURE
POLARIZING POTENTIAL 100 VOLTS

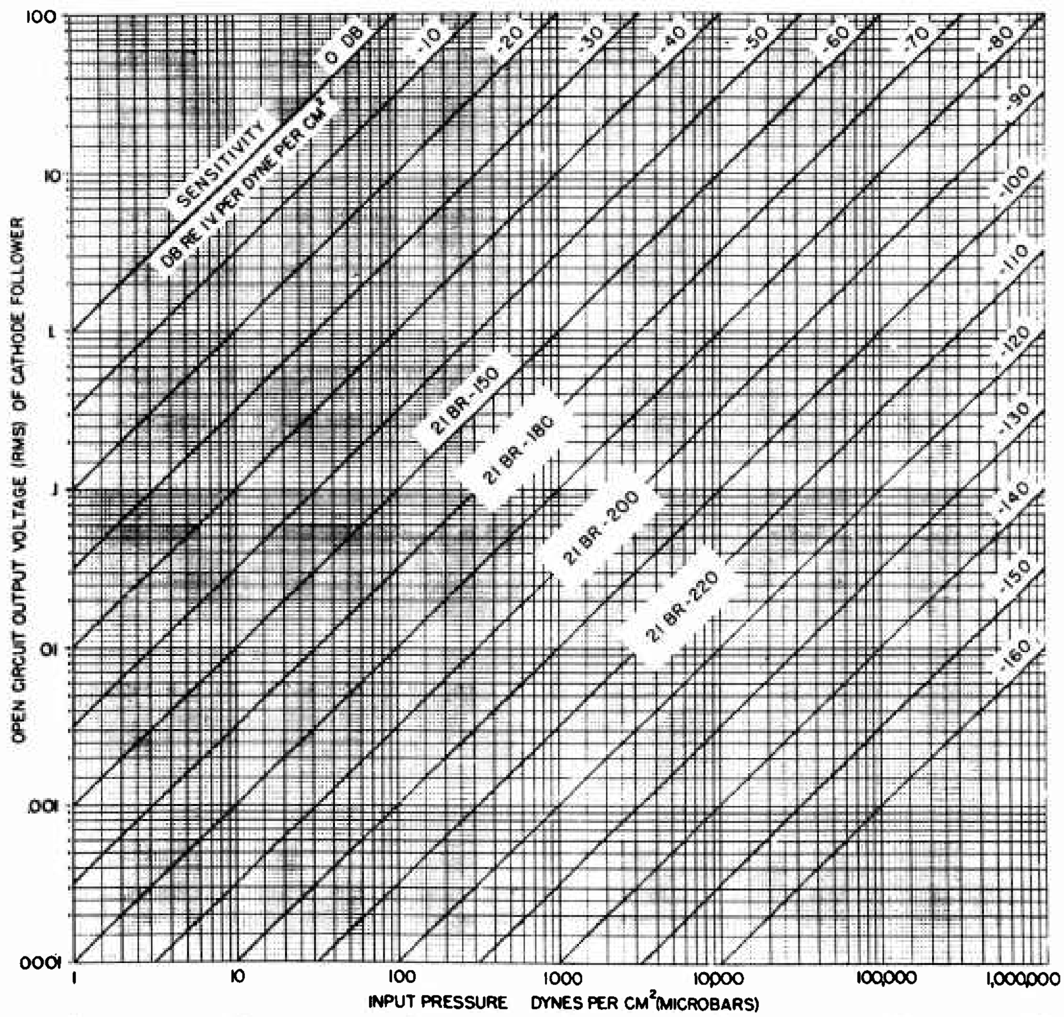



FIG. 3

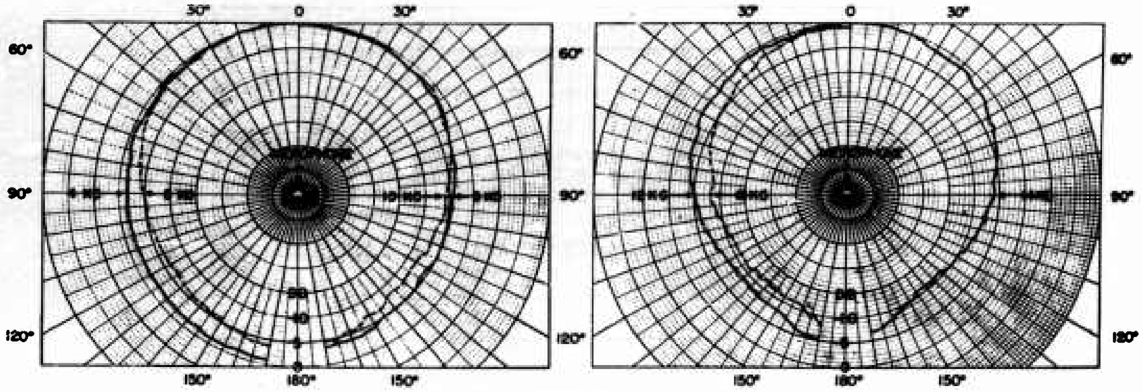



FIG.4

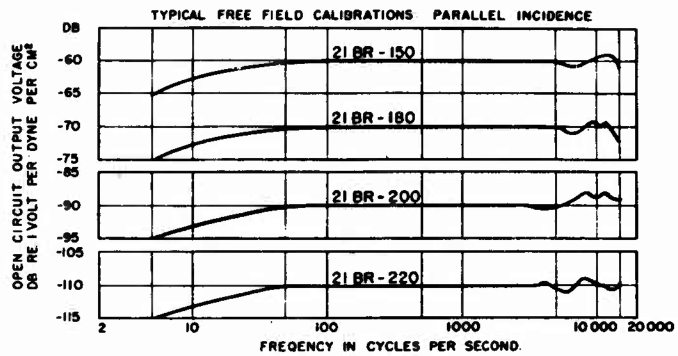
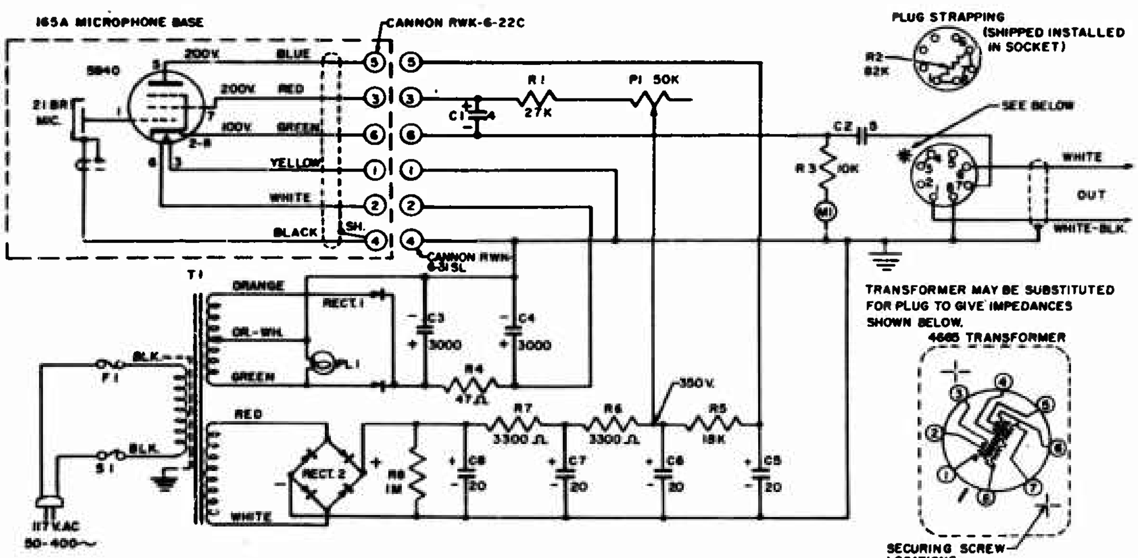



FIG.5




PARTS LIST

| | | | |
|---|---|---|---|
| C1 | 4 MFD 450V. CD BR445 | R6,7 | 3300Ω ± 10% 1WATT |
| C2 | 5 " 200V. ± 20% ELECTRO CAP AE-10286 | R8 | 1M " " 1/2 " |
| C3,4 | 3000" 15V. MALLORY WP-042 | RECT.1 | FANSTEEL 88-083M |
| C5,6,7,8 | 20-20-20-20MFD. 450V. MALLORY FP-441 | RECT.2 | SARKES TARZIAN 126-1381-0S |
| R1 | 27K ± 10% 1/2 WATT | M1 | 10MA PER ALTEC DWG.5856 |
| R2 | 82K " " " " | P1 | 50K ALLEN BRADLEY JU-5031-P-3048 |
| R3 | 10 K " 1% 2 " | F1 | FUSE 1/2AMP. 3AG-LITTELFUSE 312-500 |
| R4 | 47Ω ± 10% 4 WATTS MALLORY 4AL-47 | S1 | SWITCH H & H 1561 |
| R5 | 18K " " 1/2 WATT | T1 | TRANSFORMER ALTEC 6172 |

| IMPEDANCE, OHMS | CONNECT TO | STRAP |
|---|---|---|
| 30/50 | 1-6 | 1-5,2-6 |
| 125/150 | 1-6 | 1-4,3-6 (CT OF 2-5) |
| 250/300 | 1-6 | 2-4,3-5 |
| * 500/600 | 1-6 | 3-4 |

LEGEND

Ω = OHMS
K = 1,000 Ω
M = 1,000,000 Ω
ALL CAPACITANCE VALUES IN MFD.
UNLESS OTHERWISE INDICATED

ALTEC LANSING P526A POWER SUPPLY
FIG.6

October 11, 1957

ALTEC 20828 HIGH INTENSITY NOISE GENERATOR

The 20828 High Intensity Noise Generator is capable of producing 165 db maximum sound pressure. Its use is for sound environmental tests. It consists of two air cooled 20801 loudspeaker units driving a reverberant enclosure as illustrated in Figure 1. The dimensions of this enclosure are 3" x 3" and is in the form of a cylinder. The walls of the cylinder are composed of 1/4" thick lucite so that objects under test are visible. A pressure fitting in the center contains the 21BR-180 microphone and its 165A cathode follower base. The microphone is adjustable in position so that it can be flush with the walls or extend to the center.

The objects under test can be supported on vibration-free mounts and hooks are provided at the top for this purpose.

The test object which may be vacuum tubes, transistors, diodes, small relays, condensers, gyros, accelerometers and similar components, can be in an operating state, and a bushing is provided on the wall opposite the microphone so power and signal leads can be brought out of the chamber.

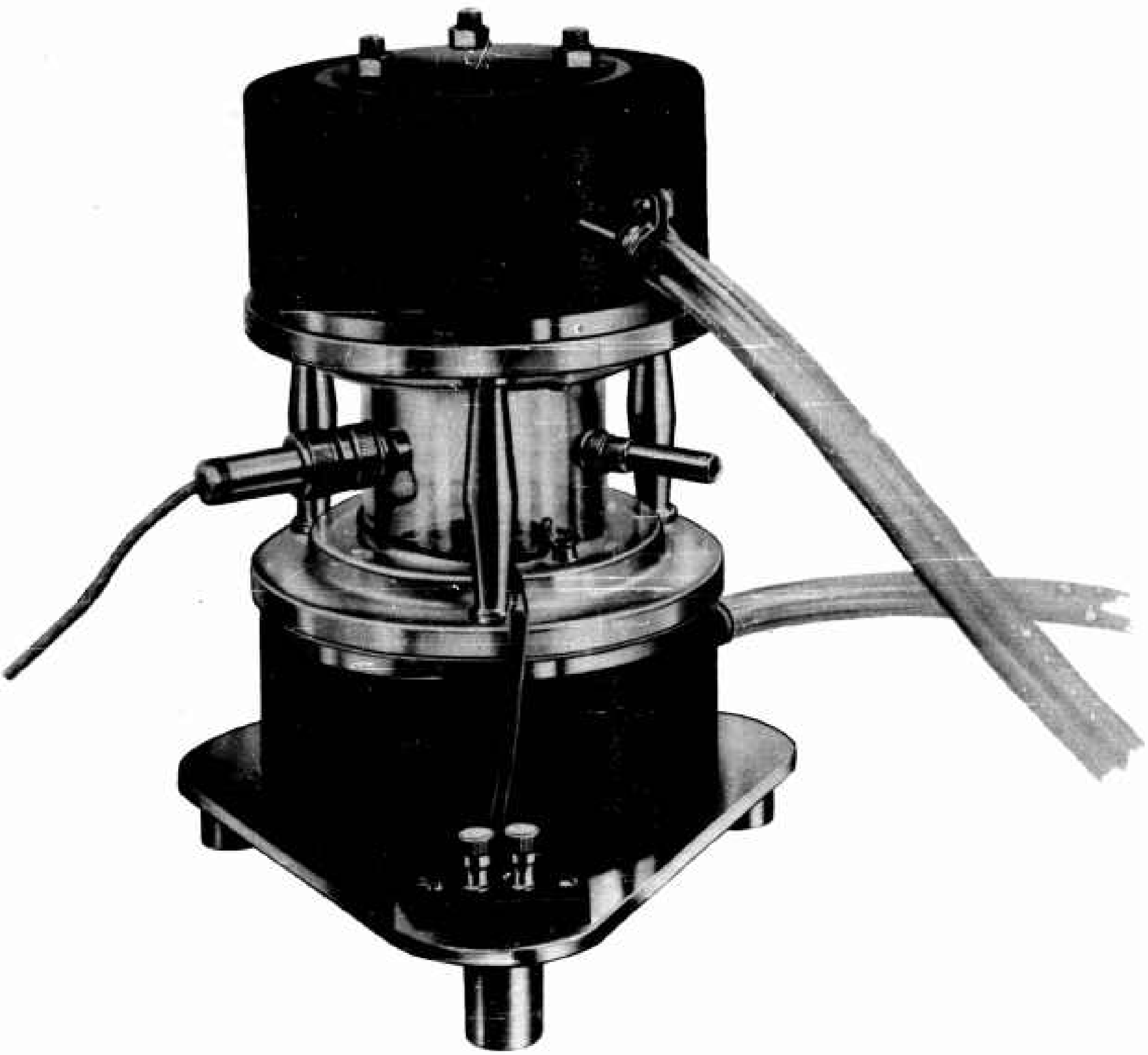
The maximum input watts to the loudspeakers is 260 watts. Under these conditions, air cooling of the diaphragm and voice coil is required for continuous operation. Approximately 5 CFM of air is required at 1-2 PSI.

Random noise or sine wave signals may be used over the range of 50-10,000 CPS.

The ambient noise outside of the chamber during operation is 40 db below that inside.

The loudspeaker diaphragms are easily replaced in case of damage and two sets of spare diaphragms are provided.

ALTEC 20828 HIGH INTENSITY NOISE GENERATOR

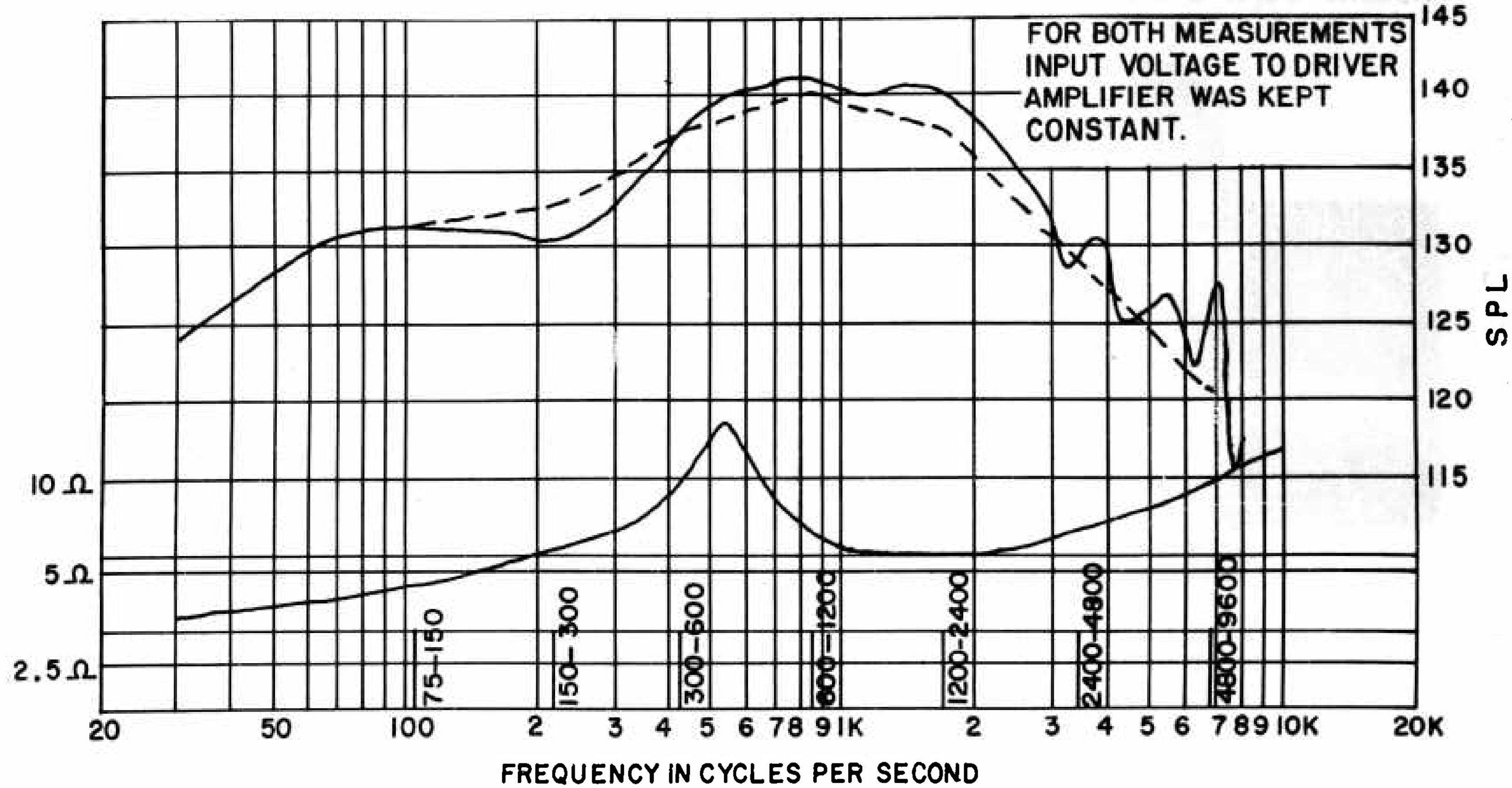


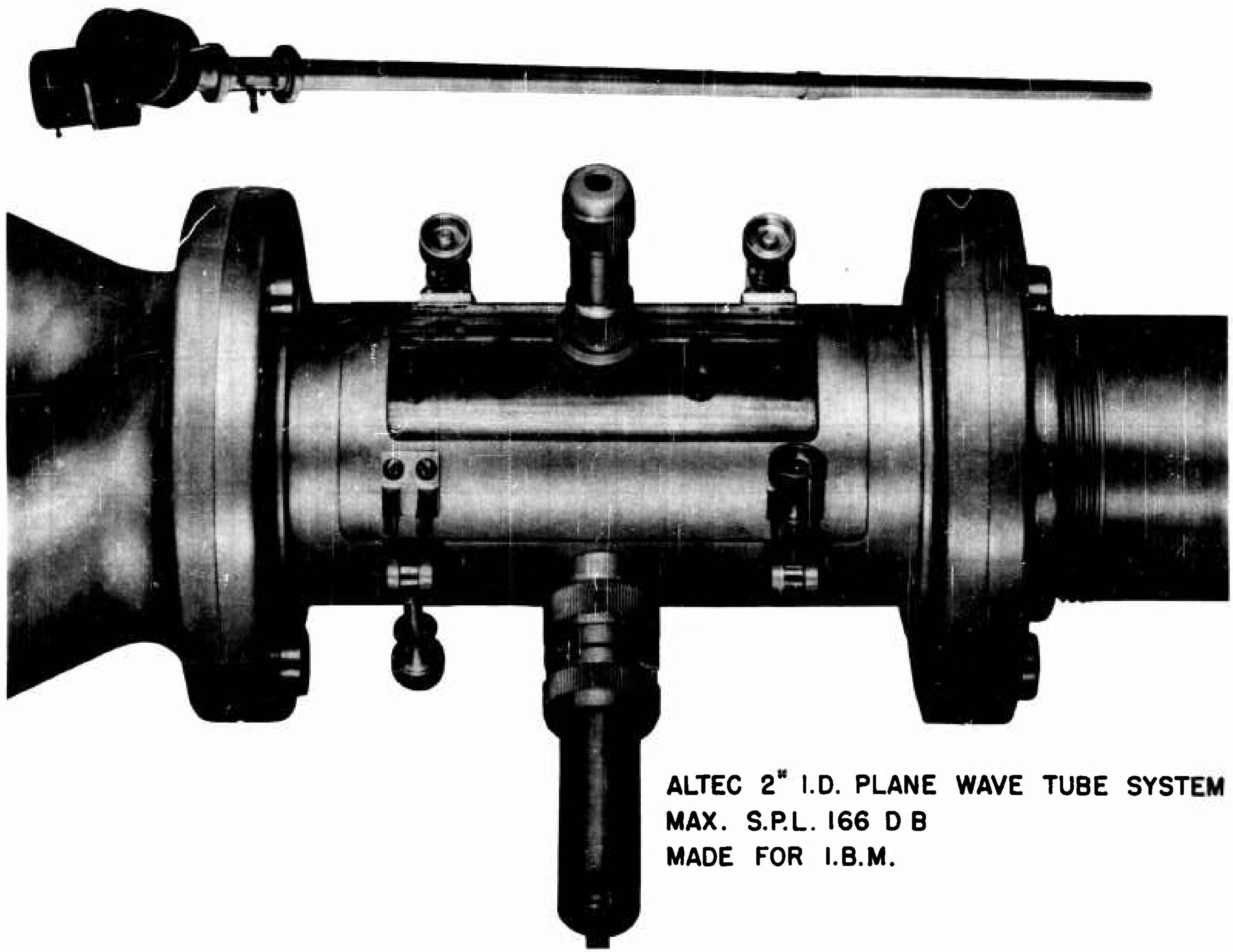
80746

2" DIA. PLANE WAVE TUBE. 2X 20801 DRIVERS

10-7-57

FREQUENCY AND IMPEDANCE RESPONSE. INPUT AT 1300 CPS 1 VOLT AMPERE
OCTAVE BAND RESPONSE. INPUT 1200-2400 CPS BAND 1 VA
166 DB SPL WITH INPUT 1200-2400 CPS BAND ONLY, 400 VA





ALTEC 2" I.D. PLANE WAVE TUBE SYSTEM
MAX. S.P.L. 166 D B
MADE FOR I.B.M.

Specification No. 4a
October, 1956

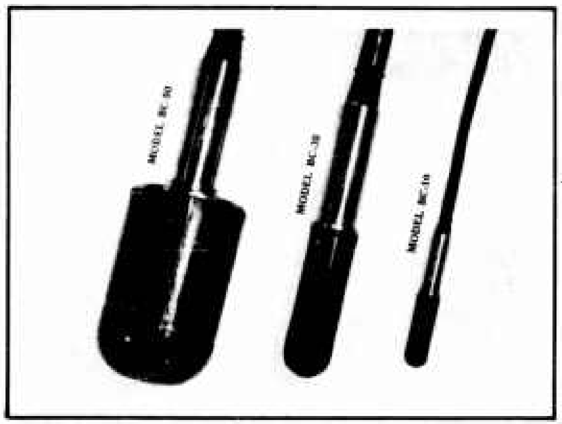
# ATLANTIC RESEARCH CORPORATION

Alexandria, Virginia

Barium Titanate

## PRESSURE TRANSDUCERS

**MODEL BC-10**
**MODEL BC-30**
**MODEL BC-50**




The Models BC-10, BC-30, and BC-50 Pressure Transducers are rugged Barium Titanate gages developed primarily for the extreme service associated with measurement of underwater and underground explosions. However, their general characteristics have made them useful in other applications, such as Sonar, geophysical investigations (particularly tideland oil exploration), and other transient pressure measurements in liquid and gaseous systems.

The construction of each of these models is similar, being based on the use of a single hermetically-sealed Barium Titanate cylinder. The whole transducer is covered with a tough pressure-molded Neoprene sheath that is actually bonded to the active face of the cylinder and cured to the Neoprene jacket of the attached cable. As a consequence, there are no stuffing glands as potential sources of leaks. The DC input resistance, for example, is maintained above 500 megohms even after prolonged immersion in salt water. A stainless steel mounting sleeve, electrically and mechanically isolated from the sensitive unit, is incorporated as an integral part of the transducer, as shown. As a result of this rugged construction, these units can withstand static pressures in excess of 5000 psi.

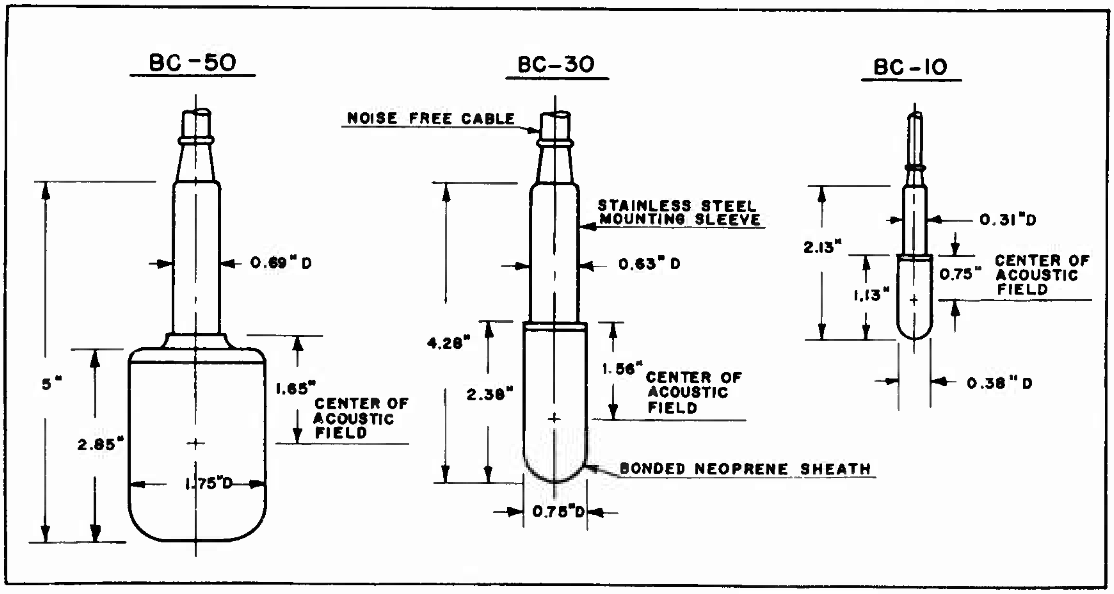
Of these three models, the BC-10 is the smallest and operates over the widest frequency range, having a substantially flat response from 3 c/s to 75 kc/s. The range of the BC-30 is 1 c/s to 40 kc/s and that of the BC-50 is 0.5 c/s to 30 kc/s. The BC-50, the most sensitive of the three models, has a nominal sensitivity of 9000 $\mu\mu$ coulombs/psi, as compared with 1500 $\mu\mu$coulombs/psi for the BC-30 and 300 $\mu\mu$ coulombs/psi for the BC-10. The beam pattern for each of these transducers is very nearly spherical. Twenty-five feet of noise-free cable is normally supplied with each transducer, although other lengths of cable, as well as custom mounting sleeves, are available upon application.

(OVER)

## NOMINAL CHARACTERISTICS

| | BC-10 | BC-30 | BC-50 |
|---|---|---|---|
| **OPEN CIRCUIT SENSITIVITY:** | | | |
| db ref 1 volt/microbar | —117 | —111 | —101 |
| volts/psi | 0.1 | 0.2 | 0.6 |
| $\mu\mu$ coulombs/psi | 600 | 1500 | 9000 |
| **FREQUENCY RESPONSE:** | | | |
| Flat ± 2 db — cycles/second | 3 to 75,000 | 1 to 40,000 | 0.5 to 30,000 |
| **CAPACITANCE:** | | | |
| microfarads | 0.006 | 0.008 | 0.015 |
| **BEAM PATTERNS:** | | | |
| (a) Horizontal | Circular (± 1 db) | | |
| (b) Vertical | Circular (± 3 db) | | |
| **LINEARITY:** | ±2% to 100 psi; ±4% to 400 psi | | |
| **DC RESISTANCE:** | | | |
| megohms | > 500 | | |
| **MAXIMUM STATIC PRESSURE:** | | | |
| pounds/inch² | > 5000 | | |
| **MAXIMUM TRANSIENT PRESSURE:** | | | |
| pounds/inch² | ∿10,000 | | |
| **TEMPERATURE:** | Useful range: —20°C to +90°C<br>Variation in charge sensitivity:<br>±2db from —20°C to +40°C | | |

## DIMENSIONS




## ATLANTIC RESEARCH CORPORATION

*ELECTROMECHANICAL DIVISION*


ALEXANDRIA, VA. TEL.: KIng 9-7500

Specification No. 8b
October, 1956

# ATLANTIC RESEARCH CORPORATION

Alexandria, Virginia

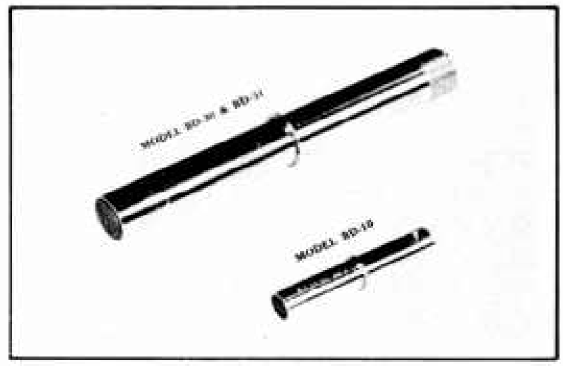
**Barium Titanate**

## BLAST VELOCITY GAGES

**MODEL BD-10**

**MODEL BD-30**

**MODEL BD-31**




The Models BD-10, BD-30, and BD-31 Blast Velocity Gages are durable Barium Titanate transducers specifically designed for the measurement of shock propagation velocities in blast studies. By spacing pairs of these units at different radial distances from the center of an explosion, the shock velocity can be determined and hence, from the Rankine-Hugoniot equations, the peak pressure. Although normally used as time-of-arrival gages, these transducers have found application as general transient pressure measuring instruments in fluids where their characteristics make them suitable.

The development of these gages was done by the Atlantic Research Corporation under contract with the *Ballistic Research Laboratories*, Aberdeen Proving Ground, and was evolved from designs and methods originated there. The construction of each model is similar, being based on the use of a stack of Barium Titanate discs consolidated with a high-strength, thermosetting cement. The stack is sealed into a stainless steel housing by means of a tough epoxy resin that is actually bonded to the active face, thus eliminating water leakage under field conditions. Moreover, the potting compound furnishes some protection from flying fragments that often accompany an explosion. The insulation is sufficient so that these gages can be repolarized, cold, with as much as 5000 volts DC applied to the terminals.

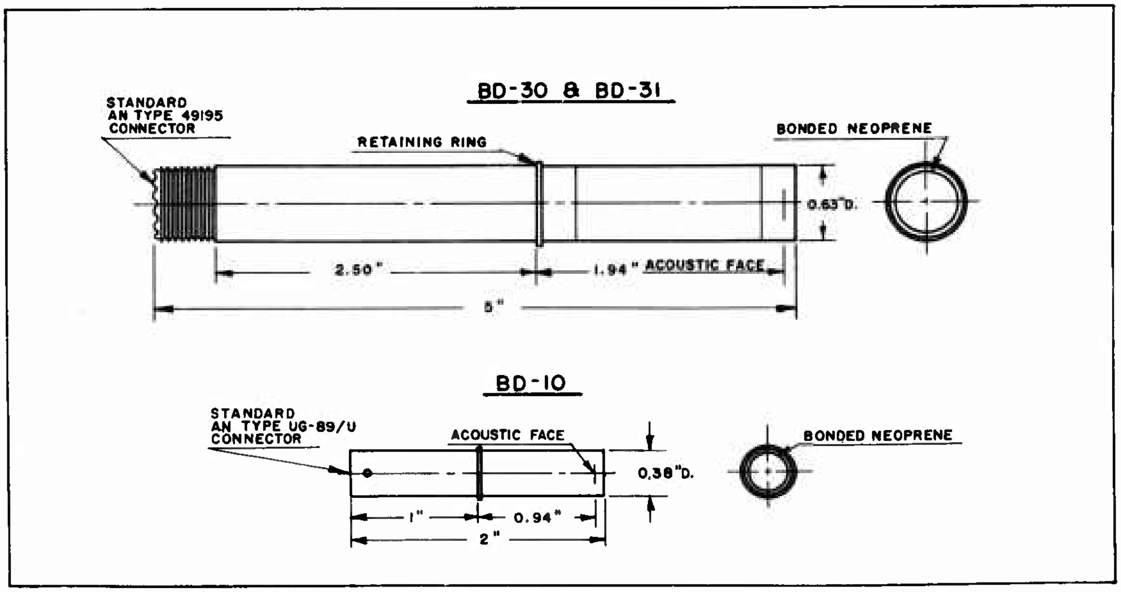
The BD-10, the smallest of the three models, has a sensitivity of 100 $\mu\mu$coulombs/psi and has substantially flat response from 5 to 20,000 c/s. The BD-30 and BD-31, although in identical housings, have nominal sensitivities of 600 $\mu\mu$coulombs/psi and 1100 $\mu\mu$coulombs/psi, respectively. Each unit terminates in a standard connector and is supplied with a removable retaining ring, useful as a mounting shoulder.

(OVER)

## NOMINAL CHARACTERISTICS

| | BD-10 | BD-30 | BD-31 |
|---|---|---|---|
| **OPEN CIRCUIT SENSITIVITY:** | | | |
| volts/psi | 0.2 | 0.2 | 0.1 |
| $\mu\mu$ coulombs/psi | 100 | 600 | 1100 |
| **FREQUENCY RESPONSE:** | | | |
| Flat ± 2 db — cycles/second | 5 to 20,000 | 1 to 15,000 | 0.5 to 15,000 |
| **CAPACITANCE:** | | | |
| microfarads | 0.0005 | 0.003 | 0.01 |
| **LINEARITY:** | ±2% to 100 psi; ±4% to 400 psi | | |
| **DC RESISTANCE:** | | | |
| megohms | > 500 | | |
| **MAXIMUM STATIC PRESSURE:** | | | |
| pounds/inch² | > 5000 | | |
| **MAXIMUM TRANSIENT PRESSURE:** | | | |
| pounds/inch² | ∿ 10,000 | | |
| **TEMPERATURE:** | Useful range: —20°C to +90°C<br>Variation in charge sensitivity:<br>±2db from —20°C to +40°C | | |

## DIMENSIONS




**ATLANTIC RESEARCH CORPORATION**

*ELECTROMECHANICAL DIVISION*

ALEXANDRIA, VA. TEL.: KIng 9-7500

Specification No. 9a
October, 1956

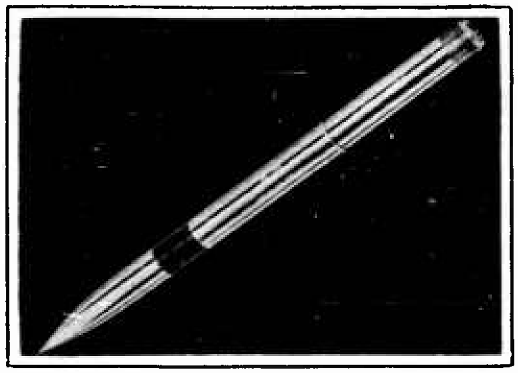
# ATLANTIC RESEARCH CORPORATION

Alexandria, Virginia

Zirconate

## PENCIL-TYPE PRESSURE TRANSDUCER

### MODEL LC-33



LC-33

Piezoelectric zirconate ceramic elements are now available to replace barium titanate in the Pencil-Type Pressure Transducer. The zirconate Model LC-33 exhibits the following improvements in comparison with our barium titanate Model BC-33:

- Temperature Stability
- Greater Sensitivity
- Extended Temperature Range

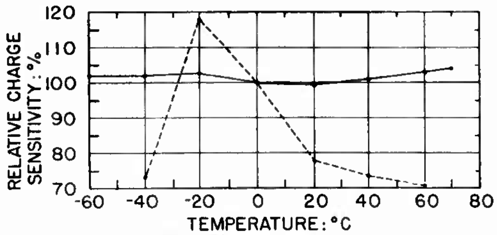



FIGURE 1.

RELATIVE CHARGE SENSITIVITIES OF TWO PIEZOELECTRIC CERAMICS

----BARIUM TITANATE WITH 3% CALCIUM TITANATE (AFTER MASON)
——ZIRCONATE (FROM MEASUREMENTS MADE BY CLEVITE RESEARCH CENTER)

The Piezoelectric Coefficient, $d_{33}$, of the zirconate ceramic shows a total variation of less than 5% in the temperature range from —60°C to +70°C. Figure 1 compares the relative piezoelectric coefficients of zirconate and barium titanate formulations. Calibration of the Model LC-33 Pressure Transducer confirms the stability of gage sensitivity, expressed in terms of charge developed per unit pressure, over the wide temperature range. The open circuit voltage sensitivity is substantially constant over the range from —20°C to +60°C. The ratio of the $d_{33}$ piezoelectric constant to the dielectric constant is taken as a measure of the voltage sensitivity. The minor effect of temperature on this ratio is shown in Figure 2.

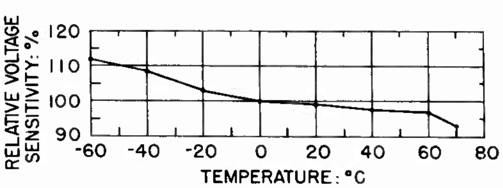



FIGURE 2.

RELATIVE VOLTAGE SENSITIVITY OF ZIRCONATE CERAMIC

(FROM MEASUREMENTS MADE BY CLEVITE RESEARCH CENTER)

(OVER)

The sensitivity of the Model LC-33 is approximately twice that of the Model BC-33.

The usable temperature range of the Model LC-33 is limited by the neoprene sheath which is bonded to the active face of the zirconate cylinder, not by the piezoelectric ceramic as in the Model BC-33. The Curie temperature of the piezoelectric element is above 300°C, although the useful high temperature limit, so far as the sensitive element itself is concerned, is about 200°C for many applications because of the decrease in resistivity at high temperatures. A pencil-type transducer is now being developed for continuous use at high temperatures to make maximum use of the improved temperature stability of the new zirconate formulations.

## NOMINAL CHARACTERISTICS

SENSITIVITY:
- 0.4 volts/psi (open circuit)
- −105 db ref 1 volt/microbar (open circuit)
- 1000 μμ coulombs/psi

OPEN CIRCUIT FREQUENCY RESPONSE:
- 1 c/s to 80 Kc/s — flat within ±2 db

CAPACITANCE:
- 0.0025 microfarads

D.C. RESISTANCE:
- >500 megohms

MAXIMUM STATIC PRESSURE:
- >500 psi

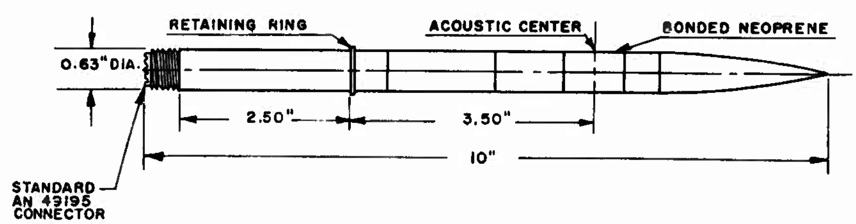
MAXIMUM TRANSIENT PRESSURE:
- ~ 1000 psi

TEMPERATURE RANGE:
- −40°C to +100°C
- (Limited by neoprene sheath — ceramic Curie temperature above 300°C)

LINEARITY:
- The sensitivity, in terms of charge developed per unit pressure in pulse calibration, is constant within ±2% up to pressures of 100 psi, at constant temperature, and within ±4% up to pressures of 500 psi. Under temperature cycling conditions, the charge sensitivity is constant within 3% from −60°C to +70°C.

## DIMENSIONS

LC-33




**ATLANTIC RESEARCH CORPORATION**

**ELECTROMECHANICAL DIVISION**


ALEXANDRIA, VA. TEL.: KIng 9-7500

Specification No. 10
December, 1956

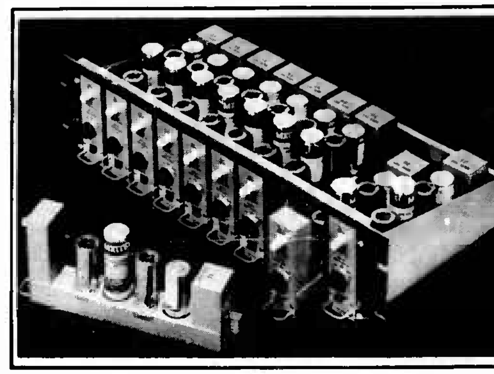
# ATLANTIC RESEARCH CORPORATION

Alexandria, Virginia

High Input Impedance

## AMPLIFIER

TYPE 104



**Type 104 Amplifiers with 104-P1 Mounting Frame**

The Amplifier Type 104 was developed for general laboratory use where high input impedance is required. This feature is especially useful with piezoelectric pressure transducers and accelerometers, for which the low frequency response is determined by the RC time constant of the transducer-amplifier input circuit. For applications not requiring high input impedance, where it is desirable to minimize low frequency noise, lower impedance values may be selected by a five-position front panel switch. The relatively low output impedance of the Type 104 makes it a useful preamplifier to adapt high impedance sources to low impedance recorders. Frequency response is essentially flat from ½ c/s-2 mc/s, a requirement for faithful reproduction of fast transients. This amplifier also features voltage gains of 1 or 10.

Compact design of the Type 104 facilitates multi-channel rack mounting. High quality components are used throughout, including deposited film resistors wherever low noise or good stability is required. Readily available parts and materials are employed to simplify user maintenance. A Type 6201 ruggedized dual triod is used as a two-stage amplifier followed by a 6BQ7A output cathode follower. The Type 6201 tube has been found to have substantially better noise characteristics than the equivalent Type 12AT7. Stable voltage feedback contributes both to the high input impedance and to the low output impedance.

This amplifier is designed for plug-in installation and, for most applications, a separate mounting arrangement will be required. The Type 104-P1 Mounting Frame is available to mount up to ten amplifiers in a standard 5¼ x 19 inch rack space. Custom mounts can also be provided.

Power must be supplied from an external source to the Amphenol "Blue Ribbon" connector at the rear of the amplifier chassis. Suitable available laboratory supplies may be used. However, d-c is recommended for the tube heaters for operation at low signal levels. Atlantic Research Corporation Type 105 Power Supply is specifically designed to furnish optimum high and low d-c voltages for up to ten amplifiers.

(OVER)

## SPECIFICATIONS

### GAIN:
**1 or 10. Accuracy: ±3% at 1 kc/s**

### HIGH FREQUENCY RESPONSE:
**±1 db to 2 mc/s with resistive loads**
**±3 db to 2 mc/s with capacitive loads <300 μμfd**

### LOW FREQUENCY RESPONSE:
**±1 db to ½ c/s with loads >100,000 ohms**

Response with lower loads is limited by 20 μfd output coupling capacitor.

### NOISE LEVEL (REFERRED TO INPUT):
**<50 microvolts**

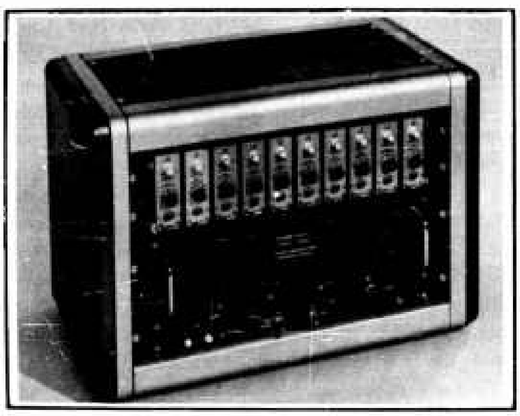
Noise level is specified for source impedance of 10 megohms or less, or with capacitive source of greater than 300 μμfd. Specification refers to total noise in the band 5 c/s-350 kc/s, and applies to both gain settings. Quoted value assumes use of d-c heater supply. A-c heater supply will increase hum level and, if used, hum balancing should be provided.

### INPUT IMPEDANCE:
**0.1, 1, 10, 100, or ~ 500 megohms, shunted by approximately 25 μμfd.**

Impedance values selected by front panel switch.

### INTERNAL OUTPUT IMPEDANCE:
**<20 ohms in series with approximately 20 μfd**

Specified impedance applies to most of frequency range but rises to approximately 80 ohms at 2 mc/s.



Type 104 Amplifiers mounted in Type 104-P1 Frame with Power Supply Type 105 in Cabinet Style 10

### OUTPUT LEVEL:
**20 volts to 100 kc/s**
**16 volts to 200 kc/s**
**8 volts to 500 kc/s**
**4 volts to 1 mc/s**
**2 volts to 2 mc/s**

These levels specified for 5,000 ohm load shunted by 300 μμfd. Maximum levels will be somewhat higher for higher load impedances.

### LOAD IMPEDANCE:
**5000 ohms minimum, shunted by 300 μμfd maximum**

Resistive loads below 100,000 ohms will limit low frequency response due to 20 μfd output coupling capacitor.

### POWER REQUIREMENTS:
**250 volts d-c regulated; 20 ma**
**6.3 volts, preferably d-c; 0.7 amperes**

Plate current may be as high as 35 ma with lowest output loads.

### DIMENSIONS:
**1¾" wide x 4¼" high x 9½" deep**

### WEIGHT:
**15 ounces**

### CONNECTORS:
Power connector: Amphenol "Blue Ribbon" (mating connector supplied)
Input: UG-625/U
Output: Terminals of power connector

Power connector is at rear of chassis for plug-in rack mounting. BNC type input connector is located on front panel. On special order, either of two options is available: (a) BNC input connector may be mounted at rear of chassis; (b) output may be brought to BNC connector at rear of chassis.

### ACCESSORIES:
1. Power Supply Type 105 to furnish power for one to ten amplifiers. See Specification No. 11.
2. Plug-In Mounting Frame Type 104-P1 to carry up to ten amplifiers for mounting in a standard 5¼" x 19" rack space. Over-all depth behind panel is 9⅝". Cabinet model is available.
3. Cabinet Style No. 10 for mounting Type 104-P1 Frame with Power Supply Type 105.


**ATLANTIC RESEARCH CORPORATION**

**ELECTROMECHANICAL DIVISION**

**ALEXANDRIA, VA.** **TEL.: KIng 9-7500**

Technical Note No. 1
November 1954
TRANSDUCERS

ATLANTIC RESEARCH CORPORATION

## ACCELERATION SENSITIVITY OF ARC PRESSURE TRANSDUCERS

The response of a pressure transducer to acceleration must often be considered in choosing the proper transducer for a specific application and in analyzing the records obtained. The data given below were obtained jointly by the Bureau of Mines Eastern Experiment Station and Atlantic Research Corporation in a brief investigation of the possible importance of acceleration response in a series of pressure measurements which had been made by the Bureau of Mines. Measurements were made on Model BC-30 Pressure Transducer, Serial No. 44, whose pressure sensitivity is 250 millivolts per psi:

**Transducer Clamped to Shake Table**

| Frequency (cps) | Table Peak Acceleration (g) | Gage Peak Acceleration Sensitivity (mv/g) |
|---|---|---|
| 100 | 0.4 | 3.5 |
| | 1.0 | 3.1 |
| 320 | 1.0 | 13 |
| 500 | 2.0 | 2.7 |
| | 5.0 | 2.5 |
| | 10* | 2.3 |
| 590 | 1.9 | 7.0 |
| 800 | 2.3 | 5.6 |
| 1000 | 4.5 | 2.1 |
| | 11* | 2.8 |
| 1070** | 2.0 | 18 |
| 1960 | 25 | 2.0 |
| 2000 | 10 | 2.3 |

* Shake table overloaded; waveform not sinusoidal.
** Clamp resonance.

**Transducer Attached to Shake Table with Wax**

| Frequency (cps) | Table Peak Acceleration (g) | Gage Peak Acceleration Sensitivity (mv/g) |
|---|---|---|
| 100 | 0.4 | 2.0 |
| 170 | 0.8 | 6.1 |
| 330 | 0.7 | 11 |
| 590 | 0.6 | 3.8 |
| 1000 | 1.0 | 2.0 |
| 1500 | 0.5 | 2.5 |
| 2000 | 0.6 | 4.4 |

(OVER)

The data indicate that the output per g will be between 1% and 5% of the output per psi in the frequency range from 100 cps to 2000 cps for the Model BC-30 Pressure Transducer. In applying these figures care must be taken to make sure that the acceleration of the gage is known. If a natural resonance of the supporting structure is excited, the accelerations may be greater than anticipated. A qualitative test indicates that the acceleration sensitivity of Model BC-10, BC-50, and BC-32 Pressure Transducers is of this same order of magnitude. The Model BC-33 Blast Pressure Gage is noticeably less sensitive to acceleration, but quantitative data have not yet been obtained for this instrument.

The Model BC-30 Pressure Transducer, held by its mounting sleeve, was first clamped to the table of an MB Model C-11 Vibrator and vibrated in a direction perpendicular to the long axis of the gage. The output was recorded at each major resonance and at several intervening frequencies in the range from 100 cps to 2000 cps. To test whether the observed peaks were caused by resonances of the clamp or of the transducer, the transducer was then attached to the table with wax and vibrated in the same direction, the acceleration being kept at 1 g or less. Again, the output at all major resonances and at a few intervening frequencies was recorded.

* * * * * * * *

Technical Note No. 2
April, 1957
TRANSDUCERS

ATLANTIC RESEARCH CORPORATION
Alexandria, Virginia

# PRESSURE RESPONSE OF PIEZOELECTRIC CERAMIC TRANSDUCERS

## Linearity • Temperature Effects • Aging
## High Static Pressure Effects

This technical note reports the results of a series of calibrations of ARC pressure transducers to obtain quantitative information about the performance to be expected from pressure-measuring devices using ceramic piezoelectric elements.

### THE CALIBRATION METHOD

The transducer is inserted in a liquid-filled system to which pressure is applied by a dead-weight tester. The pressure is released to atmospheric by opening a quick-acting solenoid valve, thus applying a known step pressure pulse to the transducer. The charge produced is measured by a ballistic galvanometer calibrated with a standard cell and standard capacitors. Over most of the range, the accuracy is better than ±1%. At low pressure, the accuracy is limited by the small galvanometer deflection; under these conditions the error may be as high as ±2%.

### LINEARITY

The calibration curves for four ARC pressure transducers, representing four types of construction, are shown in Figures 1 and 2. Figure 1 covers the pressure range from 0-300 psi. The lower end of the pressure range, 0-50 psi, is shown to a larger scale in Figure 2. Subsequent measurements made repeatedly at various pressures throughout the entire range gave values agreeing with the calibration curve within the experimental accuracy of ±1%. Examination will indicate that the curves for the Barium Titanate Transducers, Models BD-30, BC-32, and BC-50, are somewhat nonlinear.

The Model LC-33 Pressure Transducer has a lead zirconate ceramic element. Each experimental point of its calibration, with the exception of the point at 10 psi, differs from the best straight line through the origin by less than 2%. This linearity has been confirmed by the calibration of a number of Model LC-33 Pressure Transducers.

These experiments, carried out at pressures up to 300 psi, reaffirm that ceramic piezoelectric transducers are suitable for pressure instrumentation. In the case of barium titanate transducers, a single average sensitivity figure may be used, if accuracies of the order of ±1 db are sufficient. Accuracies of ±2% are possible with lead zirconate transducers, in an appropriate measurement system. If calibration curves are used, either type of transducer will provide precision of ±1%. Calibration data for ARC pressure transducers are now being reported to the customer for different pressures so that a calibration curve can be constructed.

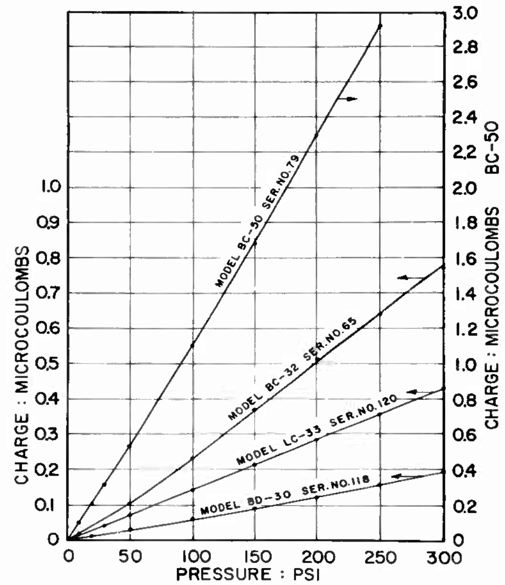



FIGURE 1
CALIBRATION CURVES
OF
ARC PRESSURE TRANSDUCERS

(over)

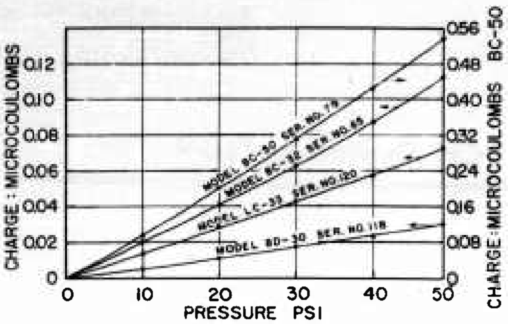



FIGURE 2

CALIBRATION CURVES
OF
ARC PRESSURE TRANSDUCERS

### TEMPERATURE EFFECTS

The sensitivity of piezoelectric barium titanate elements depends on the temperature. In lead zirconate elements, however, the dependence of sensitivity on temperature is much reduced. This effect is shown in Figure 3. The solid line gives the results of measurements of the $d_{33}$ piezoelectric coefficient of lead zirconate (Clevite PZT-4) ceramic material and is representative of results obtained in calibrating Model LC-33 Pressure Transducers at different temperatures. The dotted line shows measurements on a barium titanate (Brush Ceramic B) pencil type transducer (1).

### AGING

Mason (2) has given quantitative information on the effects of aging barium titanate ceramics at 25°C and 70°C and on the depolarization of such ceramics by pressure. ARC pressure transducers are aged before calibration, and we have not detected a change in sensitivity even over periods as long as six months. In checking the effects of age on barium titanate transducers, the calibrations must be performed at the same temperature, of course, to eliminate temperature effects.

### HIGH STATIC PRESSURE EFFECTS

To check the depolarization effect of high static pressure, Pressure Transducer Model BC-30, Serial No. 81 was given the following treatment: 5 hours at 500 psi; 2¼ hours at 1000 psi; 2¼ hours at 2000 psi; 2½ hours at 4000 psi. The gage was calibrated periodically during the experiment. The following table compares the initial with the final calibration.

CALIBRATION DATA

Model BC-30, Serial No. 81

Total Charge (microcoulombs)

| Pressure (psi) | Initial Calibration 9/24/56 | Calibration after Pressure Treatment 11/23/56 |
|---|---|---|
| 50 | 0.0685 | 0.0698 |
| 100 | 0.139 | 0.139 |
| 150 | 0.215 | 0.216 |
| 200 | 0.290 | 0.291 |

(1) C. J. Wangerin: The Effect of Ambient Temperature on Response of Air Blast Gages; BRL Memorandum Report No. 1003.

(2) W. P. Mason: Aging of the Properties of Barium Titanate and Related Ferroelectric Ceramics; Jour. Accoust. Soc. of Am. 27, 73-85 (1955).

Apparently the sensitivity of this transducer did not change in two months' time and was not measurably depolarized by being subjected to pressures of 500 psi or greater for 12 hours or 4000 psi for 2½ hours.

### CALIBRATION BY OTHER METHODS

The pulse calibration method used to accumulate the data given above has obvious disadvantages in that it does not simulate all the physical conditions to which the transducer is exposed in some applications. Other calibration methods have determined additional transducer characteristics of interest. Free-field acoustic calibrations, both in water and in air, have shown that the curve of sensitivity versus frequency is flat only to within ±2 db at high frequencies. As would be expected, variations in the frequency response curve occur at lower frequencies in air than in water. In the low-frequency, flat-response range, however, the acoustic calibrations agree with the ARC pulse calibrations within the accuracy of ±1 db claimed for the acoustic method. Also, there is some evidence from underwater acoustic calibrations that at frequencies above 60 Kc/s the frequency response curve of some transducers may be noticeably affected by changes in the static pressure, although the data are not conclusive at this time.

Shock tube calibrations, which involve both low and high frequency components of pressure change, show fairly good correlation with the ARC pulse calibration results. In a series of shock tube tests with a Model LC-33 Pressure Transducer, it was reported that the sensitivities measured by the two methods differed by less than 10%.

In conclusion, it may be pointed out that certain ARC pressure transducers have been calibrated over a dynamic pressure range of greater than 1,000,000, and the sensitivities measured in different laboratories by different methods are linear and in agreement within ±1 db, except at high frequencies where the differences are somewhat greater.

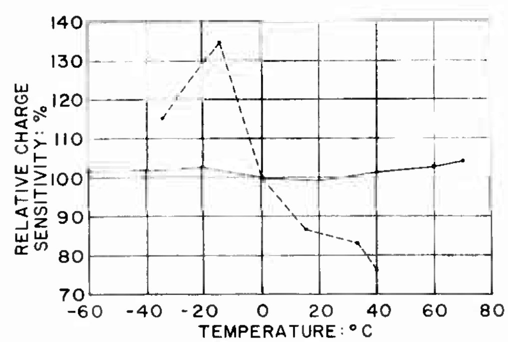



FIGURE 3

RELATIVE CHARGE SENSITIVITIES
OF
TWO PIEZOELECTRIC CERAMICS

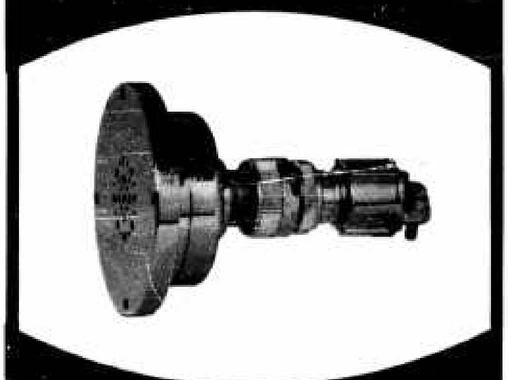
------ BARIUM TITANATE WITH 5% CALCIUM TITANATE (AFTER WANGERIN)

——— ZIRCONATE (FROM MEASUREMENTS MADE BY CLEVITE RESEARCH CENTER)

**CONSOLIDATED ELECTRODYNAMICS CORPORATION**

# *Type* 4-340 DYNAMIC PRESSURE PICKUP

***3 to 25,000 cps (Flat)***
***$10^{-4}$ to 100 PSIG***

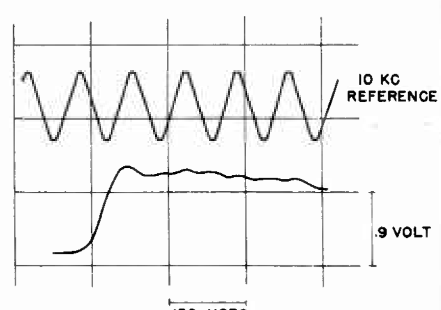


## DESCRIPTION

Consolidated's Dynamic Pressure Pickup utilizes one of the newest electrical methods for measuring pressures—the electrokinetic principle. This precision device is designed to measure true dynamic pressures which may consist of complex waves resulting from sonic vibrations, blast pressures, and water hammer in liquid-filled lines. Within the frequency range of the 4-340, the output follows the pressure signals almost ideally with no phase lag or overshoot. In addition, the output is extremely high—approximately 350 mv/psi, self-generating. Flat frequency-response range is from 3 to 25,000 cps.

## OPERATING PRINCIPLE

Operating on the electrokinetic principle, the 4-340 utilizes the electrical signals generated by a minute flow of polar liquid passing through a disk of porous material. The potential difference which is produced between the opposite faces of this disk is proportional to the applied pressure. When the direction of flow is reversed, the polarity of the generated voltage is reversed. Frequency variations have little or no effect on the output between limits of the frequency band, with the result that the instrument will respond flat between 3 cps and 25,000 cps. Pressure oscillation in this frequency range will produce electrical signals which are in phase with and proportional in amplitude to the pressure. The reason for this is that the response of the cell is governed predominantly by the mechanical resistance of the flow of fluid through the porous disk with the inertia and spring forces being small. This characteristic can be best explained by comparing it with an electrical circuit containing resistance, inductance, and capacitance in which the resistive component predominates. As a result of this phenomenon, the output across the resistance will not vary with frequency except at very low and very high frequencies, at which time the capacitance and inductance, respectively, will reduce the output to zero. The 4-340 has a finite amount of fluid constrained within its cell by two diaphragms. Since the flow cannot be maintained indefinitely in one direction the flow must be continually reversed, with respect to time, thus making the device inherently dynamic.



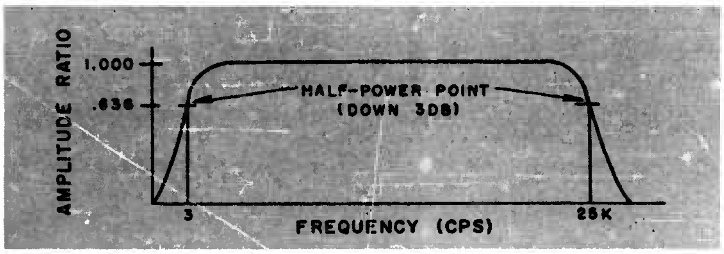

SHOCK TUBE TEST
ELECTROKINETIC PRESSURE PICKUP

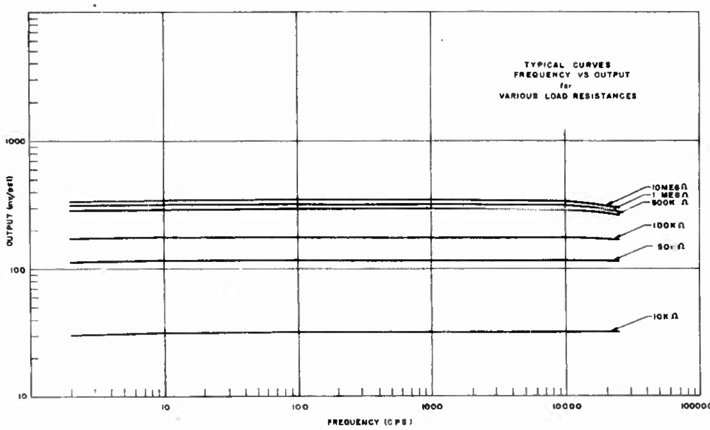
**BULLETIN CEC-1573**
**December, 1956**

**PRINTED IN U.S.A.**

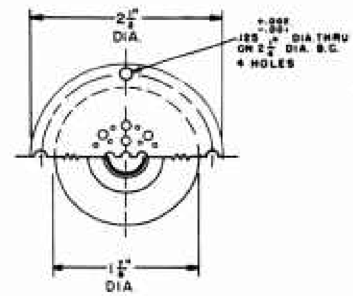
# *Specifications*

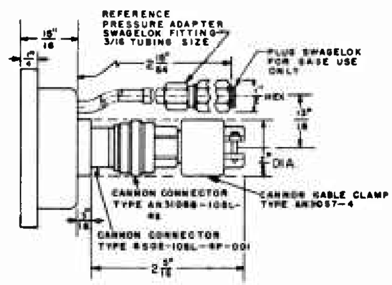
| | |
|---|---|
| **Pressure Range:** | $10^{-4}$ to 100 psig. |
| **Nominal Open-Circuit Sensitivity at 70°F:** | 350 mv/psi. |
| **Frequency Response Range:** | Flat within ± 1 db from 4 cps to 15,000 cps.<br>Flat within ± 3 db from 3 cps to 25,000 cps. |
| **Operating Temperature Range:** | −10°F to +140°F. |
| **Thermal Coefficient of Sensitivity:** | Maximum change in sensitivity from the 70°F value shall not exceed 0.5 db within operating temperature range. |
| **Acceleration Response:** | Axial: Not to exceed 3 mv/g from 0 to 15,000 cps.<br>Transverse: Not to exceed 0.5 mv/g from 0 to 20,000 cps. |
| **Internal Shunt Impedance at 70°F:** | Nominal, 100K ohms. |
| **Internal Shunt Capacitance:** | 40 $\mu\mu f$ ±10 $\mu\mu f$ at 70°F without cable. (1000 cps test frequency.) |
| **Short-Circuit Current Sensitivity:** | Greater than 3 $\mu a$/psi at 70°F. |
| **Weight:** | 10.8 oz without connector. |




TYPE 4-340 DYNAMIC PRESSURE PICKUP



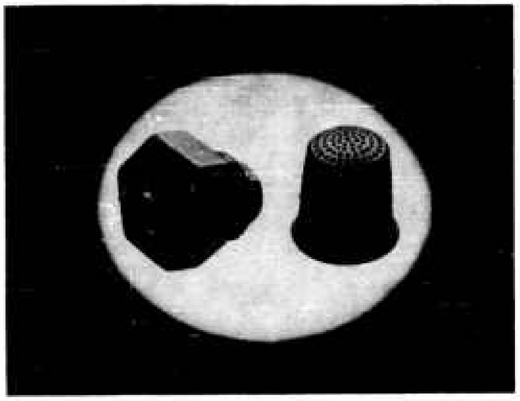

**CONSOLIDATED ELECTRODYNAMICS**

300 North Sierra Madre Villa, Pasadena, California

# DYNAMIC PRESSURE PICKUP

## Model 2501

**TRANSIENT PRESSURES MAY NOW BE READ AND RECORDED WITH SIMPLE ACCESSORY EQUIPMENT**



The Endevco Pressure Pickup is the first commercially available pickup featuring dynamic burst diaphragm calibration, large output, very fast rise time and flat frequency response for dynamic measurement applications. The Endevco Piezo-Electric Pickup provides an output suitable for oscilloscope recording of transient pressure in air and liquid. The flush mounting design provides for installations requiring minimal volume change.

## OUTSTANDING FEATURES:

| | |
|---|---|
| **HIGH OUTPUT:** | 40 millivolts/psi or greater. (500 psi full scale) |
| **HIGH RING FREQUENCY:** | 45 kilocycles (Low Phase lag and small overshoot) |
| **FAST RISE TIME:** | Faster than 10 microseconds (0 to 90%) |
| **THREE RANGES:** | 500 psi; 1000 psi; 2500 psi; (useful to pressures as low as 0.5% of full scale) |
| **SMALL SIZE:** | Less than 1 cubic inch |
| **FLUSH DIAPHRAGM:** | Minimal volume change |
| **RECORDING SIMPLICITY:** | Direct input to oscilloscope without amplifiers for transient measurements. |

## TYPICAL APPLICATIONS:

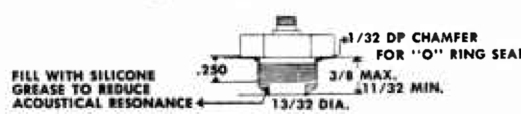
**HYDRAULIC SYSTEMS:** Measurement of transients, "water hammer," pressure surges, geophysical underwater blasts, sonar, and servo stability studies.

**AIRFLOW SYSTEMS:** Measurement of pulse, sinusoidal or shock pressures in turbines, wind tunnels, aerodynamic configurations (wing sections), and tubular structures, such as air ducts and blast areas.

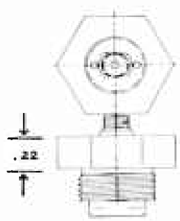
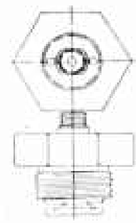
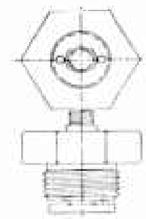
The fast rise time is ideally suited for applications requiring precise time relations, such as triggered cameras, oscilloscope sweeps and other synchronized recorders.

Another application uses the pickup in order to provide warning and automatic shutdown of compressor equipment when oscillation is greater than specified.

**FLUSH DIAPHRAGM MOUNT**
(2501-500)



# SPECIFICATIONS

| | 2501-500 500 psi | 2501-1000 1000 psi | 2501-2500 2500 psi |
|---|---|---|---|
| **OUTPUT:** | | | |
| **Volts** | 40 mv/psi | 15 mv/psi | 4 mv/psi |
| **Repeatability** | ±2% | ±2% | ±2% |
| **Frequency Response**<br>**Flat ±5% (1000 megohm load)**<br>**Flat ±5% (100 megohm load)** | 2 cps to 9 kc<br>20 cps to 9 kc | 2 cps to 10 kc<br>20 cps to 10 kc | 2 cps to 10 kc<br>20 cps to 10 kc |
| **Ring frequency** | 45 kc | 50 kc | 55 kc |
| **Rise time (0-90%)** | better than 10 microseconds | better than 10 microseconds | better than 10 microseconds |
| **Decay time (10% down)** | 100 milliseconds | 100 milliseconds | 100 milliseconds |
| **Linearity** | ±2% | ±2% | ±2% |
| **Resolution** {assuming noise 200 microvolts} | minimum 0.05 psi | minimum 0.5 psi | minimum 1.0 psi |
| **ENVIRONMENTAL:** | | | |
| **Temperature (±10%)*** | —30°C to +110°C | —30°C to +110°C | —30°C to +110°C |
| **Vibration Sensitivity (max)** | 0.5 mv/g | 0.5 mv/g | 0.75 mv/g |
| **Humidity** | Protected against normal ambient laboratory change in relative humidity and temperature | | |
| **Overload without damage** | 100% | 100% | 50% |
| **Corrosive atmosphere** | Type 303 stainless steel used in all versions (consult metallurgy chart for inertness to corrosive liquids) | | |
| **PHYSICAL:** |  |  |  |
| **Size (excluding connector)** | .75 Hex × 0.6 high | .75 Hex × 0.63 high | .75 Hex × 0.69 high |
| **Weight** | 1.4 oz. | 1.4 oz. | 1.5 oz. |
| **Mounting thread** | 9/16—24 SAE extra fine | 9/16—24 SAE extra fine | 9/16—24 SAE extra fine |
| **Diaphragm area** | 0.123 sq. in. | 0.135 sq. in. | 0.179 sq. in. |
| **Electrical connector** | Felts Microdot #3101 | Felts Microdot #3101 | Felts Microdot #3101 |

**PRIMARY USE LIMITATIONS:** The pickup is designed for use only through the temperature range from—30°C to +110°C (—22°F to +230°F), and as a dynamic measuring device. (Do not consider its use in a static pressure measuring application.)

*MODEL 2502 COOLED PRESSURE PICKUP—±10% TO 2200°F

**PRICES:** 1 unit — $225.00 each   2 to 5 units —$200.00 each   6 and over — $190.00 each

## OTHER ENDEVCO PRODUCTS

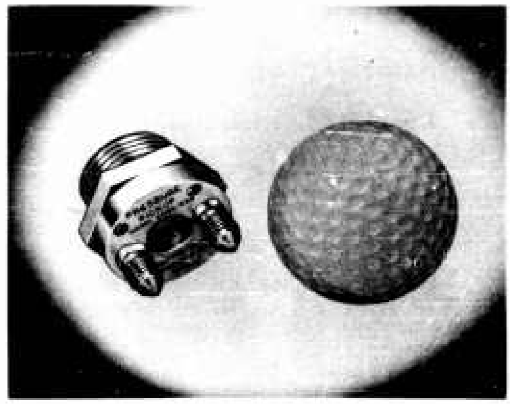
**Include:**

| | |
|---|---|
| **MODEL 2100 FORCE GAGES** | 10 Volt full scale sensitivity and high natural frequencies in full scale ranges of 100 lbs. to 5,000 lbs. |
| **MODEL 2200 ACCELEROMETERS** | High sensitivity, flat to 10 KC, weight less than 1 ounce. Temperature range to 2200°F for larger units. |
| **MODEL 2600 INSTRUMENTATION ELECTRONICS** | Laboratory and subminiature airborne cathode followers, amplifiers (1000 megohms input impedance), power supplies, vacuum tube voltmeters and analyzers. |

ENDEVCO CORPORATION
161 East California Street · Pasadena, California

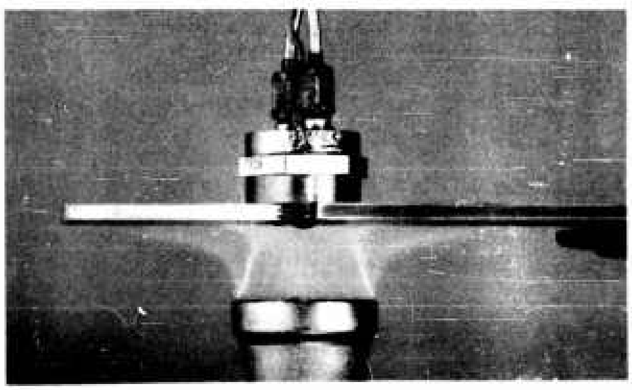


# HIGH TEMPERATURE DYNAMIC PRESSURE PICKUP MODEL 2502



## GENERAL DESCRIPTION:

The Model 2502 Dynamic Pressure Pickup is specifically designed for measuring the pressure of hot gasses and liquids, where the temperatures in the sensing area are as high as 2200°F. This high temperature air or liquid cooled pick-up is designed for flush mounting and has the high frequency design characteristics which permit the measurement of turbulent pressures in rocket engines, jet engines, and other types of explosive or high (2200°F.) temperature devices. The self-generating pickup (piezoelectric ceramic type), does not record the static pressures, so that zero suppression of the static pressure level is possible, thereby providing full scale sensitivity for the measurement of the pressure changes.



The high output sensitivity (30 mv/psi) and ring frequency (50 kc) of the Endevco Model 2501 Piezoelectric Pressure Gages are retained in the Model 2502 and an extremely efficient cooling jacket is provided in order to maintain the temperature of the sensing element within its linear temperature range. The cooling is effected by small amounts of air or liquids being conducted through the passages built in the gage. (see photo). For flight applications, a pressurized gas, such as $CO_2$, may be used and exhausted into the slip-stream so that no recirculating coolant system is needed.

ENDEVCO CORPORATION - 161 East California Street
Pasadena, California

2502

## SPECIFICATIONS

### High Temperature Pressure Pickup, Model 2502

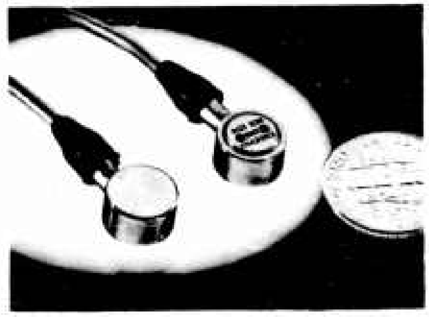
| | 2502-500 | 2502-1000 | 2502-2500 |
|---|---|---|---|
| Sensitivity (Minimum): | 30 mv/psi | 15 mv/psi | 4 mv/psi |
| Maximum Pressures: (100% overload without damage) | 500 psi | 1000 psi | 2500 psi |
| Linearity: | ±1% | ±1% | ±1% |
| Natural Frequency: | 50 kc | 50 kc | 50 kc |
| Frequency Response: | ±5%, 2 cycles to 9000 cycles (for all 3 units) | | |
| Rise Time: | Approximately 10 microseconds (for all 3 units) | | |
| Load Resistance required: | 100 megohms for ±5% frequency response down to 20 cycles, 1000 megohms for frequency response to 2 cycles. | | |
| Capacity w/3' cable: | 300 mmf. | | |
| Linear operating temperature range of diaphragm: | Up to 2200° F. | | |
| Operating temperature range of top and connections: | Up to 400° F. limited by cable and connector. | | |
| Water Pressure required: (2200° F.) | 60 psi for maximum cooling. | | |
| Water Flow required: (2200° F.) | 1000 cc/min. for maximum cooling. | | |
| Size: | 1-1/4" Hex x 1-1/8" high, excluding connectors. | | |
| Material: | Stainless Steel | | |
| Weight: | 4 oz. | | |
| Electrical Connector: | Supplied with #3030 x 36" cable assembly with mating Microdot connector. | | |
| Cooling Connectors: | AN-919-OD | | |
| Mounting: | 1"-14 x 1/2" | | |
| Price: | 1 unit - $350.00; 2-5 units - $325.00 ea; 6 units & over - $315.00 ea. | | |

ENDEVCO CORPORATION - 161 East California Street - Pasadena, California

2503

# A NEW ENDEVCO TURBULENCE GAGE

## Model 2503



For Measuring Turbulent Pressures:

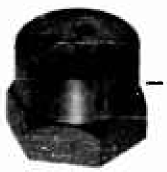
...Wind Tunnel Analysis
...Airfoil Studies
...Gas and Fluid Line Flow
...Noise Level Studies

| | |
|---|---|
| Sensitivity (minimum): - - - - - - - - - - | 40 mv/psi |
| Pressure Range: - - - - - - - - - - - - - | 0 to 10 psi |
| Overload without damage: - - - - - - - - - | 1000 psi |
| Linearity: - - - - - - - - - - - - - - - - - | 1% |
| Natural Frequency: - - - - - - - - - - - - | 50 KC |
| Frequency Response ±5%: - - - - - - - - - | 2 cps to 10 C |
| Load Resistance (required): - - - - - - | 100 megohms low frequency response ±5% to 20 cps<br>1000 megohms low frequency response ±5% to 2 cps |
| Capacity w/3' cable: - - - - - - - - - - - | 400 mmf. |
| Operating Temperature Range: - - - - - - | ±10% -30° to +230° F. (+18% at -100° F.) |
| Vibration Sensitivity: - - - - - - - - - - | Less than 0.2 mv/g |
| Size: - - - - - - - - - - - - - - - - - - | 0.388" Dia. x .255" |
| Effective Diaphragm Area:- - - - - - - - - | 0.250" Dia. |
| Material: - - - - - - - - - - - - - - - - - | Invar |
| Weight: - - - - - - - - - - - - - - - - - - | 3 grams (pickup with cable - 12 grams) |
| Electrical Connector: - - - - - - - - - - | Supplied with integral 36 inch cable assembly and mating Microdot connector. |
| Mounting: - - - - - - - - - - - - - - - - - | Flush mount with O Rings or wax or mount over .250 minimum dia. hole. |
| Price: - - - - - - - - - - - - - - - - - - - | 1 unit - $225.00; 2-5 units - $200.00 ea; 6 units & over - $190.00 ea. |

All units are supplied with individual calibrations and complete instruction manuals.

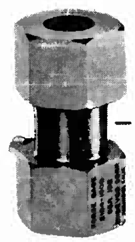
printed in USA 1056

# TRANSDUCERS



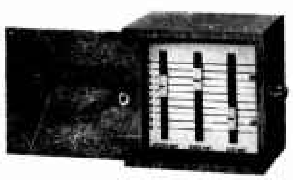
**Accelerometers**
Series 2200 features small size, light weight (0.3 oz.), and large, self-generated output (10 mv/G), without reduction of high natural frequency (40 KC), or large range (50,000 G) for vibration or shock tests.

**Pressure Pickups**
Series 2500 features high ring frequency (55 KC), self-generated outputs (40 mv/psi), and small diaphragm dimensions, for measurement of transient pressures in ranges to 2500 psi for combustion, shock, or pressure wave measurement.



**Force Pickups**
Series 2100 is available for dynamic measurement of force to 5000 pounds with outputs of 30 millivolts per pound for measurement of thrust, forcing functions, drop tests, shock absorbers, etc.

**2200°F Pickups**
Accelerometers and pressure pickups are available in artificially cooled housings for use under high temperature conditions without loss of measurement accuracies.



**Output Standardizers**
Voltage levelers in 0.1% steps are ideal for setting all pickups to the same output sensitivity per unit of measurement improving low frequency response without affecting the high frequency response.

## GENERAL TRANSDUCER DESCRIPTION

Dynamic self-generating piezoelectric pickups are finding wide use in test programs because of their basic design characteristic which generates large outputs for the changing or dynamic variables and suppresses the DC or quiescent values.

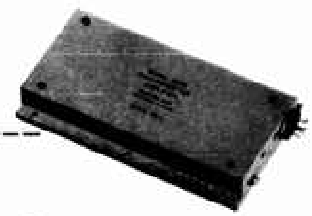
High frequency response and wide ranges (2 cps to 55 KC) suggest the extremes that this pickup features without loss of high output characteristics. Individual pickup calibrations provide the user with authoritative data for use as a secondary dynamic, acceleration, pressure, and force standards.

# ENDEVCO INSTRUMENTATION ELECTRONICS

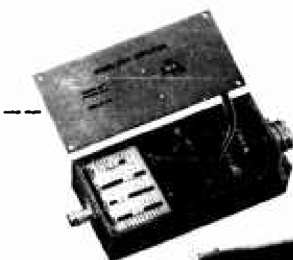
**Cathode Follower, Model 2608**
Subminiature, environmentally protected from vibration, etc., with Gain of 0.95 and frequency response from 2 cps to 20,000 cps.

**Telemetering Amplifier, Model 2607**
A 50 millivolt input into 1000 megohms is amplified to 5 volts for telemetering oscillators with flat response from 2 cps to 20,000 cps. Designed for airborne environments.

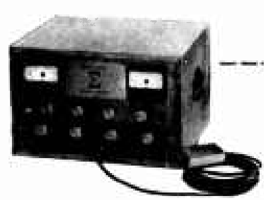
**Galvanometer Amplifier, Model 2609**
An output of 110 ma into 10 ohms for direct galvanometer operation over a frequency range from 5 cps to 5,000 cps are featured in addition to the Model 2607 characteristics.



**Laboratory Input Amplifier, Model 2614**
Impedance transformation from 1000 megohms to 2500 ohms, with voltage Gains of 1, 3, and 10, and an input pickup standardizer, make this an ideal general purpose laboratory unit.



**Power Supplies, Model 2621 and 2622**
AC operated with an extremely low noise DC filament and plate supply for Models 2607, 2608, 2609, and 2614.

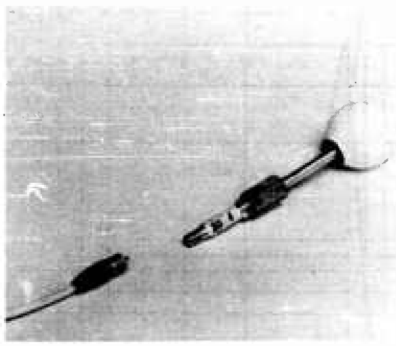


**Meters and Analyzers**
Special purpose vacuum tube voltmeters and analyzers reading in RMS, Peak to Peak, and Pulse Peak volts with high current. Gains to 30 ma. System frequency response from 2 cps to 100,000 cps.

**ENDEVCO CORPORATION**
161 EAST CALIFORNIA STREET, PASADENA, CALIFORNIA

Bulletin P-600

# GLENNITE*HIGH-INTENSITY MICROPHONE
# MODEL P-600



The GLENNITE P-600 Microphone, a major improvement in acoustical engineering, has been developed for the testing, measurement and calibration of high-intensity sound sources. The continual and ever-increasing use of devices such as jet engines, sirens and alarm systems in industrial and military applications has created a demand for a reliable and accurate instrument which can provide precise data on high intensity sounds.

The P-600, a small, lightweight unit utilizing a GLENNITE piezoelectric ceramic as the pickup element, has been specifically designed to meet this need. The microphone, an omni-directional instrument, features simplicity of design, excellent linearity, and high sensitivity .

## ELECTRICAL CHARACTERISTICS

| | |
|---|---|
| Sensitivity: | -106 db referred to 1V/dyne/cm$^2$ |
| Frequency Response: | Flat to 4000 cps |
| Linearity: | Linear response to 168 db (maximum intensity of source used in test) |

## ENVIRONMENTAL SPECIFICATIONS

| | |
|---|---|
| Temperature Range: | To 80°C |
| Isolation Mounting: | Decouples element from support above 10 cps (See Vibration Sensitivity Curve) |

## MECHANICAL SPECIFICATIONS

| | |
|---|---|
| Connectors: | 10-32 thread, mates with GLENNITE C5-P connector on cable |
| Cable: | 6 ft. GLENNITE C5 supplied (other lengths available on request) |
| Dimensions | |
| Size of sensitive element (hollow sphere): | 1.0" outside diameter<br>0.093" wall thickness |
| Overall Length: | 3.63" |
| Weight: | 32 Grams |
| Shipping Weight: | 1 Pound (approx.) |

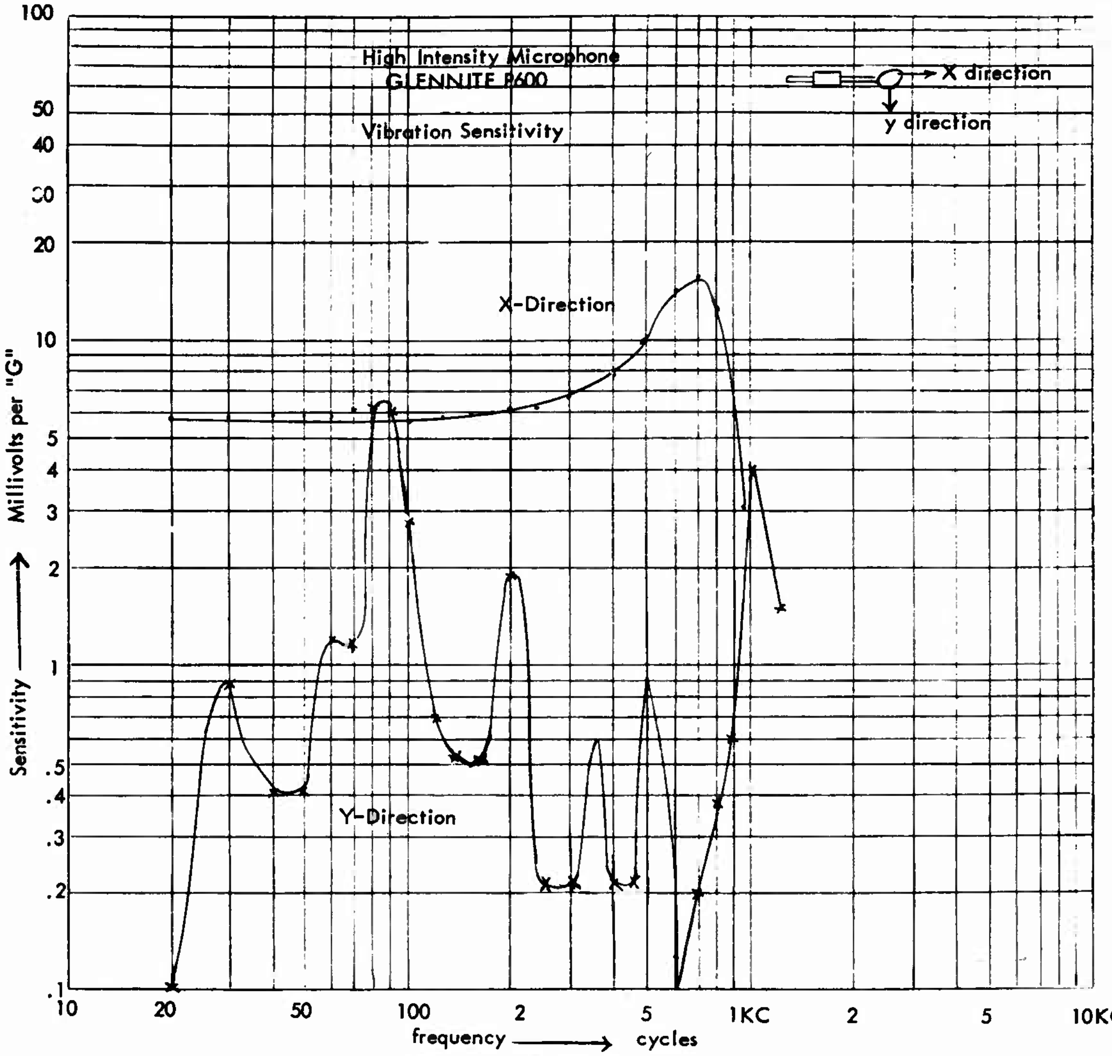
7/57
supersedes
8/55

*Reg. U.S. Pat. Off.

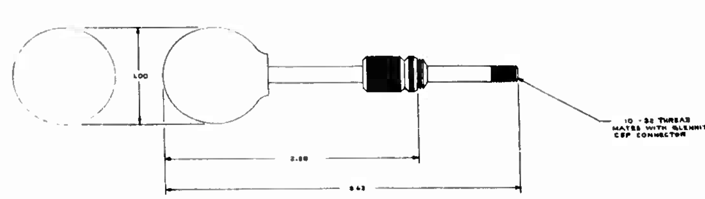


Printed in U. S. A.

VIBRO-CERAMICS DIVISION
Gulton Industries, Inc.
212 Durham Avenue, Metuchen, New Jersey • Telephone: Liberty 8-2800
TWX: 499-Metuchen, N. J.
CABLE: GULTON-METUCHEN

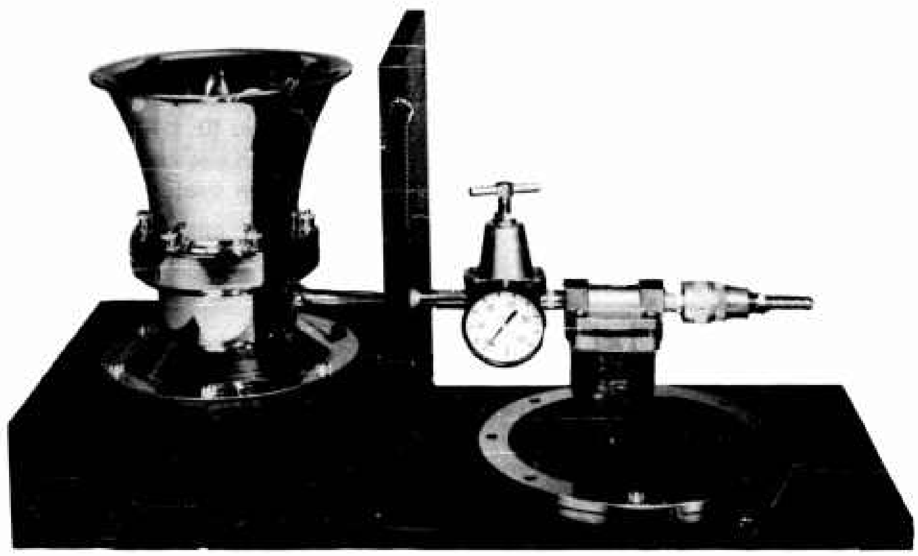



ACOUSTICAL SENSITIVITY
-106 db re 1V/dyne/cm$^2$
Tested ±1 db from 75 to 300 cycles per second



# GLENNITE® MULTIWHISTLE ACOUSTIC AIR-JET GENERATOR
## MODEL RB-12

The GLENNITE Multiwhistle, the newest advance in the art of ultrasonics, considerably broadens the scope of ultrasonics for use in industrial applications such as chemical processing, agglomeration of aerosol particles, acoustic drying, emulsification and cleaning. High power sonic or ultrasonic vibrations have been used successfully for these processes but in many cases the commercial development has been limited by the expense of installation or by environmental factors such as high voltage or corrosive atmospheres.



MULTIWHISTLE

PRESSURE GAUGE AND AIR FILTER - not included but may be ordered separately.

The Multiwhistle may be operated at temperatures up to 1100°F, even in corrosive atmospheres. As there are no moving parts there can be no mechanical breakdown and maintenance is minimized. Driven by compressed air or other gas, the efficiency is high - up to 20% with no extra power requirements. Air pressure is moderate, requiring only 40 to 75 psi. Operating costs are negligible and there are no hazards such as high voltage or rotating parts.

VIBRO-CERAMICS DIVISION
Gulton Industries, Inc.
212 Durham Avenue, Metuchen, New Jersey • Telephone: Liberty 8-2800
TWX: 499-Metuchen, N. J.
CABLE: GULTON-METUCHEN



3/57
Printed in U. S. A.

The generator can operate at any frequency or group of frequencies from 3 KC to 40 KC and whistles can be adjusted individually to give a desired complex wave spectrum. Whistles can be synchronized to a single frequency or high intensity beat patterns can be set up. Frequency stability depends only on a uniform air pressure supply.

Compact and simple in design, it can be used in a relatively small chamber for high sound concentration and, if required, a number of Multiwhistles can be used together in a single chamber.

## APPLICATIONS

1. Agglomeration of Aerosols

   Smokes, mists, and other fine gas-borne suspensions may be broken down. The alternate pressures and rarefactions cause small particles (0.1 to 20 microns) to cohere together, and to reach such a size that they may be easily removed with cyclone separators or similar devices.

2. Acoustic Drying

   Water or other liquids can be extracted by spraying the dissolved or suspended material into the acoustic field. The alternations of pressure literally squeeze the moisture out without substantial temperature rise. Soaps, foodstuffs, pharmaceuticals, and the like have been dried by this technique.

3. Acoustic Testing

   There is an increasing need, particularly in the aircraft and missile field, for environmental test facilities for extremely high intensity acoustic levels. With a reverberation chamber including one or more Multiwhistles, acoustic levels of 160 db or higher can be maintained with any desired spectrum from 3 KC to 40 KC. Lower frequency units are being developed.

4. Chemical Processing

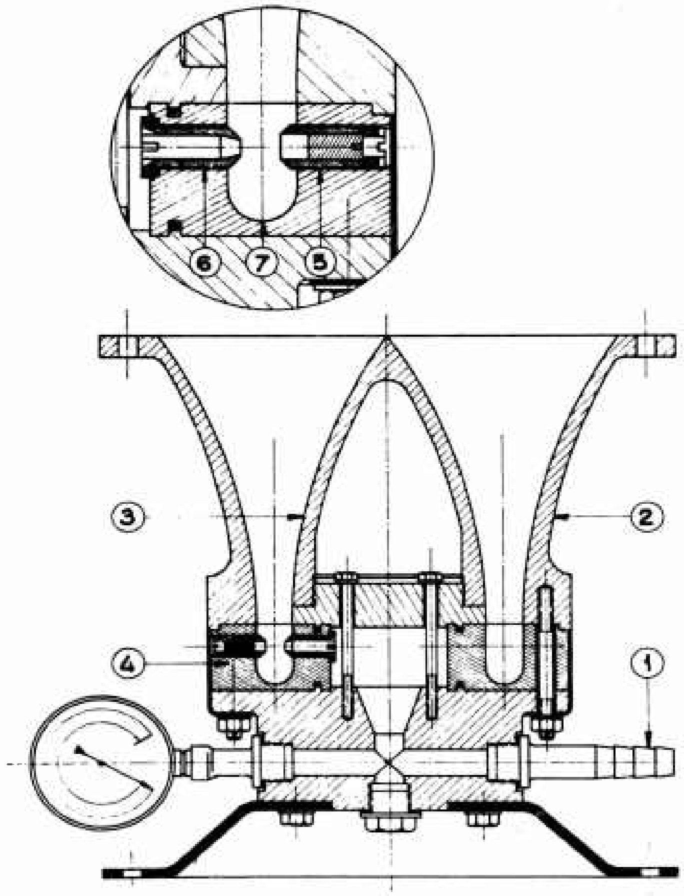
Certain chemical reactions are known to be accelerated by ultrasound. The Multiwhistle is particularly suitable for reactions which take place in a gaseous phase because of its frequency flexibility and its ability to operate in most environments.

5. Liquid Operation

In many operations the low cost and environmental advantages of the Multiwhistle can be used where acoustic energy is to be coupled in liquids. For example emulsification and dispersion in liquids, even of high viscosity, have been accomplished by inverting the Multiwhistle closely over the vessel holding the liquid or by operating on a continuous thin sheet. In spite of the apparent mismatch of impedance, a large share of energy is transferred to the liquid in a series of reflections from the closed horn. In some cases this may prove advantageous over standard techniques employing piezoelectric or magnetostrictive transducers.

## PRINCIPLE OF OPERATION

The Multiwhistle, based on developments in France by Dr. R. Boucher, makes use of a series of gas jets at supersonic velocity, directed at a corresponding group of resonators. Schlieren photographs of the jet show that the sound field is set up by the vibration of a shock wave front resulting from the interaction of the direct air jet and that reflected periodically from the resonator. The operation is basically similar to that of the Hartmann whistle, but the efficiency has been increased from Hartmann's figure of 4 to 5% to approximately 20% by careful adjustment of parameters and by the addition of a secondary resonator system.




Cross-Sectional View of Multiwhistle

Key Index

1. Air Supply Intake
2. Exponential Horn
3. Inner Ogive
4. Whistle Mounting Ring
5. Primary Resonator
6. Supersonic Air Jet Nozzle
7. Secondary Resonator

## SPECIFICATIONS

| | |
|---|---|
| Number of Whistles: | 12 |
| Frequency Range: | 3000 to 40,000 cps (Specify frequency required on order) |
| Power Output: | 400 to 600 Acoustic Watts |
| Air Pressure: | 40 to 75 psi (depending on adjustment and frequency) |
| Air Consumption: | 26 to 55 cu. ft./min. |
| Material: | Stainless Steel (can be made in special materials such as titanium or Hastelloy for even more rigorous environments) |
| Weight: | 50 pounds |
| Shipping Weight: | Approximately 90 pounds |

Interchangeable whistles may be obtained for other frequencies.

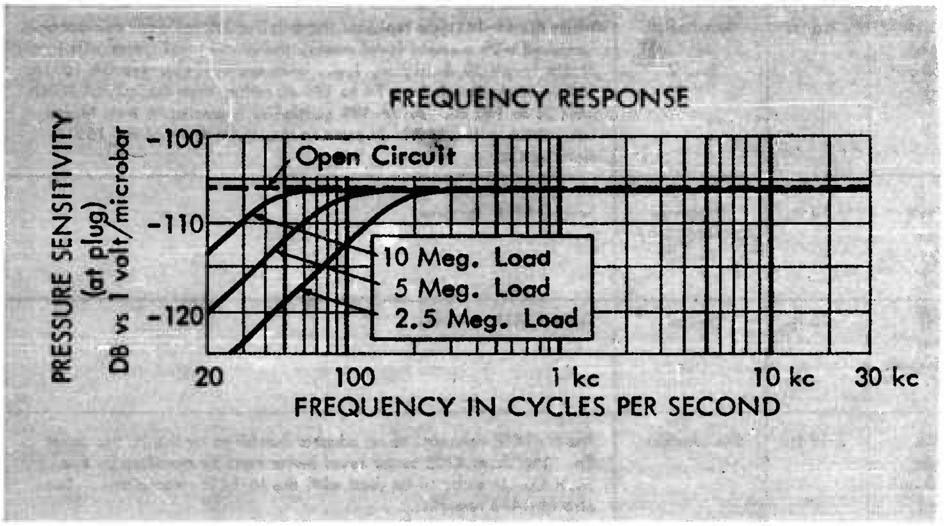
## APPLICATION AND CONSULTING SERVICE

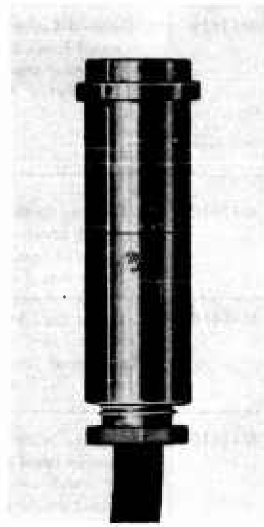
Gulton Industries maintains laboratories for investigation of a wide range of ultrasonic applications using both air jet and electrical generating techniques. These services are available to industry for a moderate charge. Study programs will be arranged to meet customers' needs and will be kept in complete confidence and under the customers' control.

*precision in* *electroacoustics*

# Massa M-141 TYPE HIGH LEVEL MICROPHONES

The M-141 type microphone is a low-cost, rugged instrument designed to meet a growing demand for a general-purpose, standard microphone capable of making simple, direct, accurate measurements of high sound pressure levels and blast pressures. The mechanical structure is stiffness controlled throughout the entire frequency range up to 30 kc, and its acoustic impedance is virtually infinite. These characteristics permit the accurate reproduction of transient pressure waves without distortion even if measurements are made inside small enclosures where other types of microphones would seriously affect the ambient environmental conditions and lead to erroneous data. The microphone will measure rise times of the order of 100 microseconds, thereby showing the steepness of a wave front and giving true information concerning the destructive force of the blast. These microphones meet the requirements of ASA standards for Laboratory Standard Pressure Microphones Type M.



The unit employs the identical ADP crystal assembly being used in the M-125 standard that has been in widespread use for many years. The physical design is such that the microphone can be suspended in a sound field to measure free field pressure or coupled through an opening into the wall of a chamber for making sound pressure measurements therein. Although the maximum operating temperature is 160°F, transient high temperatures such as heat generated by gunfire will have no effect on the unit due to its high thermal inertia.

The microphones can be used directly with any general-purpose metering equipment or sound level meter without the use of a preamplifier or power supply, to make accurate sound pressure measurements from a few microbars to several million microbars over the entire audible frequency range. An integral cable permits remote location of the measurement standard from the metering or recording equipment.

## APPLICATIONS

Analysis of jet noise, propeller noise, engine exhaust, gear noise, etc.

Design of acoustic filters and sound transmission systems.

Pilot microphone for maintaining intensity level of a sound field.

Reference standard for calibrating other microphones.

Shock wave propagation studies - accurate reproduction of instantaneous shock wave.

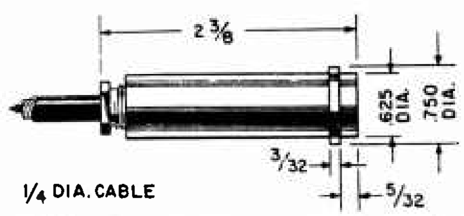
Blast pressure measurements - peak pressures of many psi; true reproduction of steepness of wavefront.

(Over)

The M-141 type microphones and cables are calibrated and adjusted to deliver the same sensitivity level (-106 db versus 1 volt/microbar) at the various meter input terminals. The total capacity of the microphone and cable, including the input capacity of the respective meter, is approximately 500 µµf. The various available M-141 type microphones are listed below.

| Massa Model No. | For Use With | Approx. Cable Length* | Plug | Remarks |
|---|---|---|---|---|
| M-141A | Ballantine 310A VTVM (meter input cap. 20 µµf, Input res. 2.2 meg)<br><br>See remarks also. | 18 ft. | General Radio 274 ND | The M-141A has the most universal application of the various M-141 type microphones available, since it can be used with any metering or recording instrument with an input capacity of 20 µµf. It can also be used with the Massa M-185 amplifier-power supply to permit low level sound measurements.<br><br>When the M-141A is plugged into a Ballantine 310A VTVM, the meter's decibel scale will read directly sound pressure levels from 100 to 200 db. If a "times ten" amplifier is used with the voltmeter, the sound level readings will begin at the 80 db level. |
| M-141B | General Radio 1551A sound level meter (meter input cap. 50 µµf, input res. 7 meg) | 16 ft. | Amphenol 91-3MC3MT Pos. 2 | When the M-141 type replaces the original Rochelle salt microphone furnished with a sound level meter, the sound level meter will indicate levels 50 db higher, i.e., with the M-141B, the GR 1551A will indicate levels from 74 to 190 db rather than the normal levels from 24 to 140 db. An M-188 multiplier is available from Massa Labs which will add 20 db more to the upper limit of the 1551A meter scale. |
| M-141C | General Radio 759B sound level meter (meter input cap. 125 µµf, input res. 7 meg) | 12 ft. | Amphenol 91-3MC3MT Pos. 2 | See M-141B remarks. |
| M-141D | Dawes Ltd. 1400D sound level meter (meter input cap. 50 µµf, input res. 7 meg) | 16 ft. | Special | See M-141B remarks. |
| M-141E | H. H. Scott 410B sound level meter (meter input cap. 20 µµf, input res. 5 meg) | 18 ft. | See remarks | The M-141E connects to an adaptor furnished by the H. H. Scott Co. The Scott 410B sound level meter must be modified by the Scott Co. in order to be used with the M-141E microphone. See also M-141B remarks. |

*Longer cable lengths can be provided on special order if desired, with a corresponding decrease in the standard -106 db sensitivity: 50 ft. -112 db; 100 ft. -118 db; 250 ft. -126 db.



Dimensions of the Massa Model M-141 Standard Microphone.

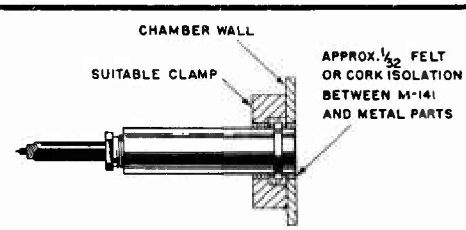
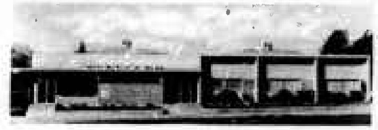


Diagram of recommended installation of the Massa Model M-141 Standard Microphone in the wall of a chamber.

*precision in* *electroacoustics*

MASSA LABORATORIES, INC. Hingham, Massachusetts

CABLE ADDRESS: PHOTOCON PASADENA, CAL.



# Photocon Research Products

421 NORTH ALTADENA DRIVE · PASADENA CALIFORNIA · SYcamore 2-4131 · RYan 1-6751

## PRICE LIST

| | UNIT PRICE |
|---|---|
| DYNAGAGE MODEL DG-400 COMPLETE WITH ONE 25 FOOT CABLE | $965.00 |
| DYNAGAGE MODEL DG-500 PLUG-IN UNIT | 650.00 |
| POWER SUPPLY PS-500 | 210.00 |

### MICROPHONE TRANSDUCERS

#### STRETCHED DIAPHRAGMS

| | |
|---|---|
| MODEL 374AT, 3/4" DIAMETER, .750-40 THREADED SECTION, MAXIMUM PRESSURE 170 DB OR 180 DB. (NOTE: THIS MODEL CAN BE FURNISHED WITHOUT THREADED SECTION AT THE SAME PRICE; BUT CANNOT BE FURNISHED WITH WATER-COOLING.) | 250.00 |
| MODEL 364A, 1" DIAMETER, MAXIMUM PRESSURE LEVEL 154 OR 160 DB | 300.00 |
| MODEL 364 AT, 1.032" DIAMETER, THREADED SHELL 1.032-40 THREAD, MAXIMUM PRESSURE LEVEL 154 OR 160 DB | 310.00 |
| MODEL 364, 1" DIAMETER, MAXIMUM PRESSURE LEVEL 154 OR 160 DB, WATER-COOLED | 350.00 |
| MODEL 364T, 1.032" DIAMETER MAXIMUM PRESSURE LEVEL 154 OR 160 DB, WATER-COOLED, THREADED SHELL 1.032-40 THREAD | 360.00 |
| MODEL 354A 2" DIAMETER, MAXIMUM PRESSURE LEVEL 140 DB | 350.00 |
| MODEL 354 AT, 2.032" DIAMETER, THREADED SHELL, 2.032-40 THREAD, MAXIMUM PRESSURE LEVEL 140 DB | 365.00 |
| MODEL 354, 2" DIAMETER, WATER-COOLED, MAXIMUM PRESSURE LEVEL 140 DB | 400.00 |
| MODEL 354T, 2.032" DIAMETER, THREADED SHELL, 2.032-40 THREAD, WATER-COOLED, MAXIMUM PRESSURE LEVEL 140 DB | 415.00 |

#### SOLID MACHINED DIAPHRAGMS

| | |
|---|---|
| MODEL 320A, 1" DIAMETER, MAXIMUM PRESSURE LEVELS 180, 186, OR 192 DB | 300.00 |
| MODEL 320AT, 1.032" DIAMETER, THREADED SHELL, 1.032-40 THREAD, MAXIMUM PRESSURE LEVEL 180, 186, OR 192 DB | 310.00 |
| MODEL 320, 1" DIAMETER, MAXIMUM PRESSURE LEVEL 180, 186, OR 192 DB, WATER-COOLED | 350.00 |
| MODEL 320T, 1.032" DIAMETER, THREADED SHELL, 1.032-40 THREAD, MAXIMUM PRESSURE LEVEL 180, 186, OR 192 DB, WATER-COOLED | 360.00 |
| ADAPTOR #2154 FOR WESTERN ELECTRIC 640AA | 140.00 |

8/9/57 F.O.B. PASADENA, CALIFORNIA

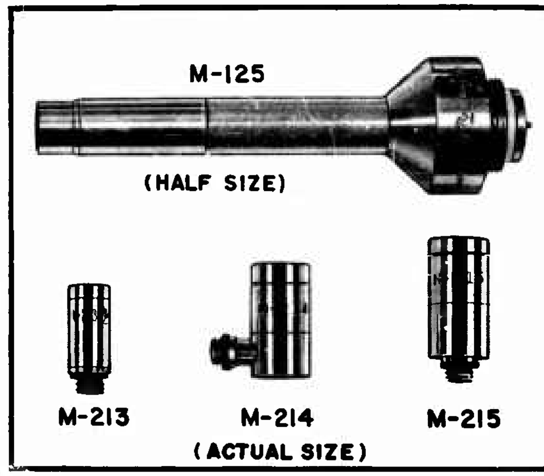
*precision in* *electroacoustics*

# Massa WIDE-RANGE SOUND PRESSURE MEASUREMENT EQUIPMENT

This new line of Massa sound pressure measurement equipment makes available a number of precision instruments which incorporate all the improvements in standard microphone construction developed by Massa Laboratories during the past decade. Hundreds of earlier models of these instruments are in widespread daily use making fundamental acoustic measurements over both the audible and ultrasonic ranges up to levels exceeding 200 db versus .0002 microbars. The present models offer the ultimate in reliability of calibration plus increased flexibility and greater convenience in the accurate measurement of a wide variety of sound fields. All the new standard microphones may be used interchangeably with the same wide-range amplifier equipment described below.

MICROPHONES The new standard microphones have virtually infinite acoustic impedance and are designed for making accurate sound pressure measurements over very wide frequency and dynamic ranges under practically any acoustic environment. The microphones are stiffness controlled over the specified frequency ranges of operation and therefore introduce no phase shift errors, making the new units ideal for the accurate reproduction of acoustic transients. The high acoustic impedance also results in linear response to extremely high magnitudes of sound pressures, so that the microphones are suitable for the measurement of not only conventional sound pressure levels, but also blast pressures and shock waves such as are generated by gunfire or explosions.

The new microphones employ ADP crystal as the active element, and the design is such that the fundamental piezoelectric constant of the material is employed for the conversion of acoustic energy into electrical energy. This means that the microphones behave essentially as primary standards insofar as sensitivity and stability are concerned. The permissible operating temperature range is -40°F to 160°F, the upper limit being set by the cements used in the construction. Higher transient temperatures of short duration such as heat generated by gunfire will not damage the units.




MICROPHONES

APPLICATIONS The smallest structure, Model M-213, is best suited for measuring transients with extremely fast rise times or in making free-field measurements where minimum diffraction errors are desired. This unit is also very well suited to the measurement of sound pressures extending well into the ultrasonic region such as occurs in the exhaust from jets or missiles. Models M-214 and M-215 are somewhat larger than the M-213 but have increased sensitivity, which results in a lower threshold for these units. These new tiny instruments make ideal probe-type elements for accurately measuring the intensity and phase of wave fronts in travelling or standing wave systems. The small cylindrical structures may be conveniently attached, through small circular openings, into walls of conduits or chambers, or they may be easily installed at various specific points inside enclosures where sound pressure measurements are to be made. Model M-125 is the largest of the standards and has the highest sensitivity. This structure has the lowest threshold of the group and is particularly suitable for making accurate calibrations of sound fields throughout the audible frequency spectrum.

SPECIFICATIONS

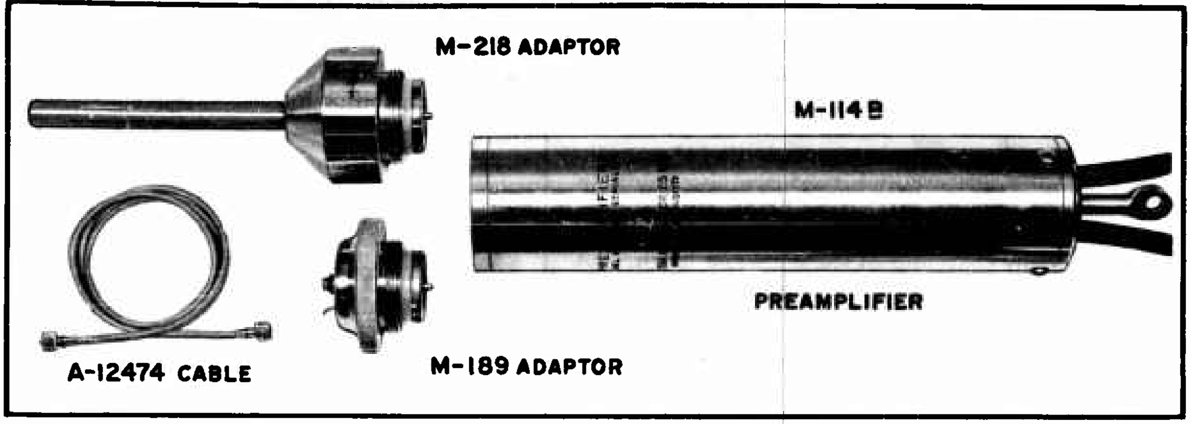
| Model No. | Frequency Range cps | Open Circuit Sensitivity | | Capacity µµf | Dimensions Dia. x Length inches | Weight oz. | Rise Time µsec. | Threshold* db vs. 1 µbar | |
|---|---|---|---|---|---|---|---|---|---|
| | | µV/µbar | db vs. 1 V/µbar | | | | | 1 kc | 10 kc |
| M-125 | 20 - 35,000 | 23.6 | -92.5 | 120 | 5/8 x 5-1/2 | 8.5 | 10 | -66 | -86 |
| M-214<br>M-215 | 20 - 80,000 | 12.5 | -98 | 18 | .344 x 11/16<br>.344 x 3/4 | .2 | 3-1/2 | -52 | -72 |
| M-213 | 20 - 120,000 | 8.0 | -102 | 12 | .236 x 1/2 | .1 | 2-1/2 | -46 | -66 |

* Threshold is the equivalent sound pressure level per 1 cycle band width to generate a signal equal to the thermal noise voltage of the microphone.

Over

ADAPTORS The M-213, M-214 and M-215 microphones may be connected to the M-114B preamplifier by means of the M-218 adaptor, which provides a probe-type mounting for the microphones. For other applications of the microphones, the M-189 adaptor permits the use of a Microdot cable between the microphone and the preamplifier.

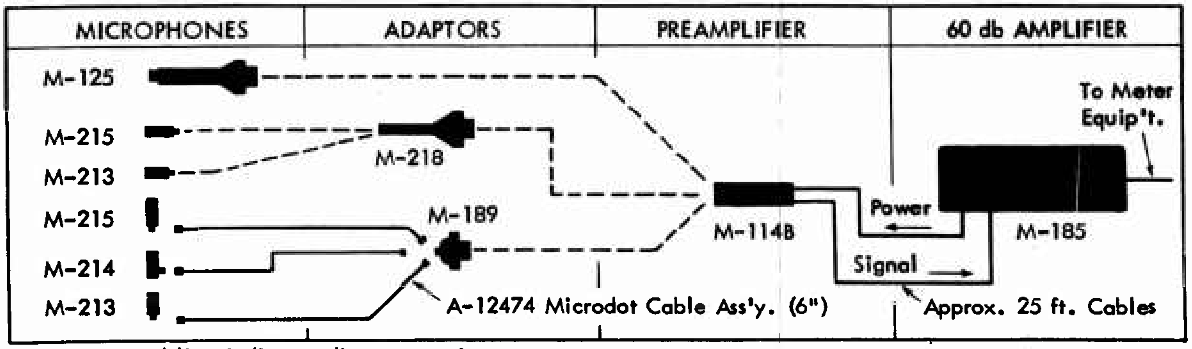
M-114B PREAMPLIFIER The M-114B preamplifier is a low-noise universal coupling preamplifier which is flat from 3 cycles to 300 kc and is designed for use with all Massa standard microphones and accelerometers. It has an input impedance of approximately 200 megohms shunted by 6 μμf, and an output impedance of 600 ohms in series with 1 μf. The preamplifier is contained in a splashproof cylindrical stainless steel housing 1-5/8" diameter by 7" long, and is provided with two 25 ft. cables, one for connection to a power supply and the other for delivering the output signal. The M-114B preamplifier includes a precision calibrating resistor to permit convenient system calibrations when the unit is used with standard Massa microphones or accelerometers.




M-185 AMPLIFIER AND POWER SUPPLY The M-185 amplifier and power supply is an a-c operated precision, 60 db gain amplifier designed to utilize the entire dynamic and frequency ranges of all Massa standard instruments and to provide the power for operating the M-114B preamplifier. An extremely accurate calibrated attenuator with 70 db range is provided for permitting extremely fast and accurate frequency-response measurements or to permit the exact comparison of the sensitivity between a standard and an unknown being calibrated. See Massa Bulletin 185 for more detailed specifications.

M-116D POWER SUPPLY This is a battery-operated power supply which is suitable for field applications where portability and freedom from outside power sources are desired. The M-116D is complete with batteries, battery test meter, and calibrating circuit, and is housed in a cabinet approximately 6-1/2" X 7" X 9" and weighs 13 lbs.

MASSA SOUND PRESSURE MEASUREMENT SYSTEMS EQUIPMENT

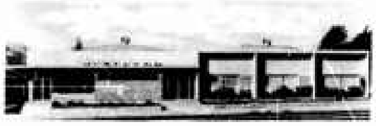



---- Dotted line indicates direct mounting

*precision in electroacoustics*

MASSA LABORATORIES, INC., Hingham, Mass.

CABLE ADDRESS: PHOTOCON PASADENA, CAL.



Photocon Research Products

421 NORTH FOOTHILL BOULEVARD • PASADENA 8, CALIFORNIA • SYCAMORE 2-4131 - RYAN 1-6751

# PRICE LIST

## DYNAGAGE — PRESSURE TRANSDUCERS — ACCESSORIES

| | |
|---|---|
| DYNAGAGE MODEL DG-400 COMPLETE WITH ONE 25 FOOT CABLE | $965.00 |
| AMPLIFIER CA-401 FOR USE WITH GALVANOMETER OSCILLOGRAPH OUTPUT ±40 MILLIAMPERES | 375.00 |

RACK MOUNTING: 8-3/4" X 19" STANDARD PANEL. FINISH - BLACK WRINKLE. OTHER FINISHES CAN BE SUPPLIED ON SPECIAL ORDER.

| | |
|---|---|
| 1 MODEL DG-400 DYNAGAGE COMPLETE WITH 25 FOOT CABLE | 990.00 |
| 2 MODEL DG-400 DYNAGAGES COMPLETE WITH 25 FOOT CABLE | 1970.00 |
| 1 MODEL DG-400 DYNAGAGE AND 1 MODEL CA-401 CURRENT AMPLIFIER | 1375.00 |
| 1 MODEL CA-401 CURRENT AMPLIFIER | 395.00 |
| 2 MODEL CA-401 CURRENT AMPLIFIERS | 780.00 |

## PRESSURE TRANSDUCERS

SINCE MANY OF OUR TRANSDUCERS ARE SUBJECTED TO EXTREMELY SEVERE OPERATING CONDITIONS, WE HAVE A CONTINUOUS RESEARCH AND DEVELOPMENT PROGRAM TO IMPROVE OUR TRANSDUCERS. WE RESERVE THE RIGHT TO DISCONTINUE MODELS AND TO SUBSTITUTE IMPROVED MODELS OF OUR TRANSDUCERS AS RAPIDLY AS DEVELOPED. OUR CUSTOMERS WILL BE NOTIFIED OF ANY MAJOR CHANGE IN PHYSICAL DIMENSIONS WHICH MIGHT AFFECT THEIR INSTALLATION.

18MM TRANSDUCERS:

| MODEL | COOLING | DIAPHRAGM | MAXIMUM RATED PRESSURES (PSI) | PRICE |
|---|---|---|---|---|
| 301A | NONE | FLUSH | 10 TO 5,000 | $250.00 |
| 301AR | NONE | RECESSED | 25 TO 7,500 | 275.00 |
| 301AR | NONE | RECESSED | 10,000 TO 25,000 | 300.00 |
| 321 | WATER | FLUSH | 500 TO 2,000 | 350.00 |
| 334 | WATER | PROTECTED | 1 TO 10 | 325.00 |
| 334A | NONE | PROTECTED | 1 TO 10 | 250.00 |
| 341 | WATER | FLUSH | 15 TO 100 | 375.00 |
| 341 | WATER | FLUSH | 250 TO 2,000 | 350.00 |
| 341 | WATER | FLUSH | 3,000 TO 5,000 | 375.00 |
| 341R | WATER | RECESSED | 15 TO 100 | 400.00 |
| 341R | WATER | RECESSED | 250 TO 2,000 | 375.00 |
| 341R | WATER | RECESSED | 3,000 TO 25,000 | 400.00 |

1"-14 TRANSDUCERS:

| MODEL | COOLING | DIAPHRAGM | MAXIMUM RATED PRESSURES (PSI) | PRICE |
|---|---|---|---|---|
| 302A | NONE | FLUSH | 10 TO 10,000 | 250.00 |
| 302AR | NONE | RECESSED | 25 TO 7,500 | 275.00 |
| 302AR | NONE | RECESSED | 10,000 TO 25,000 | 300.00 |
| 302AR | NONE | RECESSED | 35,000 TO 75,000 | 325.00 |
| 322 | WATER | FLUSH | 500 TO 2,000 | 350.00 |
| 324 | WATER | PROTECTED | .25 TO 10 | 325.00 |
| 324A | NONE | PROTECTED | .25 TO 10 | 250.00 |
| 342 | WATER | FLUSH | 15 TO 100 | 375.00 |
| 342 | WATER | FLUSH | 250 TO 2,000 | 350.00 |
| 342 | WATER | FLUSH | 3,000 TO 5,000 | 375.00 |
| 342R | WATER | RECESSED | 15 TO 100 | 400.00 |
| 342R | WATER | RECESSED | 250 TO 2,000 | 375.00 |
| 342R | WATER | RECESSED | 3,000 TO 25,000 | 400.00 |
| 342R | WATER | RECESSED | 35,000 TO 75,000 | 425.00 |
| MODEL 325 - SPECIAL WATER-COOLED TRANSDUCER | | | 500 TO 2,000 | 350.00 |

14MM TRANSDUCERS:

| MODEL | COOLING | DIAPHRAGM | MAXIMUM RATED PRESSURES (PSIG) | PRICE |
|---|---|---|---|---|
| 303A | NONE | FLUSH | 30 TO 5,000 | 250.00 |
| 303AR | NONE | RECESSED | 30 TO 5,000 | 275.00 |
| 303 | WATER | FLUSH | 30 TO 100 | 375.00 |
| 303 | WATER | FLUSH | 250 TO 2,000 | 350.00 |
| 303 | WATER | FLUSH | 3,000 TO 5,000 | 375.00 |
| 303R | WATER | RECESSED | 30 TO 100 | 400.00 |
| 303R | WATER | RECESSED | 250 TO 2,000 | 375.00 |
| 303R | WATER | RECESSED | 3,000 TO 5,000 | 400.00 |
| 323 | WATER | FLUSH | 500 TO 2,000 | 350.00 |

TRANSDUCERS WITH RECESSED DIAPHRAGMS ARE FABRICATED WITH THE DIAPHRAGM LOCATED AT THE TOP OF THE THREADED SECTION OF THE TRANSDUCER.

MICROPHONES AND LOW PRESSURE TRANSDUCERS WITH REPLACEABLE STRETCHED DIAPHRAGMS:
DIAPHRAGMS ARE PROTECTED BY A PERFORATED METAL PLATE.

| MODEL | MOUNTING THREAD | COOLING | MAXIMUM RATED PRESSURES (PSI) | PRICE |
|---|---|---|---|---|
| 304A | NONE | NONE | .25 TO 10 | $225.00 |
| 304 | NONE | WATER | .25 TO 10 | 300.00 |
| 324A | 1"-14 | NONE | .25 TO 10 | 250.00 |
| 324 | 1"-14 | WATER | .25 TO 10 | 325.00 |
| 334A | 18MM | NONE | 1 TO 10 | 250.00 |
| 334 | 18MM | WATER | 1 TO 10 | 325.00 |

PLEASE SPECIFY MAXIMUM SOUND LEVEL.

## ACCESSORIES

CARRYING CASE: TOP GRAIN COWHIDE LEATHER, NATURAL FINISH.
FOR: DYNAGAGE DG-400 — 39.50
CURRENT AMPLIFIER CA-401 — 39.50

CABLES FOR CONNECTING PRESSURE TRANSDUCERS WITH BAYONET CONNECTORS TO DYNAGAGE:

| | | |
|---|---|---|
| 1 | CB-25 CABLE - 25 FEET LONG | 18.75 |
| 1 | CB-50 CABLE - 50 FEET LONG | 21.25 |
| 1 | CB-100 CABLE - 100 FEET LONG | 26.25 |

CABLES FOR CONNECTING PRESSURE TRANSDUCERS WITH SCREW CONNECTORS TO DYNAGAGE:

| | | |
|---|---|---|
| 1 | CS-25 CABLE - 25 FEET LONG | 22.75 |
| 1 | CS-50 CABLE - 50 FEET LONG | 25.25 |
| 1 | CS-100 CABLE - 100 FEET LONG | 30.25 |

SPECIAL TEFLON CABLES FOR AMBIENT TEMPERATURES 175°F. TO 450°F. FOR CONNECTING PRESSURE TRANSDUCERS WITH BAYONET CONNECTORS TO DYNAGAGE:

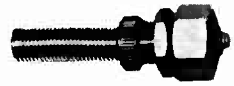
| | | |
|---|---|---|
| 1 | TCB-10 CABLE - 10 FEET LONG | 25.00 |
| 1 | TCB-25 CABLE - 25 FEET LONG | 37.00 |
| 1 | TCB-50 CABLE - 50 FEET LONG | 59.00 |

SPECIAL TEFLON CABLES FOR AMBIENT TEMPERATURES 175°F. TO 450°F. FOR CONNECTING PRESSURE TRANSDUCERS WITH SCREW CONNECTORS TO DYNAGAGE:

| | | |
|---|---|---|
| 1 | TCS-10 CABLE - 10 FEET LONG | 29.00 |
| 1 | TCS-25 CABLE - 25 FEET LONG | 41.00 |
| 1 | TCS-50 CABLE - 50 FEET LONG | 63.00 |

NOTE: CABLE LENGTHS UP TO 1200 FEET CAN BE SUPPLIED WITH SPECIAL CABLE ADAPTORS. RECOMMENDATIONS AND PRICES WILL BE FURNISHED ON REQUEST.

CONNECTORS:



| | | |
|---|---|---|
| 1531 | SPECIAL CABLE CONNECTORS FOR STANDARD TRANSDUCER (BAYONET TYPE) | 3.50 |
| 1536 | SPECIAL CABLE CONNECTOR FOR STANDARD TRANSDUCER (SCREW TYPE) | 7.50 |

(THE BAYONET CONNECTION IS RECOMMENDED FOR ALL NEW INSTALLATIONS.)

FLEXIBLE METALLIC WATER TUBES FOR HIGH TEMPERATURE APPLICATIONS:

| PART NO. | FOR TRANSDUCERS: | |
|---|---|---|
| 1869 | 301, 304, 309, 321, 324, 334, 341 | 7.00 |
| 1870 | 325 | 7.00 |
| 1871 | 302, 322, 342 | 10.00 |

(LENGTH 16")

FLEXIBLE RUBBER WATER TUBING:

| | | |
|---|---|---|
| 1/8" x 3/16" RUBBER TUBING | PER FOOT | .10 |
| MINIATURE HOSE CLAMPS FOR 301, 304, 309, 321, 324, 334, 341, AND 325 TRANSDUCERS | EACH | .25 |

GASKETS:

| | |
|---|---|
| SOLID SOFT COPPER GASKET FOR 1"-14 SHOULDER SEALING | .35 |
| SOLID SOFT COPPER GASKET FOR 1"-14 BOTTOM SEALING | .25 |

TERMS: F.O.B. PASADENA, CALIFORNIA; NET 30 DAYS.

JANUARY 30, 1956

SHEET 1157

# DG-500 PLUG IN DYNAGAGE


The DG-500, used with Photocon's microphones and pressure transducers measures sound levels from 50 decibels to pressures of 75,000 psig with frequency response from 0 to 15,000 cycles per second. A dynamic range exceeding 80 decibels gives an excellent signal to noise ratio for use with microphone transducers.

The DG-500 used with Photocon's proximity and displacement transducers measures movements from .000001 inch to 2 inches over a wide frequency range.

The DG-500 Dynagage is available as a plug-in unit for all Tektronix oscilloscopes in the 530 and 540 series, and may be ordered separately or complete with oscilloscope.

An auxiliary housing and power supply, PS-500 is available for operating the DG-500 Dynagage as a separate instrument independent of the oscilloscope.

A separate low impedence output connector is provided to operate auxiliary readout instruments.

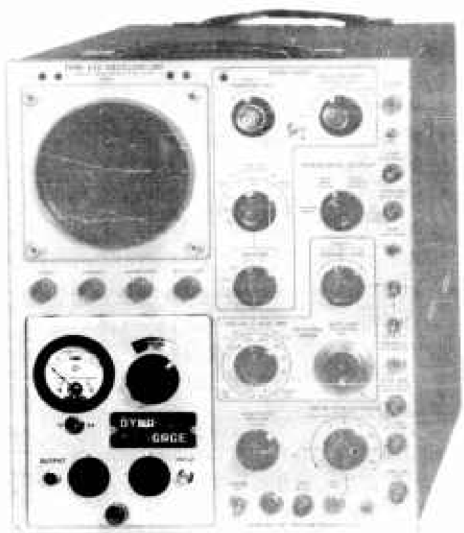
**An electronic instrument for the measurement of static and dynamic pressures and displacements.**

**• Rocket and Jet Propulsion studies • Blast Pressures • High Level Sound • Shock Tubes • Underwater Explosions • Hydraulic Systems • Automotive, Aircraft, and Diesel Internal Combustion Engines • Compressors • Pumps • and similar applications.**

The DG-500 Dynagage is a compact versatile instrument designed as a plug-in unit for Tektronix Oscilloscopes. Wherever static and dynamic pressures or displacements must be accurately measured or photographed, this combination Dynagage-Oscilloscope finds wide application.

## OUTSTANDING FEATURES . . .

- **Wide Frequency Response:**
  0 to 15,000 cycles per second.
- **Ease of Calibration:**
  Transducers calibrated with static pressures.
- **Ease of Operation:**
  Simple three step adjustment.
- **Remote Operation:**
  Transducer cable lengths up to 1000 feet. Eliminates the necessity of mounting the electrical equipment where it may be subjected to excessive noise and vibration.
- **High Level Output:**
  Eliminates the need for high gain amplifiers with a corresponding reduction in extraneous signal pickup.



**DG-500 PLUG-IN DYNAGAGE**
**With Tektronix Model 535 Oscilloscope**

*Designed & Manufactured by*

**PHOTOCON RESEARCH PRODUCTS**

## PRINCIPLE OF OPERATION

The diaphragm of the pressure transducer in conjunction with an insulated electrode form an electrical capacitor. The pressures to be measured are applied to the diaphragm which produces small changes in capacity proportional to the pressure. This capacity is connected to an inductance which has been built into the pressure transducer to form a tuned radio frequency circuit. This circuit is link-coupled by means of low impedance cable to the oscillator-detector circuit or Dynagage. The Dynagage consists of a radio frequency oscillator coupled to a diode detector circuit. The small changes in capacity of the pressure transducer produce relatively large changes in the diode detector impedance. The output of the detector is therefore proportional to the pressure applied to the transducer diaphragm.

The filtered-rectified output of the detector is coupled through a single stage amplifier for driving the cathode ray oscillograph.


**PS-500 POWER SUPPLY**

- **Input:** 105-125 V.A.C., 60 cps, 50 watts
- **Size:** 10½"W x 8"H x 11"D.
- **Weight:** 12 pounds

**Frequency Response DG-500**

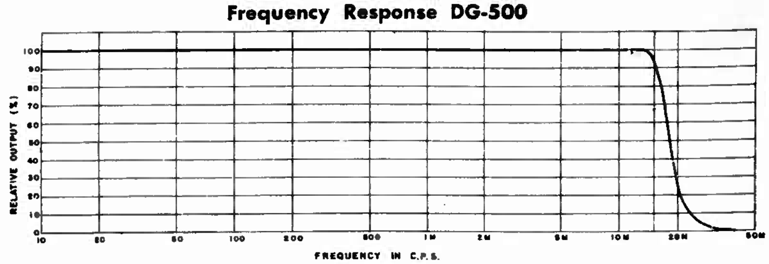



**Figure 3**

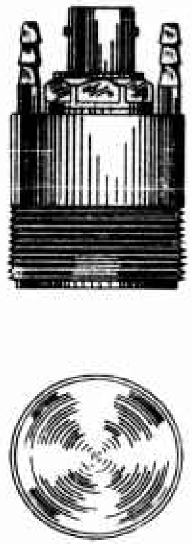
## SPECIFICATIONS

- **Frequency Response:**
  ±3% 0 - 10,000 cps (Figure 3)
  ±5% 0 - 15,000 cps
- **Linearity:**
  Dependent on transducer and cable length.
  Normally less than ±2% deviation from the best straight line.
- **Resolution:**
  Greater than 1 part in 10,000 (80 db).
- **Square Wave Rise Time:**
  40 Microseconds.
- **Front Panel Controls:**
  Tuning: 5/1 vernier tunes all Photocon transducers.
  Vertical positioning: 10 turn potentiometer.
  Gain: 9 step attenuator, 3 db. per step with 1% accuracy.
  Gain multiplier: (4x) increases gain to vertical amplifier by four times.
- **Front Panel Connectors:**
  Input: UG-1094/U with UG-88C/U
  Output: AN-3102A 8S1S with AN-3106A 8S1P
- **Input Cable:**
  25 feet RG58A/U standard length (CB-25).
  Cable lengths up to 1000 feet available on special order.
  Teflon cables available for high temperature applications.
- **Auxiliary Output:**
  Internal impedance: 1500 ohms.
  Output load impedance: 50,000 ohms or higher.
  Output voltage: ±15 volts maximum.
- **Power Requirements:**
  Supplied by Tektronix oscilloscope or
  Photocon PS-500 Power Supply.
- **Housing:**
  Plate aluminum.
- **Finish:**
  Natural aluminum.
- **Size:**
  5⅜"W x 9¼"D x 6⅜"H.
- **Weight:**
  10 pounds.

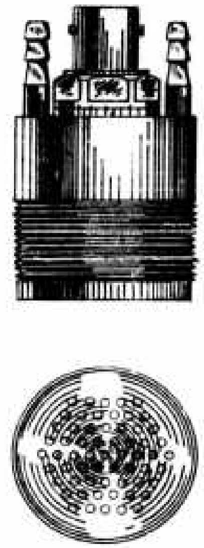
Specifications subject to change without notice.

**PHOTOCON RESEARCH PRODUCTS**
*421 N. Altadena Dr., Pasadena, California; SYcamore 2-4131, RYan 1-6751*

# PHOTOCON CONDENSER MICROPHONES

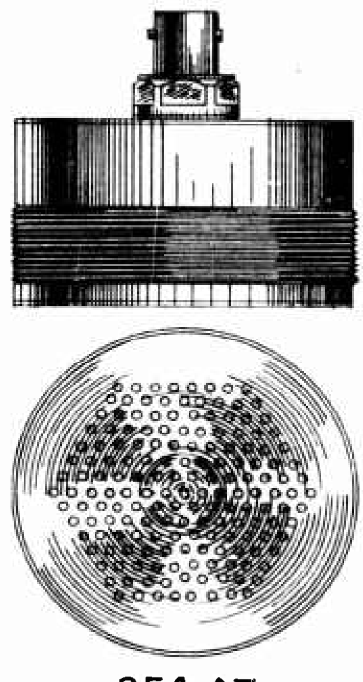


320-T



364-T

374-AT



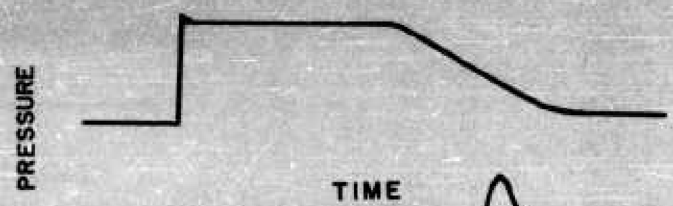
354-AT

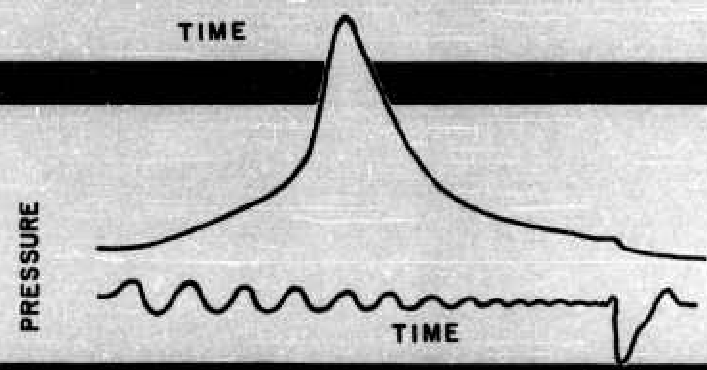
Full Scale


**PHOTOCON RESEARCH PRODUCTS**

421 No. Altadena Drive

Pasadena — California


MODEL DG-400

# the new dynagage

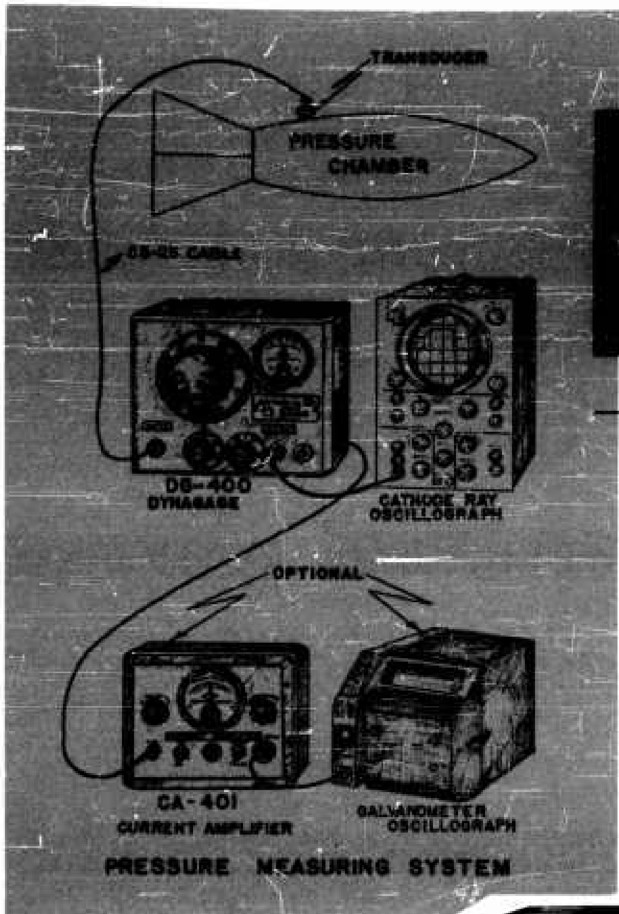
## An electronic instrument for measuring static and dynamic pressures

AUTOMOTIVE, AIRCRAFT, AND DIESEL INTERNAL COMBUSTION ENGINES • JET AND ROCKET PROPULSION STUDIES • HYDRAULIC SYSTEMS • AIR BLAST PRESSURES • UNDERWATER EXPLOSIONS • COMPRESSORS • PUMPS • HIGH LEVEL SOUND MEASUREMENTS • OTHER SIMILAR APPLICATIONS

*designed and produced by*

**PHOTOCON RESEARCH PRODUCTS**

*421 N. Foothill Blvd., Pasadena 8, Calif.*



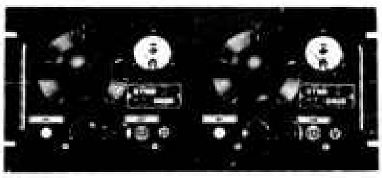
PRESSURE MEASURING SYSTEM

# THE NEW dynagage DG-400

**COMPACT · LIGHTWEIGHT · SIMPLIFIED TUNING**

## *Outstanding Features*

- Pressure ranges from .25 PSI to 75,000 PSI.
- Outputs up to 15 volts into a 25,000 ohm load.
- Frequency response from 0 to 20,000 C.P.S.
- Flush diaphragm construction.
- High stability with water cooling.
- Insensitivity to cable vibrations.
- Insensitivity to vibration and shock.
- Stainless steel construction.



Two DG-400 Dynagages mounted in a single 8 ¾" x 19" steel rack.


### Versatile, Positive, Dependable

The Model DG-400 Dynagage is an extremely versatile instrument for measuring static and dynamic pressures under the most adverse conditions. It has found wide application for measuring pressures in automotive and aircraft internal combustion engines, jet and rocket propulsion studies, hydraulic systems, air blast pressures, underwater explosions, compressors, pumps, high level sound measurements, and other similar applications.

The Model DG-400 Dynagage replaces the DG-101 Dynagage and PS-102 Power Supply with improved performance, 75 per cent reduction in size and weight, and simplified tuning.

**REFERENCE:**
**An Improved Indicator for Measuring Static and Dynamic Pressures by C. E. Grinstead, R. N. Frawley, H. F. Schultz, and F. W. Chapman, SAE Journal (Transactions) Vol. 52 No. 11, Pages 534-556.**

## DYNAGAGE DG-400

• Output—±15 volts • Output Impedance—3500 ohms • Output Load Impedance—25,000 ohms or higher • Frequency Response—±3% 0-10,000 C.P.S., 60% at 20,000 C.P.S. • Gain Control—9 step, 3 DB. per step • Power Requirements—105-130 V. A.C. 60 C.P.S. 50 watts • Size 8½" W x 11½" D x 7" H. Cast aluminum case. • Weight—25 lbs. • Standard cable length (Dynagage to Transducer) 25 ft. • Special cable lengths up to 1000 feet available • Special Teflon jacketed cable available for high ambient temperatures.

A DG-400 Dynagage and a CA-401 Current Amplifier mounted in a single 8 ¾"x 19" steel rack.

## CA-401 CURRENT AMPLIFIER

A stable - linear - direct coupled amplifier with a frequency response from 0-20,000 cycles per second and output current up to ± 40 milliamperes is available for driving high frequency galvanometer oscillographs and other applications.

# An Electronic Instrument for Measuring Static and Dynamic Pressures

**AUTOMOTIVE, AIRCRAFT, AND DIESEL INTERNAL COMBUSTION ENGINES • JET AND ROCKET PROPULSION STUDIES • HYDRAULIC SYSTEMS • AIR BLAST PRESSURES • UNDERWATER EXPLOSIONS • COMPRESSORS • PUMPS • HIGH LEVEL SOUND MEASUREMENTS • AND OTHER SIMILAR APPLICATIONS**

## *Features of the* dynagage transducer system

**1.** A wide range of pressure transducers are available for measuring pressures from 1 PSI to 75,000 PSI.

**2.** Pressure transducers are available with water cooled diaphragms for measuring pressures at high temperatures.

**3.** The physical dimensions of the transducer are small enough to facilitate installation of modern engines.

**4.** The construction is compact and rigid enough to minimize the effects of severe vibration, that is, the inertia forces are small.

**5.** The natural frequency response of the elastic system is usually well above the frequency encountered in pressure measurements. (Pressure changes as high as 6000 C.P.S. are common in the combustion chamber of some engines under detonating conditions.) The natural frequency of the diaphragm of a 1000 PSI transducer is over 50,000 C.P.S.

**6.** Several models of the transducers are constructed so that they can be installed with their diaphragms flush with the walls of the pressure chamber. This type of installation eliminates the possibility of surge effects in connecting passages and avoids a change in chamber shape and volume.

**7.** The design provides adequate electrical shielding and a convenient means of cable connection.

**8.** The pressure transducer may be located remotely from its associated electrical equipment. Cable lengths up to 1000 feet can be used with a special adapter. The importance of this remote operation is well illustrated in applications on propeller torque stands, dynamometer rooms and firing pits. This feature also eliminates the necessity of mounting the electrical equipment near the pressure source where it may be subjected to air blasts, noise and excessive temperatures.

**9.** The high level voltage output of the Dynagage eliminates the need for high gain amplifiers, with a corresponding reduction in extraneous signal pickups.

**10.** The stainless steel construction of the transducers is resistant to highly corrosive atmospheres.

**11.** A completely new internal construction of the pressure transducer has resulted in improved cooling of the diaphragm. This new construction has practically eliminated zero shift with thread stretching and heating, with a subsequent reduction in shock noise transmission through the threads.

## *Principle of Operation*

The diaphragm of the pressure transducer in conjunction with an insulated electrode form an electrical capacitor. The pressures to be measured are applied to the diaphragm which produces small changes in capacity proportional to the pressure. This capacity is connected to an inductance which has been built into the pressure indicator to form a tuned radio frequency circuit. This circuit is link-coupled by means of low impedance cable to the oscillator-detector circuit or Dynagage. The Dynagage consists of a radio frequency oscillator coupled to a diode detector circuit. The small changes in capacity of the pressure transducer produce relatively large changes in the diode detector impedance. The output of the detector is therefore proportional to the pressure applied to the transducer diaphragm.

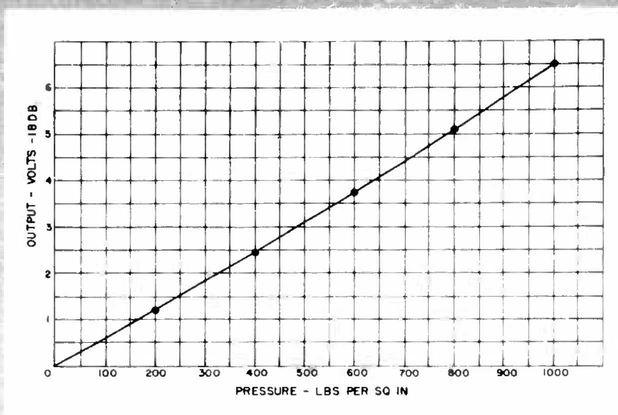
The filtered-rectified output of the detector is coupled through a single stage cathode follower amplifier for driving a cathode ray oscillograph, or a current amplifier for a mechanical oscillograph.

The Dynagage is housed in a cast aluminum case to provide rigid construction.

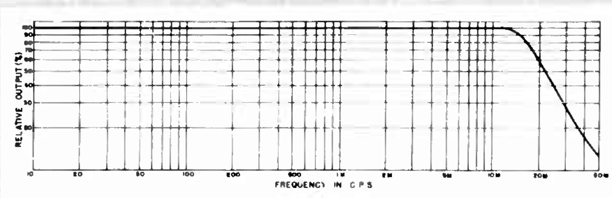
# dynagage

**THE FIRST PRESSURE TRANSDUCER CAPABLE OF MEASUREMENT AT 6000° F.**

**Typical Dynagage Performance Curves**




Output Voltage of Dynagage vs. Pressure in PSI of a 1000 PSI Transducer.




Overall Frequency Response of Standard Dynagage, Transducer and Cables.

## STANDARD PRESSURE RANGES AVAILABLE

| PSIG | PSIG | PSIG |
|---|---|---|
| 0-.25 | 0-30 | 0-3,000 |
| 0-1* | 0-50 | 0-5,000** |
| 0-2.5* | 0-100 | 0-7,500** |
| 0-5* | 0-250 | 0-10,000**† |
| 0-10 | 0-500 | 0-25,000**† |
| 0-15 | 0-1,000 | 0-50,000**† |
| 0-25 | 0-2,000 | 0-75,000**† |

*Available in non-cooled pickups only.
**Bottom sealing of threads recommended.
†Available in Model 342R recessed diaphragm.

*Note:* A complete list of Pressure Transducers, recommended operating ranges and accessories for installation, are shown on supplementary sheets.

The Photocon capacitive type pressure transducers have undergone major redesign, resulting in improved performance characteristics, so that they are now capable of operating at temperatures up to 6000° F., in highly corrosive atmospheres, with the broadest range of measurement parameters. The highly stable characteristics exhibited at elevated temperatures, under high vibration, provide an instrument that is outstanding for any pressure measurements.

## TYPICAL SPECIFICATIONS

**For Capacitive Type Pressure Transducers**
**1000 P.S.I. — Water Cooled**

Accuracy: ±3%.

Repeatability: ±1%.

Resolution: Greater than 1 part in 1000.

Temperature Coefficient: Less than ±.005%/° F. change in ambient temperature.

Hysteresis: Less than 0.1% of full scale output.

Linearity: Less than 2% deviation from the best straight line.

Vibration: Less than 0.1% of full scale output for 10 G.'s from 0-100 C.P.S.

Overload: 100% safety factor up to 5000 P.S.I.

Temperature Range Body: —50° F. to 400° F. ambient temperature.

Diaphragm: —50° F. to 6,000° F.

Diaphragm Response: 100% rise time in less than 50 microseconds.

PRP

*Specifications subject to change without notice.*

56-8

**PHOTOCON RESEARCH PRODUCTS**
421 North Foothill Blvd. • Pasadena 8, California • SYcamore 2-4131 • RYan 1-6751

Bulletin No. PG260TC (1)
October, 1956

Statham
LABORATORIES, INC.

# SPECIFICATIONS

## MODEL PG260TC PRESSURE TRANSDUCERS

### for the measurement of gage pressures to +400° F.

RANGES: 0-5 to 0-500 psig. See Col. 2 of Selection Table.

PRESSURE MEDIA: Non-corrosive fluids.

MAXIMUM ALLOWABLE PRESSURE: Two times range. See Col. 3 of Selection Table.

TRANSDUCTION: Resistive, complete balanced bridge, Statham unbonded strain gage as described in Bulletin No. 1.0.

NOMINAL BRIDGE RESISTANCE: 350 ohms.

EXCITATION: 5 volts DC or AC (rms), including carrier frequencies.

OUTPUT: 20 millivolts full scale open circuit at 5 volts excitation.

*Because of the stepless character of the output, the ultimate resolution of these pressure transducers is limited only by the characteristics of the receiver.*

NON-LINEARITY AND HYSTERESIS: Not more than ±1% of full scale.

NATURAL FREQUENCY: See Col. 4 of Selection Table.

ACCELERATION RESPONSE: See Cols. 5 and 6 of Selection Table.

*This model is designed not only for the measurement of pressure at elevated temperatures but also for use in the presence of vibration or acceleration.*

AMBIENT TEMPERATURE LIMITS: −100° to +400° F.

THERMAL COEFFICIENT OF SENSITIVITY: 0.01%/°F. from −65° to +400° F.

*(Please state the impedance of the receiving instrument.)*

THERMAL ZERO SHIFT: 0.01%fs/°F. from −65° to +400° F.

PRESSURE CONNECTION: Flush diaphragm.

*Interchangeable adapters are offered to convert the basic transducer into a chamber-type pressure transducer.*

ELECTRICAL CONNECTION: Four numbered terminal pins.

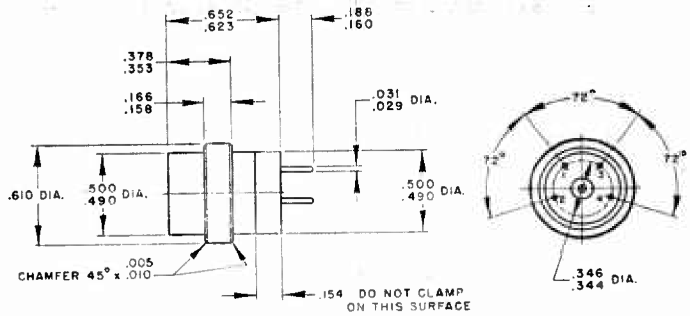
*(A suitable solder is Kirkson No. B95G (94½% lead; 5½% silver), or equal.)*

CALIBRATION: Statham pressure transducers are calibrated individually by qualified technicians using specialized equipment of laboratory accuracy. Pertinent performance data are furnished in a certificate at time of shipment.

IDENTIFICATION: RED banding and lettering indicate transducers for operation to +400° F. The model designation, serial number, range, excitation voltage and manufacturer are permanently marked on each instrument.

## SELECTION TABLE

| — 1 — MODEL DESIGNATION | — 2 — PRESSURE RANGE | — 3 — MAXIMUM ALLOWABLE PRESSURE | — 4 — APPROXIMATE NATURAL FREQUENCY | LINEAR ACCELERATION RESPONSE ALONG ANY AXIS: — 5 — APPROXIMATE VIBRATORY ACCELERATION SENSITIVITY FROM 0 TO 2500 CPS | LINEAR ACCELERATION RESPONSE ALONG ANY AXIS: — 6 — APPROXIMATE STATIC ACCELERATION SENSITIVITY |
|---|---|---|---|---|---|
| PG260TC-5-350 | 0-5 psig | +10 psi | 5,500 cps | 0.1 %fs/g | 0.08%fs/g |
| PG260TC-10-350 | 0-10 psig | +20 psi | 7,000 cps | 0.06%fs/g | 0.05%fs/g |
| PG260TC-15-350 | 0-15 psig | +30 psi | 8,500 cps | 0.03%fs/g | 0.03%fs/g |
| PG260TC-25-350 | 0-25 psig | +50 psi | 11,000 cps | 0.02%fs/g | 0.02%fs/g |
| PG260TC-50-350 | 0-50 psig | +100 psi | 12,500 cps | 0.01%fs/g | 0.01%fs/g |
| PG260TC-100-350 | 0-100 psig | +200 psi | 16,000 cps | 0.01%fs/g | 0.01%fs/g |
| PG260TC-150-350 | 0-150 psig | +300 psi | 19,000 cps | 0.01%fs/g | 0.01%fs/g |
| PG260TC-300-350 | 0-300 psig | +600 psi | 22,000 cps | 0.01%fs/g | 0.01%fs/g |
| PG260TC-500-350 | 0-500 psig | +1,000 psi | 28,000 cps | 0.01%fs/g | 0.01%fs/g |




MODEL PG260TC PRESSURE TRANSDUCER
WEIGHT: 11 grams, approximately

### PRICE

MODEL PG260TC PRESSURE TRANSDUCER............................................................$350.00

*MODIFICATION: If variation of the standard specifications would make the instrument more suitable, please outline the special requirements of the application so that a specific quotation may be submitted.*

The prefix in the model designation of a pressure transducer indicates the service for which the instrument is intended, as follows:

- PA = Absolute pressure transducers
- PG = Gage pressure transducers
- PL = Uni-directional differential pressure transducers
- PM = Bi-directional (±) differential pressure transducers

When marked on the instrument, the model number will include a lower case alphabetical suffix which is subject to change. Variations in this suffix are not to be interpreted as an alteration of the model designation.


Statham LABORATORIES, INC.
12401 WEST OLYMPIC BOULEVARD
LOS ANGELES 64, CALIFORNIA
SCIENTIFIC INSTRUMENTS



12/56 3M L10368 HP-2303

WESTERN ELECTRO-ACOUSTIC LABORATORY
11789 San Vincente Boulevard
Los Angeles 49, California
Granite 7-9441

Paul S. Veneklasen
Director

Acoustical Measurement and
Consulting Services

Manufacturer of Precision
Instruments

ADDITIONAL INSTRUMENTS AND SERVICES AVAILABLE FROM THIS LABORATORY

1. Sound Spectrum Analyzer, Type 1000G.

This is a laboratory instrument designed for precise analysis and quantitative measurement of sound spectra by dividing the spectrum into octave bands and metering the effective sound pressure level in each band, as well as the level of the over-all spectrum.

The Analyzer consists of the combination of three instruments:

1. Condenser Microphone Complement, Type 100E.
2. Octave Band Pass Filter, Type 500C.
3. Vacuum Tube Voltmeter, Type 400B.

This equipment is designed to use the Western Electric 640AA microphone.

2. Condenser Microphone Complement

This is a laboratory instrument designed to assist in the measurement of Sound Pressure Level with a condenser microphone. The Type 100E instrument is intended for use with the Western Electric 640AA Condenser Microphone or equivalent. The instrument consists of three complementary components:

1. Pre-Amplifier: A cathode-follower type whose function is to furnish the necessary polarizing voltage for the microphone, and to act as an impedance transformer, presenting to the condenser microphone a very high input impedance, and to a line a low output impedance, which makes possible the transmission of the signal over useful distances without loss of level or frequency discrimination.
2. Line Amplifier: Raises the level of the microphone output so that it can be measured with a voltmeter or inserted into filters, equalizers, mixers, analyzers, or other measuring equipment.
3. Regulated Power Supply: Maintains a constant polarizing voltage for the condenser microphone.

3. Octave Filter Set, Type 500C

This is a laboratory instrument designed for the precise analysis of electrical signals consisting of a broad spectrum. This analysis is accomplished by measuring the energy within octave intervals of frequency throughout the audible spectrum.

The filter set consists of separate high-pass and low-pass sections with complete isolation between them. Thus the filter may be used in high-pass, low-pass, or band-pass arrangement. Cut-off frequencies may be chosen independently for the high-pass and low-pass sections, or the frequency selecting dials may be linked together so as to maintain an octave interval.

4. Voltmeter Type 400B or 401B

This is a laboratory instrument for the measurement of alternating current voltages. It is designed for the utmost versatility and usefulness in electronic and acoustic measurements.

5. Thermal Noise Source, Type 300B

This is a laboratory instrument designed to furnish a broad, continuous and steady noise spectrum for use in physical and psychological measurements associated with acoustics.

6. High Intensity Sound Generating System

This is a loudspeaker type system capable of providing 130 db SPL in chambers of approximately 1000 cu ft. The system consists of a thermal noise source, an instrument for providing low level electronic crossover and equalizations, two power amplifiers, and high and low frequency loudspeakers with their necessary horn enclosures.

7. Ten Channel Condenser Microphone Complement Type 130A.

This instrument provides for simultaneous operation of 10 condenser microphone channels. The output of the instrument is automatically or manually commutated to the output of each microphone channel. This system enables 10 microphone positions to be monitored on a single tape recorder.

8. Dual Channel Condenser Microphone Complement Type 120A.

This instrument provides for the simultaneous operation of two condenser microphone systems.

9. Condenser Microphone Complement Type 100D with Booster Preamplifier.

The special preamplifier used with this condenser microphone complement allows a condenser microphone to be operated with long cable extensions. As an example of this preamplifier's versatility, it will drive 1200 ft of cable with only a 0.3 decibel degradation in response at 30 Kc/sec (as referred to system response at 1 Kc/sec). One thousand feet of cable may be driven with a decrease in (mid-band) response of 0.5 db at 110 Kc/sec. Maximum input level to the system at mid-band, for negligible distortion in the output is 154 db SPL. The cable used with the Booster-Preamplifier was specially designed by this laboratory and is available as extension cables on reels for use with this instrument.

10. Half-Octave Filter Type 520A.

Spectrum analysis by half-octaves is possible with this instrument over the range of 9.6 Kc/sec to 109 Kc/sec. This instrument may be used in conjunction with the standard type 100 sound analyzer to provide very wide range frequency analysis. Proper equalization may be incorporated into the condenser microphone complement to provide the system with a very uniform response (±6db) to 109 Kc/sec when used with the Western Electric 640AA microphone.

11. Combined Octave Analyzer and Electronic Voltmeter Type 600A.

This instrument combines in a single unit a Type 500C Octave Filter Set and a Type 410B Electronic Voltmeter with additional monitoring conveniences. The specifications of the individual units combined in this instrument also apply to the combination.

12. Transducer Calibrations.

Complete facilities are available for the absolute calibration of all types of microphones as well as many types of pressure transducers. Free field reciprocity calibration of the Western Electric 640AA microphone to 100 Kc/sec is available on a commercial basis. Equalization may be provided as an accessory to Condenser Microphone Complement for operation of the 640AA to 100 Kc/sec.

APPENDIX C

Part I

"Condenser Microphones for Measurements of High Sound Pressures"

Part II

"Generation of High Intensity Sound Using Loudspeakers"

Author

John K. Hilliard

John K. Hilliard

Director of Advanced Engineering

Altec Lansing Corp., Beverly Hills, Calif.

The following papers were presented at the

General Electric Industrial Acoustics Symposium

February 7, 1957

Schenectady, New York

Second Issue
March 15, 1957

PART I

CONDENSER MICROPHONES FOR MEASUREMENTS OF HIGH SOUND PRESSURES

A series of small condenser microphones of the 21BR type have been developed for the measurement of high sound pressure levels. The paper describes the construction of the several elements of the microphone system and presents performance data. Four basic interchangeable microphones, all employing clamped glass plate diaphragms, provide linear measurements over a pressure range of 1 to $10^8$ dynes/$cm^2$. The equipment can be used over a wide range of temperature and barometric pressure and is sufficiently rugged to withstand severe overload and rough handling.

PART II

GENERATION OF HIGH INTENSITY SOUND USING LOUDSPEAKERS

This paper suggests some methods which may prove useful in the testing of electronic components, guidance systems and air frame structures to the unusual stresses produced by high intensity sound fields.

FIGURES FOR

CONDENSER MICROPHONE FOR MEASUREMENTS OF HIGH SOUND PRESSURES

PART I


Fig. 1 - typical electrical circuit of 21BR Microphone.

Fig. 2 - cross section of 21BR Type Microphone.

Fig. 3 - power supply schematic used with 21BR Microphones.

Fig. 4 - sensitivity-linear limit-noise threshold data on typical types of 21BR Microphones.

Fig. 5 - typical frequency response of 21BR Microphones.

Fig. 6 - polar pattern of 21BR Microphones.

Fig. 7 - cross section of special 21BR Microphone to be independent of altitude.

Fig. 8 - variation in response at various altitudes of 21BR Microphone.

Fig. 9 - comparison between measurement and computation of response of varying altitudes.

Fig. 10 - change in sensitivity with variation in temperature.

Fig. 11 - photograph of special 21BR Microphone with flush face for boundary layer measurements.

Fig. 12 - photograph of special 21BR Microphone with pin hole for boundary layer measurements.

Fig. 13 - schematic of insert voltage technique for calibration purposes.

Fig. 14 - cross section of acoustic calibrator.

Fig. 15 - frequency response of acoustic calibrator.

Fig. 16 - distortion versus output of cathode follower.

Fig. 17 - performance of cathode follower at various output levels with added capacity of long extension cables.

Fig. 18 - photograph of 6117 Probe Microphone.

Fig. 19 - frequency response of 6117 Probe Microphone.

Fig. 20 - cross section of 6117 Probe Microphone.

Fig. 21 - photograph of head band assembly using 21 Type Microphone.

Fig. 22 - head band assembly using noise cancelling 21 Type Microphones.

Fig. 23 - 150 mc FM transmitter using 21 Type Microphone.

Fig. 24 - Sensitivity of BR Microphone above 15 KC.

## PART I

## CONDENSER MICROPHONE FOR MEASUREMENTS OF HIGH SOUND PRESSURES

The power of jet engine and missiles in their many forms is being increased at a rapid rate and sound pressure levels of great magnitude are developed. This intensity is sufficient to fatigue metals, interfere with ground personnel hearing and produce harmful effects such as nausea and dizziness. Vacuum tubes, accelerometers and other electronic components malfunction in various ways. The microphones to be discussed have been designed to provide a rugged instrument to measure high sound pressures. This application dictates low distortion, stable construction, use of materials having special physical properties, appropriate electrical circuits, and accurate individual calibration.

### Microphone Description

In the condenser microphone, the conversion of mechanical to electrical energy is accomplished via an electrostatic field. The principal features of the electrical circuit are shown in Fig. 1 which is typical for the 21BR microphone.

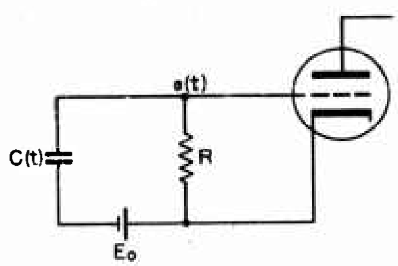



Fig. 1

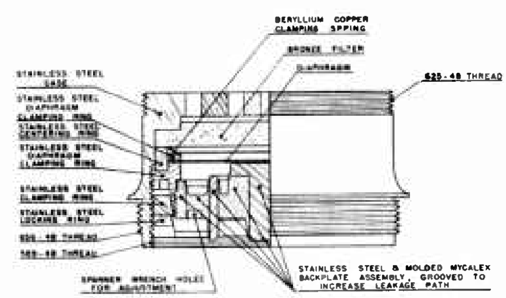



Fig. 2

As the voltage developed by the condenser microphone is proportional to the amplitude of motion of the diaphragm, to produce an output independent of frequency requires that the moving system be stiffness-controlled.

Fig. 2 shows the cross section of a microphone. Diaphragm resonance is damped by the resistance of the thin air space between the diaphragm and back plate, the space between diaphragm and sintered bronze sound entrance, and the resistance in the sintered bronze filter itself.

## Microphone Construction

The microphone is 0.6 inch in diameter and 0.4 inch thick. It is constructed of stainless steel and glass compounds. The 21 type is unique among condenser microphones in employing a clamped plate as a diaphragm. The clamped plate has advantages since it does not require the aging process needed with a stretched diaphragm. This plate is 0.5 inch in diameter, it is made of glass in thicknesses from 0.004 to 0.013 inches depending on the required sensitivity and it is ground to optical flatness. A thin, conducting layer of gold on one surface provides the conductor for the moving electrode.

The center electrode is a machined part extending through a Mycalex dielectric to provide a terminal for electrical connection. The dielectric is formed with annular corrugations between the center contact and outer sleeve to extend the length of the surface leakage paths. To insure highest surface resistivity, prevent moisture absorption, and promote retraction of a moisture film into globular particles, the surface of the dielectric is treated with silicone compounds.

## Preamplifier

Because of the extremely high impedance of the condenser, the capacitance of which is approximately 6 mmf, a cathode follower tube serving as an impedance transformer is placed as close as possible to the microphone. The tube is housed in the base which also mounts the microphone. The cathode follower permits transmission of the signal to remote measuring apparatus with minimum frequency discrimination and noise pickup. The tube is a 5840 pentode with a shock rating of 500 G. No physical grid resistor is employed; as a consequence, the low frequency response is extended and the noise threshold is lowered.

The free grid cathode follower vacuum tube operation has been described elsewhere.[1] The noise sources are: (1) thermal noise of the effective grid leak, (2) leakage currents in all insulators including the vacuum tube, and (3) tube noise. This noise has a negative slope of 6 db per octave from the lowest frequency.

The 165A Base which mounts the microphone and tube terminates in a 15 foot cable for connection to the power supply.

---

1. J. K. Hilliard and J. J. Noble, Proc. Inst. Radio Engrs., Professional Group on Audio, Vol. AU-2, No. 6 (November-December, 1954.)

## Power Supply

The power supply is shown in Fig. 3.

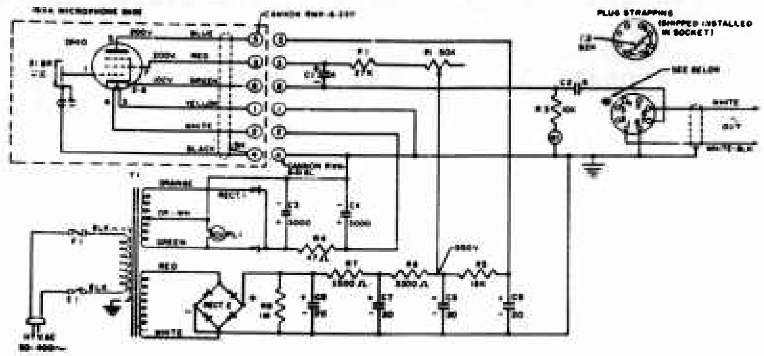


Fig. 3

Combined screen and plate current is 10 ma and the cathode resistor is 10,000 ohms. This combination provides a polarizing potential of 100 volts and the microphones are calibrated at this voltage. The internal output impedance of the cathode follower is approximately 250 ohms, but a load of 50,000 ohms or higher is recommended. Provisions are made to accommodate a plug-in transformer for use where low load impedance is used or when the output line is to be ungrounded or balanced.

Special considerations apply to the power transformer for this circuit. The possibility that the following amplifier may be separated from the power supply by hundreds of feet of unbalanced signal cable exposes the low level line to pickup of power line frequency. This complex problem has been solved effectively by maintaining minimum and balanced capacity between primary winding and all other windings, the core and the shield.

## Calibration and Performance

The pistonphone is used for calibration in the frequency range from 5 cps to 300 cps. A sound pressure level of 124 db is produced in the pistonphone cavity. In the range from 100 cps to 15 KC, the frequency response is compared in the anechoic chamber with a calibrated W. E. 640AA as a standard. The overlap between 100 and 300 cycles provides a continuity check on the pistonphone and anechoic methods. After frequency response calibration is completed, a linearity check is made by placing the microphone in the closed end of a special standing wave tube (after Oberst[2],) which produces a maximum sound pressure of 184 db at 400 cycles. In this tube, a pure sinusoidal pressure is produced regardless of possible driver distortion.

---

2. L. L. Beranek, Acoustic Measurements, (John Wiley and Sons, Inc., New York.)

To cover the wide range of sound pressure, four interchangeable microphone types are available for use with this system, differing principally in thickness of the diaphragm. Average characteristics of each type, for 100 volts polarizing potential, are listed in Fig. 4.

| Code | Open Circuit Sensitivity db re 1 v/ dyne/cm$^2$ | Av. Linear Limit SPL re 0.0002 dyne/cm$^2$ | Av. Noise Threshold SPL |
|---|---|---|---|
| 21BR-150 | -55 to -65 db | 164 db | 68 db |
| 21BR-180 | -70 to -80 db | 179 db | 83 db |
| 21BR-200 | -85 to -95 db | 194 db | 98 db |
| 21BR-220 | -105 to -115 db | 214 db | 118 db |

Fig. 4

Typical frequency response characteristics are shown in Fig. 5. The response below 20 cps is mainly dependent upon the input admittance of the 5840 cathode follower. Individual tubes may vary by 7-10 db at 5 cps. It is recommended that in those cases where measurements are of importance in this range, a re-check be made with each change of cathode follower tube.

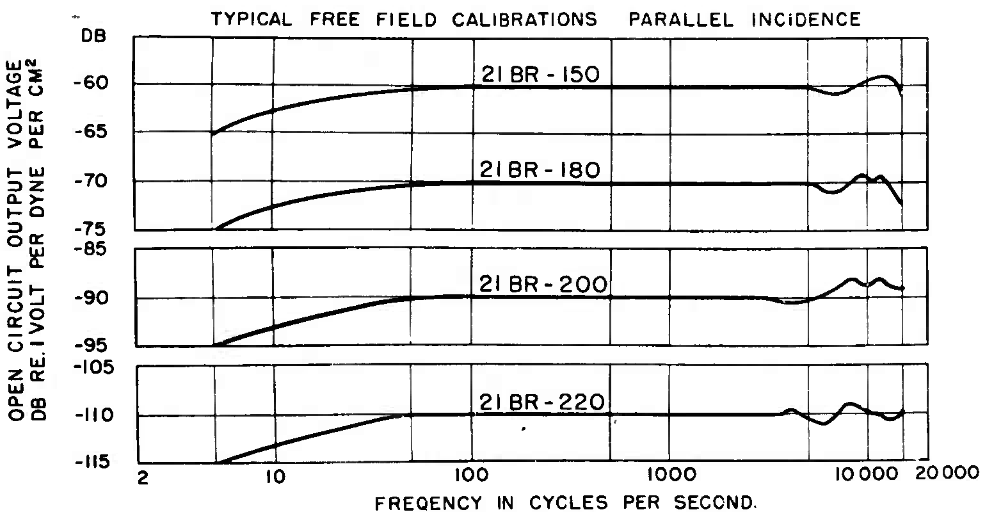



Fig. 5

By virtue of their small size, the microphones are essentially omnidirectional. Typical polar patterns are shown in Fig. 6.

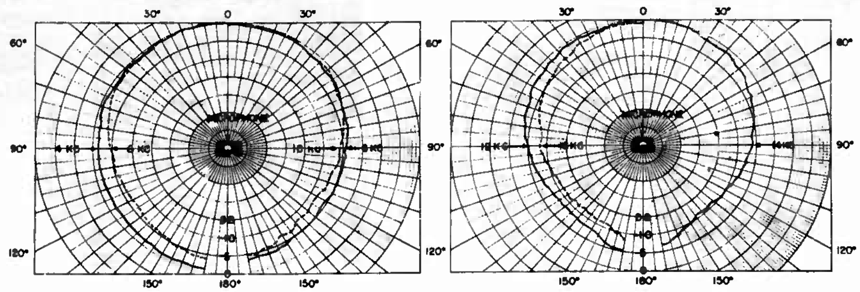
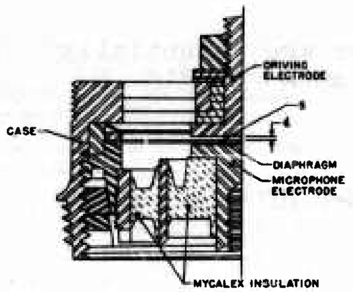



Fig. 6

In the research on high speed aircraft and missiles, acoustic measurements have become more and more important during the last years. These measurements not only give information on sound pressure levels under which the complicated electronic equipment of the missile has to operate, but also gives new information on aerodynamic problems through the measurement of boundary layer noise. Many of these acoustic measurements have to be made at high altitudes as well as at varying altitudes from sea level up to 80,000 feet.

The 21BR Condenser Microphones are very widely used for such measurements. One member of this family is designed especially for performance to be independent of altitude. The movement of the glass plate below its first resonance mode is determined by its mechanical stiffness. The first mode of vibration or first resonance of the diaphragm is damped by the resistive component of the air film formed between glass plate and stationary electrode. I. B. Crandall has derived the mathematical expressions for the resistive and reactive components of such an air film. It states that down to some minimum ambient pressure, the resistive component will remain constant and will be only a function of its dimension and the viscosity of air.

Fig. 7 shows a microphone with increased spacing between diaphragm and backplate which was expected to show only little variations with altitude. To measure this microphone at high altitude, it is also equipped with an auxiliary electrode to provide an electrostatic drive. The electrostatic driving force is independent of altitude. The spacing between the driving electrode and the glass diaphragm is made essentially larger than the spacing between diaphragm and microphone electrode to minimize the effect of the additional acoustic elements.




$$F = \frac{\epsilon \epsilon_0 S E_0}{d^2} \cdot E_1$$

| | | |
|---|---|---|
| $\epsilon$ | RELATIVE DIELECTRIC CONSTANT | |
| $\epsilon_0$ | PERMITTIVITY OF FREE SPACE | $F\,m^{-1}$ |
| $E_0$ | POLARIZING VOLTAGE | V |
| $E_1$ | AMPLITUDE OF DRIVING VOLTAGE | V |
| S | ELECTRODE AREA | $m^2$ |
| d | ELECTRODE SPACING | m |
| F | FORCE BETWEEN ELECTRODES | N |

$\epsilon = 1$
$\epsilon_0 = 8.854 \cdot 10^{-12}\,F\,m^{-1}$
$E_0 = 200V$
$E_1 = 140V$

$S = 2 \cdot 10^{-5}\,m$
$d = 1.27 \cdot 10^{-4}\,m$

$F = 31.4 \cdot 10^{-6}\,N = 31.4$ dyn
EQUIVALENT SPL. 90 db
MICROPHONE OUTPUT
APPROX. 3 mV

Fig. 7

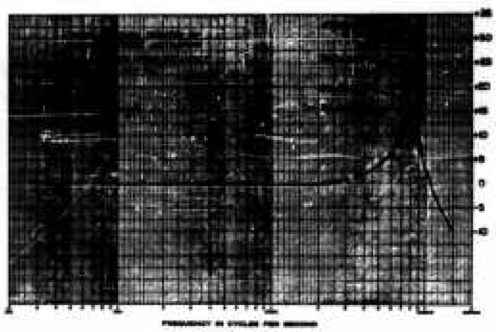


Fig. 8

Northrop Aircraft Company, under the supervision of Douglas Welch, measured the frequency response of this instrument up to altitudes of 87,000 feet and at various temperatures, and was kind enough to permit the use of their measurements for this presentation (Fig. 8.) The frequency response is independent of altitude (or ambient pressures) up to frequencies approximately 1/2 octave below the first resonant mode of the diaphragm. As expected, the system has little damping and shows a peak of 14-1/2 db at its resonance. At increasing altitudes, the resistance begins to decrease, resulting in an increase of the resonance peak which reaches 32 db at 87,000 feet. The height of the peak is inversely proportional to the damping resistance.

Fig. 9 shows a comparison between measurement and computation. The height of the resonance peak was plotted against altitude. The slight discrepancy between computed and measured values is thought to be due to the inaccuracy of the measurement of the distance between the diaphragm and backplate. This distance enters the formula with approximately the third power. The deviations at high altitudes can probably be explained by the fact that the computation was made without accounting for possible mechanical losses. Considering these facts, it appears that computed and measured values check out well.

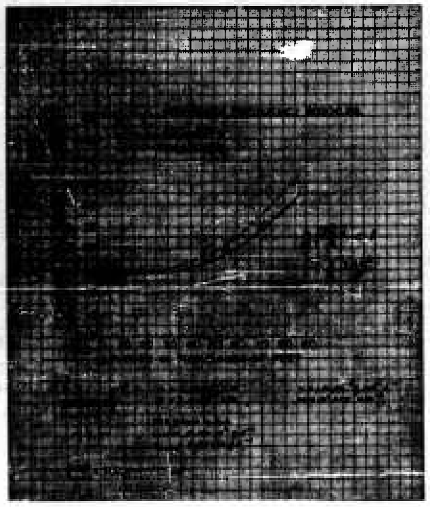


Fig. 9

Fig. 10

In the course of these measurements, frequency responses were also measured through a temperature range from -50 to $+160^{\circ}$F. These results were not too consistent. They actually allow only the statement that the variations in this temperature range occur in a strip of 2-1/2 db (Fig. 10.) The sensitivity tends to decrease with increasing temperature. Assuming the trend to be linear as shown by the solid line in Fig. 10, the temperature coefficient computes to .012 db per degree F. The inconsistency of the sensitivity versus the temperature measurements is probably caused by non-uniformity of the diaphragm clamping. This matter is under further investigation.

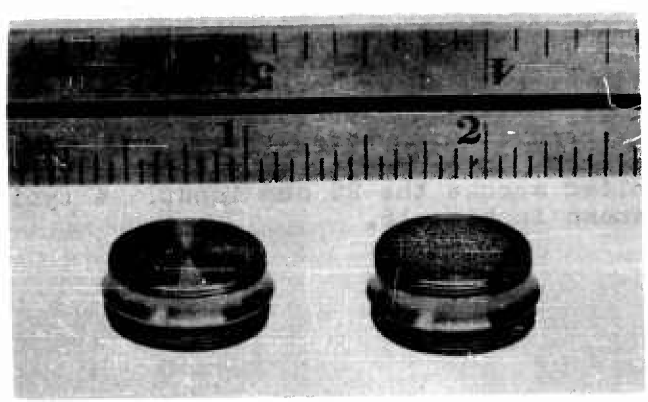


Fig. 11 Fig. 12

Microphones of a special design which provide performance independent of pressure over a wide range as described previously, can be built to meet the special requirements for boundary layer measurements as applied to high speed aircraft. Two types have been developed which allow flush mounting and are considered to cause minimum additional turbulence. Fig. 11 shows a design in which the sound entrance is formed by a pinhole of approximately 5 mil diameter; Fig. 12 shows the 21BR 180-5 which is another design in which the sound enters the microphone through a fine sintered bronze screen. These microphones are now undergoing field trial in a fighter aircraft where twelve units are mounted in an array one inch apart.

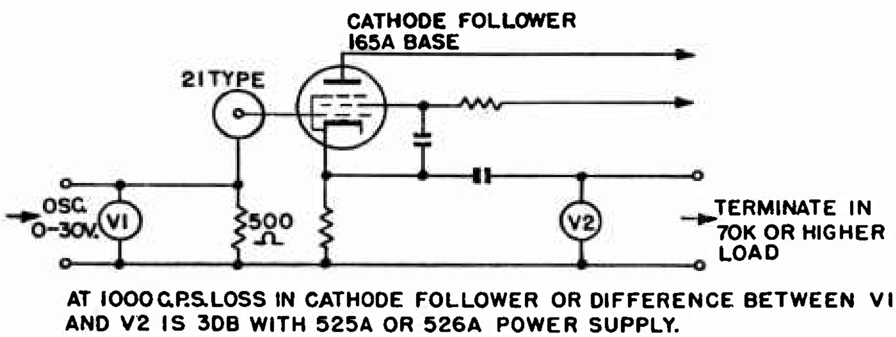



Fig. 13A

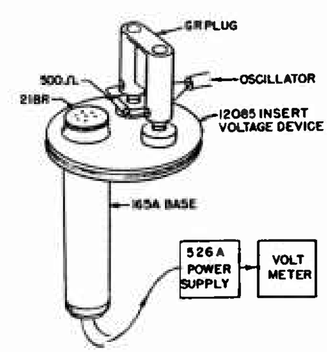



Fig. 13B

To re-check the calibration outside the laboratory, two methods are available; namely, the insert voltage procedure, and the acoustic calibrator. The insert voltage technique is very useful for evaluating the response of the overall electrical system which includes the coupling of the microphone to the cathode follower, the cathode follower itself, and subsequent amplifier and recorder equipment (Figs. 13A and 13B.) The acoustic calibrator as shown in Fig. 14 consists of a pressure unit working into a small cavity of approximately 1/2 cubic centimeter. The microphone is inserted in a threaded sleeve and couples to the cavity. A sound pressure level in excess of 150 db is obtained up to 1,000 cps with 4 volts applied across the 22 ohm input. A typical calibration of such a unit is shown in Fig. 15.

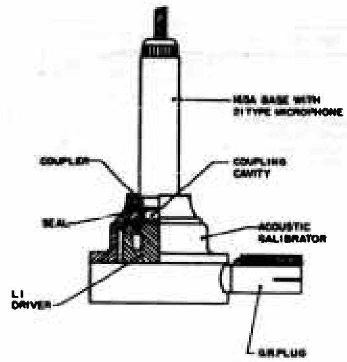



Fig. 14

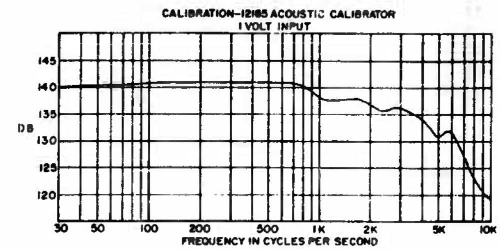



Fig. 15

This device enables one to make a quick check of the overall sensitivity of the system, even in the presence of high ambient noise fields. The acoustic calibrator permits occasional re-check of microphone sensitivity, or the routine standardization of the sensitivity of the overall measurement system from acoustic input to the data recording output.

Axial acceleration of the mass of the diaphragm causes it to deflect to an extent proportional to the density and inversely proportional to the square of the thickness of the diaphragm. Expressed in equivalent sound pressure level, the sensitivity of the microphone to axial sinusoidal acceleration having a peak value of 1 G is 99 db equivalent sound pressure level for the 21BR-150 and 109 db for the 21BR-220.

Microphone System Distortion

As discussed above, the microphone itself responds essentially linearly to variations in sound pressure; therefore, the linear range of operation is limited by the distortion of the cathode follower as shown in Fig. 16. A conservative statement is that the distortion is less than 5% for 25 V. output up to 15 KC and with the standard 15 foot cable. The values listed in Fig. 4 for Linear Limit are based on this output and the mean sensitivities. Added capacity due to the use of long extension cables increases the distortion as shown in Fig. 17.

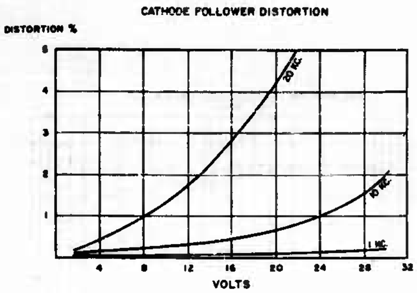



Fig. 16

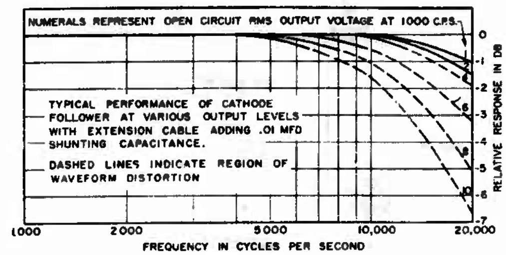



Fig. 17

6117 Probe Microphone

Fig. 18 shows a resistance-terminated short probe tube developed in our laboratories. The probe tube is two inches long and 1/2 inch in diameter. It is coupled to a special 21BR Microphone. At the tip and comparatively close to the diaphragm, resistive elements are provided. The special 21BR Microphone is essentially of the type previously described. It has very little damping and therefore exhibits a peak at a resonance which compensates for the losses in the probe tube at high frequencies. The design is based on research done by Professor Leonard of UCLA and reported at the second International Meeting of the Acoustical Society in Boston. The basic idea is to terminate the probe tube at its tip with an acoustic resistance equal to the characteristic impedance of an infinite pipe. By this measure, the probe tube has been made infinitely long as far as its acoustic properties are concerned. Unfortunately, the ideal condition cannot be fully realized practically because of the unavoidable reactive part associated with the resistance of the tip; therefore, the termination is not perfect and reflections occur resulting in standing waves in the tube causing peaks and dips in the frequency response of the whole system. To minimize these irregularities, an additional resistive element had to be provided in the tube near the diaphragm of the microphone. The resistive elements are made, at the present time, of sintered bronze discs. By carefully selecting the optimum discs, a fairly smooth frequency response of the whole system up to 10,000 cps without any loss of sensitivity can be obtained (Fig. 19.) The probe tube itself is made of stainless steel to withstand high temperatures. Investigation is under way to replace the sintered bronze with sintered stainless steel.

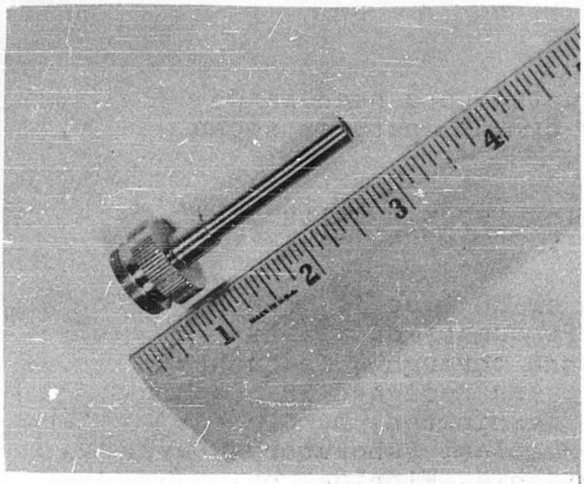


Fig. 18

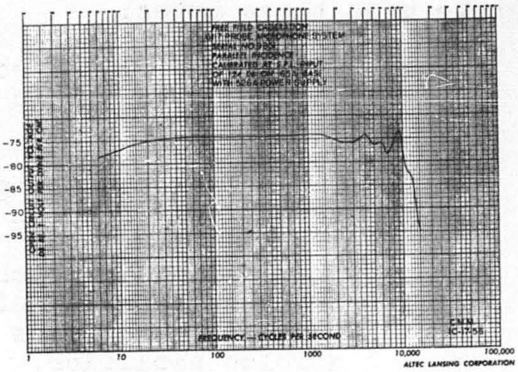



Fig. 19

Fig. 20 shows the cross section of the probe tube.

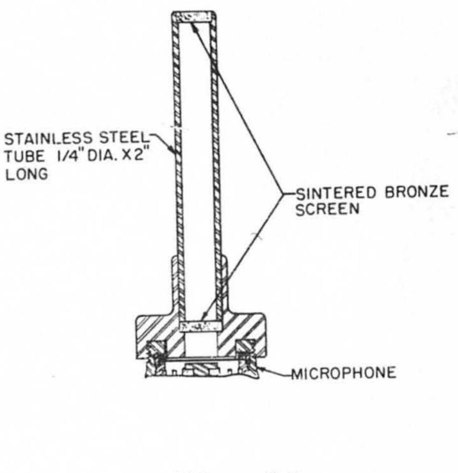



Fig. 20

Communication in the presence of noise has always been a problem, but in addition we must now deal with the added impact of ever-increasing noise levels.

Our experimental work using microphones having a high degree of linearity seems to have some advantage. Recent tests aboard airliners, aircraft carriers, control towers and engine test cells, indicate progress in this direction.

We have used three types:

1. The single 21D Microphone mounted on a head band and operated within 0.5 inch of the mouth as shown in Fig. 21.

2. The noise cancelling type using two 21D units back to back as shown in Fig. 22.

3. The FM link in which the 21D or BR type is used as the tank capacity of a high frequency oscillator which in turn feeds the antenna through a frequency doubler amplifier. This unit was designed in cooperation with Jansky & Bailey in Washington, D. C. Several are in use by the Acoustical Laboratory, Dept. of Medicine, U. S. Navy, Pensacola, Florida, on carriers and other mobile applications (Fig. 23.)

A tape recording prepared by G. C. Tolhurst and S. N. Morrell at Pensacola is available indicating the scope of this work of communicating through noise fields up to 140 db SPL.

Fig. 21

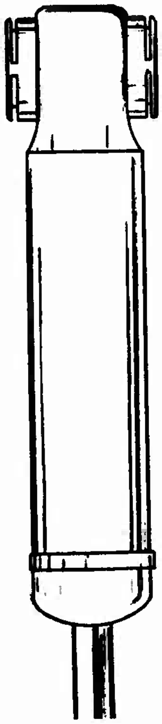


Fig. 22

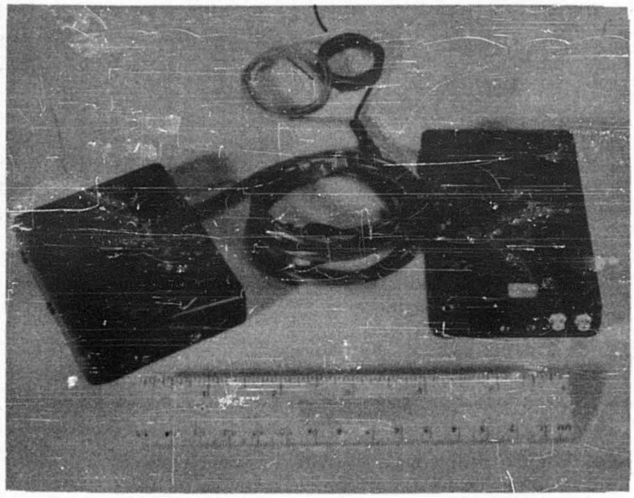


Fig. 23

Special Applications

Several versions of probe tubes have been used culminating in the 6117 type previously described. Probe tubes are essential where it is desirable to simulate a point pick up and provide a temperature differential between source and microphone. They have been found useful to determine burning conditions within an engine, and probe tubes having lengths of several inches are inserted in the burning cans to indicate burner instability and the status of the problem of flame-driven standing waves. P. L. Blackshear, Jr. at NACA has published work in this regard.

The Northrop Aircraft Company have an extensive program of using 21BR Microphones in connection with the Snark missile program. For some time, as many as twelve microphones are placed in strategic positions within the missile to determine the sound pressure levels at the points where malfunction of equipment exists. Also, through captive launchings measurements of sound pressure levels are made to determine safety conditions for operating ground personnel.

At Pensacola we have a 1 KW loudspeaker system which in a small room holding 25 persons, can deliver approximately 400 acoustic watts over the range of 50 cps to 20 KC. It uses 64 Altec speakers. Various types of sounds are reproduced over this system to evaluate ear plugs, lethal effects on animals and effects of noise on the human. Douglas Aircraft Company in the design of their new DC-8 jet plane use our large theatre-type loudspeakers energized from tape recorded jet noise to determine the attenuation of the cabin walls. These loudspeakers are placed within a few feet of the outside wall and the 21 Type Microphones are placed at various stations within the cabin.

## The 12531 Shell

The 5840 vacuum tube used as a cathode follower in the 165 Base is a ruggedized low microphonic tube. However, when used with a 21 BR 200 or 21 BR 220 Microphone which has a low sensitivity, the residual microphonics of the tube interferes with the frequency response in the range of 5-8 KC.

The 12531 Shell is available to replace the standard case normally supplied on the 165A Base. It is a heavy brass shell and provides an additional 20 db reduction in microphonics over the standard shell. It is recommended for use in measurements with the 21 BR 200 - 21 BR 220 Microphones and it is interchangeable with the standard shell.

## The 527A Regulated Power Supply

The 527A Regulated Power Supply is under design and will be available for use with all 21 Type Microphones. The 527A will maintain the cathode to ground voltage (and therefore the microphone polarizing potential) within one percent over a wide range of A.C. line voltage. Means will be included for maintaining proper cathode follower heater current for varying lengths of cable between microphone and power supply. Meters to indicate polarizing potential and heater current will be provided.

## The 12530 Impedance Translator

The 12530 accessory will presently be made available to allow the use of cable lengths up to several thousand feet between the 165A Base and the power supply without excessive high frequency loss or distortion at rated output. This small, passive plug-in unit, will contain the necessary components to reduce the impedance level of the circuit before transmission on the long cable.

## Sensitivity of BR Microphone above 15 KC

Recently we have received a number of requests for information regarding the sensitivity of our 21 type Microphones in the range above 15 KC. The need for data in this range arises from 1/5 scale model work on air frames and in atomic power plant work. A typical calibration is shown in Figure 24.

## Conclusion

This series of high intensity microphones providesthe flexibility required for the numerous uses to measure sound pressure levels up to $10^7$ dynes/cm$^2$. Probe tubes of various lengths and working temperatures can be used, flush-type microphones for boundary layer measurement are available, acoustic calibrators provide rapid re-check on original calibration and vented microphones are available for use in high ambient barometric pressures.

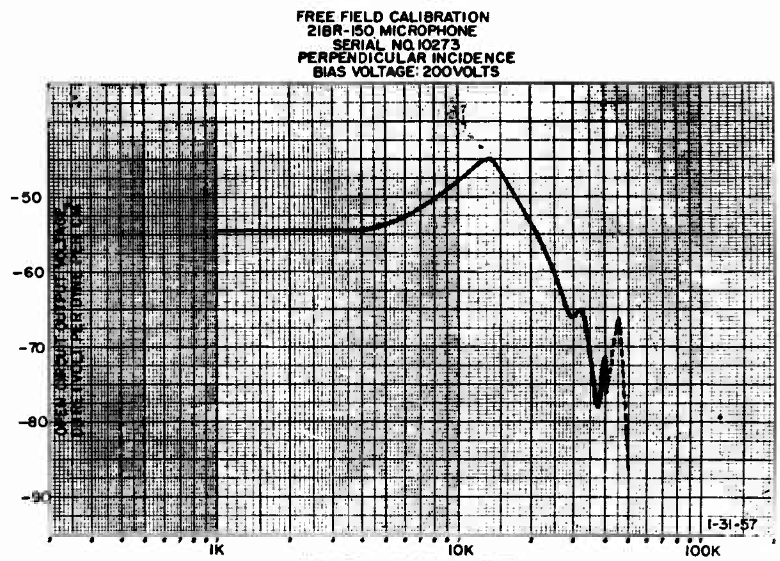

FREE FIELD CALIBRATION
21BR-150 MICROPHONE
SERIAL NO. 10273
PERPENDICULAR INCIDENCE
BIAS VOLTAGE: 200 VOLTS
-50
-60
-70
-80
-90
1-31-57
1K
10K
100K
FREQUENCY IN CYCLES PER SECOND

FIGURE 24

## PART II

Fig. 1 - The Convair-Pomona plane wave tube, full view.

Fig. 2 - The Convair-Pomona plane wave tube, closeup showing lucite cover.

Fig. 3 - Photograph of non-dissapative Altec Lansing reverberant chamber.

Fig. 4 - Octave band response for reverberant box.

Fig. 5 - Photograph of semi-reverberant room, Acoustic Laboratories, U. S. Navy, Pensacola.

Fig. 6 - Standing wave tube of the Oberst type.

Fig. 7 - Bell Aircraft standing wave tunable tube pressure distribution curve.

Fig. 8 - Bell Aircraft 40" x 40" resonant chamber with movable piston.

## PART II

This paper suggests some methods which may prove useful in the testing of electronic components, guidance systems and air frame structures to the unusual stresses produced by high intensity sound fields.

In the range of 125 to 180 db sound pressure levels, slight to serious malfunction of vacuum tubes, transistors, relays and gyros are reported. In order to test the co-ordinates of malfunction, simulative acoustic energy can be generated by sirens, air choppers, air modulated devices, and loudspeaker generators.

The apparatus under test may be subjected to various types of acoustic excitation such as:

1. Free field
2. Plane wave tubes
3. Reverberant rooms or boxes with diffusion
4. Standing wave enclosures

Each may offer a special advantage depending upon the size and required amount of acoustic excitation.

### Free Field

This condition of testing will not be discussed now because of its limited application resulting from the excessive amount of acoustic energy required.

### Plane Wave Tubes

Air frames, engines, missiles, and personnel are exposed to high intensity noise under conditions similar to free field. The plane wave tube provides essentially a free field condition in depth and confines the energy within the walls of the tube. In this case, the sound pressure and particle velocity are in phase for those conditions where the wave length is large compared to the dimension of the tube. This makes it possible to investigate the sensitivity of equipment to acoustic waves propagated in specific directions at the lower frequencies, but at the higher frequencies plane wave conditions do not prevail.

The Convair-Pomona plane wave tube as shown in Fig. 1 is 16' long, 2' in diameter, and has an acoustic termination at the far end. In order to cover the full spectrum, three different types of loudspeakers are used. Three 515 low frequency units cover the range from 30 to 700 cps. Four large compression type units extend from 700 to 5,000 cps, and the highest portion of the spectrum is covered by four smaller 802C Drivers. Fig. 2 shows the 1" thick lucite cover over the object being tested and so designed as to permit complete visual observation. Two 21BR Microphones hang over the test object to record the sound pressure level. This tube was designed to accommodate a section of a missile 1' in diameter.

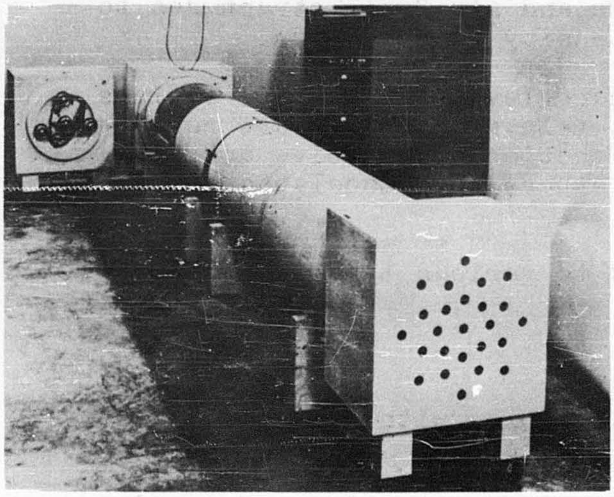


Fig. 1

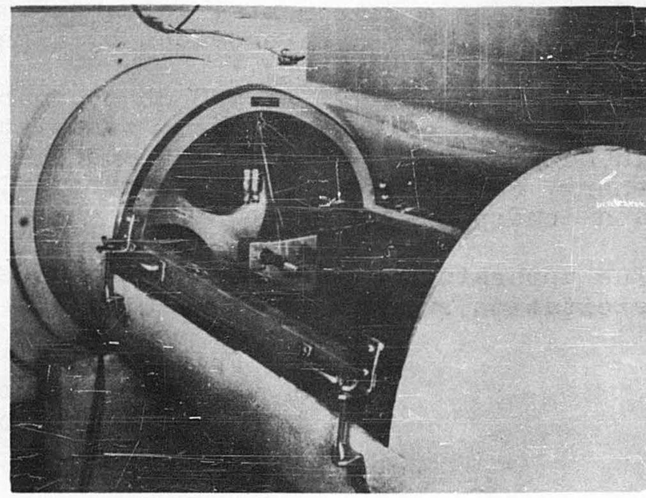


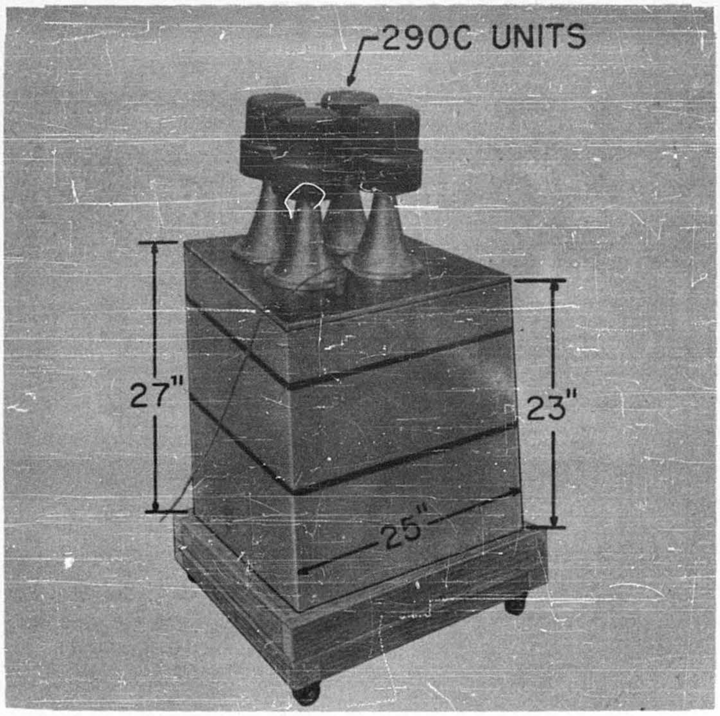
Fig. 2

When a 290C unit is mounted in a plane wave tube having a diameter of 6" and provided with circulating air cooling which will be described later, it can produce a sound pressure level of 148 db from 200 electrical watts at frequencies between 700 - 3,000 cps.

Reverberant Rooms or Boxes with Diffusion

The generation of high sound intensity in free space or in a plane wave tube over an area sufficient for testing large components, requires the production of great amounts of acoustic power. A sound field of 160 db represents an intensity of one watt per square centimeter or one kilowatt per square foot, and requires an electrical power of at least four kilowatts per square foot.

The use of a space completely enclosed by walls of low absorption is attractive since any particular wave passes a point many times before it is substantially attenuated. This is not identical to the same sound pressure level in a plane wave tube since it does not represent a corresponding density of power propagation in a single direction. A non-dissapative concrete box having dimensions of 25 x 27 x 23" has been constructed to provide the highest possible sound pressure level with our latest design of loudspeakers using air cooling (Fig. 3.)




The box is intentionally made unsymetrical so as to maintain a uniform energy condition. The inside surface is glazed so as to achieve the lowest possible absorption.

This box can be energized with either sine wave or octave band power.

Fig. 4 shows the response in octave bands; the solid line using four 290C units, the dotted line four 288 units, and the dashed line four 802C units. Their respective power sensitives were made with 0.45 VA input. At the top of the chart, the sound pressure level of the 1,000 cycle octave band is indicated for four 290C units only with 180 VA input, and is 150 db. The maximum variation for various positions in the box is 3 db. Four 290C units may be used with a total power input of 800 watts to produce 156 db SPL.

It has been found that the absorption of the units is negligible for the frequency range reported. This indicates that higher sound pressures can be achieved by using higher power along with the necessary number of units.

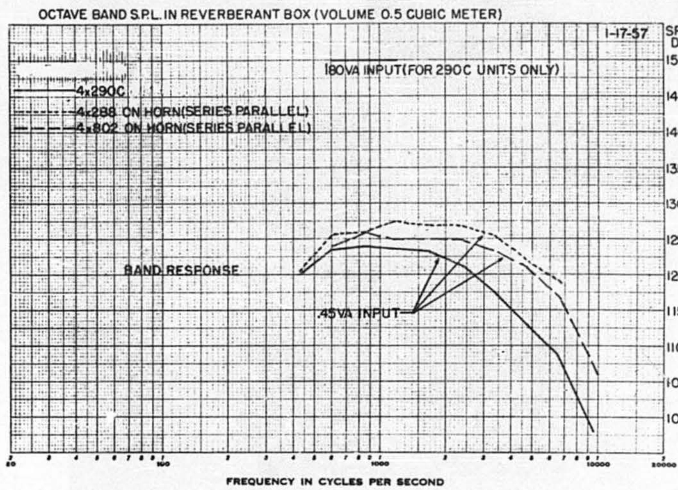



Fig. 4

Work carried on at the Acoustic Laboratory at Pensacola under Mr. Scott Morrill, approximates such a room except that absorption is added to produce optimum reverberation time. This room, as shown in Fig. 5 provides a gain of approximately 20 db over free field conditions. A sound pressure level of 140 db is achieved over several octaves at a distance 3' from the mouth of the horns.

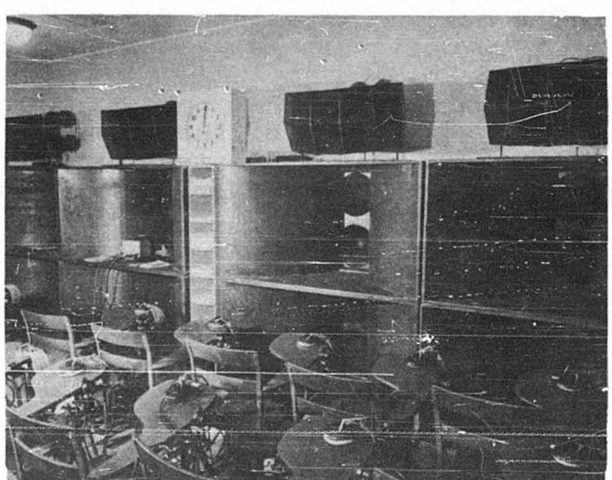
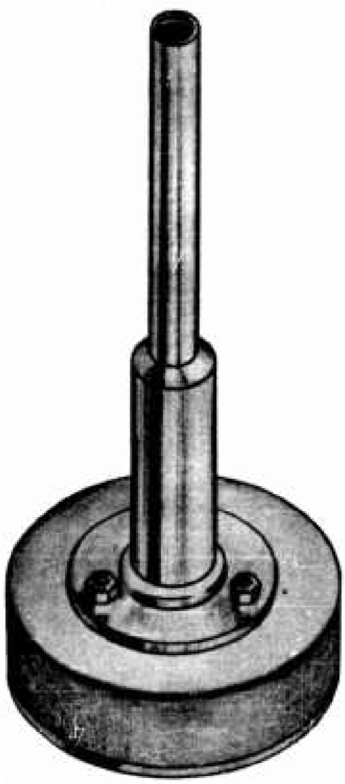


Fig. 5

## Standing Wave Enclosures

When using a standing wave tube of the Oberst type (Fig. 6) having dimensions 14" x 1½" x 3/4", a sound pressure level as high as 185 db has been obtained using a 290C type loudspeaker unit with 40 electrical watts input. The apparatus consists of two pieces of tubing of different lengths and diameters which are threaded together. When this combination of tubes is excited at one of the many resonances, between 400 and 5,000 cps, a nearly pure sinusoidal pressure occurs at the far end of the smaller tube. At the present time this tube is being used when required to check the linearity of the 21BR Type Microphones up to 185 db at 400 cps. Very small components can be placed in this tube to observe the effects of high intensity exposure.

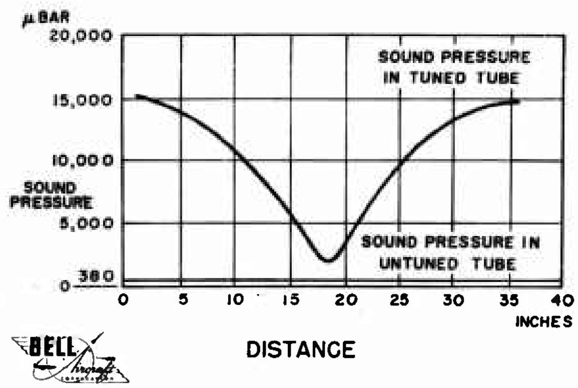


290C DRIVER UNIT WITH
12084 STANDING WAVE TUBE

Fig. 6

Dr. Fricke at Bell Aircraft is using a larger standing wave tunable tube of constant diameter and reports a sound pressure level of 158 db. Fig. 7 shows the distribution of pressure along the tube. Such a tube closed at both ends resonates when the distance between driver and opposite end is N x $\lambda/2$. A movable piston provides a simple method of adjusting the tube length for resonance at any frequency and the pressure is uniform across the tube up to the first transverse mode. This first occurs at $\pi$ times the radius of the tube.

Dr. Fricke has constructed a chamber with a rectangular cross section of 40" x 40" to test larger missile components. Resonant principles are also used in this design to provide modes of excitation. One end of this box is a movable piston as shown in Fig. 8. Here again, three different types of loudspeakers are used in a manner similar to that of the Convair-Pomona plane wave tube.




SOUND PRESSURE DISTRIBUTION ALONG THE TUBE LENGTH

Fig. 7


BAC RESONANCE CHAMBER, 1600 CM² CROSS-SECTION, FOR PRODUCING HIGH SOUND INTENSITY

Fig. 8

## High Power Loudspeakers

In the case of compression-type drivers, the maximum sound pressure level that can be developed is limited by the greatest permissible amplitude of the driver and the temperature rise caused by current in the voice coil. In a typical case of our 290C Driver Unit, a 3" diameter copper ribbon is used for the voice coil. It has a dc resistance of 1.8 ohms at 25°C. With 50 watts of electrical power input the temperature rise is 69°C above ambient. At powers in excess of 100 watts, the temperature is more than 125°C, and with continuous duty, the heat melts cement and enamel used in the voice coil construction. When air cooling is provided for the unit, it is possible to increase the power to 225 watts with the same temperature rise of 69°C that was observed with 50 watts of input and no air cooling. In the case of this higher power, the limitation is amplitude and for this particular unit the maximum permissible stroke of 140 mils peak to peak is obtained at 700 cps. Under these conditions it is possible to obtain 4 to 6 db more output with air cooling. A pressure differential of approximately $\frac{1}{2}$ lb provides the required amount of air to obtain this cooling effect and is equivalent to a static bias of 5 mils of displacement.

We are compelled to use sine wave signals for resonant enclosures and at the present time, for the non-resonant cases, we are at least required to divide the spectrum into several parts. This is because no single set of loudspeakers is capable of providing the required acoustic power over the entire testing band. It is generally necessary for highest efficiency to fill the end of the tube or box with drivers and this necessitates a change of units for each of the three mentioned bands.

Justification of this method was made at Bell Aircraft in an extensive study comparing the microphonic output of vacuum tubes using sinusoidal signals and the octave band noise of rockets. In both cases the vacuum tubes were found to have comparable sound sensitivity. Processing of the data using sine wave excitation is also considerably simplified.

To summarize the characteristics of the several types of enclosures, the free field may most closely represent the normal environment of the parts to be tested, but the sound field that can be produced in test is very limited. The plane wave tube provides the first degree of restriction imposed to permit the production of higher sound intensities. The reverberant room permits still higher intensities, but produces a complex diffusion of wave directions. In standing wave tubes the highest pressures are produced, but at resonant frequencies only, and the sound field is specialized in that the locations of maximum pressures are the regions of zero particle velocity.

The author wishes to acknowledge the valuable contribution of Messrs E. S. Seeley and W. T. Fiala in the preparation of this paper

# NEW SONIC TEST ENVIRONMENTS AND FACILITIES

K.R. JACKMAN
HEAD ENGINEERING TEST LABORATORIES

PRESENTED AT THE
IAS NATIONAL SUMMER MEETING
JUNE 17 – 20, 1957

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
POMONA CALIFORNIA

## CONTENTS


Part I – "Sonic Environments" .............................. 1

Introduction .............................. 1

Typical Specifications .............................. 2

Acoustical Facilities .............................. 6

Part II – Convair "Sound Cabin" Test Facility .............................. 27

Bibliography High Intensity Acoustics .............................. 33


## ILLUSTRATIONS


Figure

1. Turbo-Jet Noise Data .............................. 4
2. Typical Sound Pressure Levels, Turbo-Jet and Rockets ..... 5
3. Convair-San Diego, Jet Test Facility, Seaplane Ramp ...... 6
4. Microphone Data, M.T.S. at Convair-Pomona, 4 June 1957 .............................. 7
5. B.B. & N. Microphone Summary .............................. 8
6. Convair-Pomona, Acoustical Laboratory .............................. 9
7. Convair-Pomona, Large "Plane Wave Tube" .............................. 9
8. Speaker Enclosures .............................. 10
9. Frequency Response Curves of Plane Wave Tube .......... 11
10. Klystron Evaluation Under Sonic Environments .......... 12
11. Test Area Viewing Window in Plane Wave Tube .......... 12
12. Cone Attenuation Studies .............................. 12
13. Outside Vendor Test .............................. 13
14. Convair-Pomona Resonant Tube .............................. 13
15. Horn End of Convair-Pomona, Resonant Tube .......... 14
16. Rototest Inverse Exponential Chamber .............................. 15
17. Rototest Octave-Band Response of Acoustic Facility ........ 16
18. Altec Acoustical Chamber .............................. 16
19. Octave-Band Response of Altec Chamber .............................. 17
20. Northrop's Pulse-Jet Test Facility .............................. 18
21. Frequency Response of Northrop Pulse-Jet Facility ........ 19
22. Northrop's 130 DB Interim Chamber .............................. 19
23. Frequency Response Curve of Northrop Interim Chamber .... 20

Figure


24. Douglas Siren System, Schematic Diagram . . . . . . . . . . . . . . 22
25. Douglas Siren Installation in Acoustics Laboratory . . . . . . . . . 23
26. Sound Drive Pico Canyon Siren Test Facility . . . . . . . . . . . . 24
27. Sound Drive Siren Internal View . . . . . . . . . . . . . . . . . . . . 24
28. Bell Aircraft Large "Standing Wave" Tube . . . . . . . . . . . . . . 25
29. B.A.C. Tests on Electron Tubes . . . . . . . . . . . . . . . . . . . . 26
30. Convair Sound Cabin No. 1 Survey Near G.E. TG-180 Turbo-Jet . . . . . . . . . . . . . . . . . . . . . . . . . . . 28
31. Convair Sound Cabin No. 1 in Rear Position Near Turbo-Jet . . . . . . . . . . . . . . . . . . . . . . . . . . . . 29
32. Effects of Sound Cabin No. 1 and Cabin Insulation on Turbo-Jet Noise . . . . . . . . . . . . . . . . . . . . . . . . . . . 30
33. Support Structure of an Engine Test Stand . . . . . . . . . . . . . . 32

## Part I
## "SONIC ENVIRONMENTS"

### INTRODUCTION

Recently a Northrop engineer referred to sonic environmental testing as "noise with a purpose," that is, noise to help make the mission of airborne vehicles successful. Considerable agitation was caused by an article discussing this new sonic test environment which appeared in the September 1956 issue of the magazine "Research and Engineering," entitled "New Sound Barrier: Obstacle and Opportunity." In this article Editor M. Mandell (Reference 1) summarized the early 1956 state of this new acoustic environment as follows: "Noise generated by increasingly powerful jet and rocket engines has recently been tagged the culprit in aircraft structural failures and equipment malfunction. Identification of the cause has started a flurry of activity in a significant segment of our engineering industries; duplicating noise sources for development testing, analysis of its effects on proprietory products, and ideas for combating it. Worth investigating is the industry that will boom because of the need for sonic test set-ups on the production line. Here's the situation and what will be done about it from those few now in the know."

He went on to say, "Since at least 1952, airframe manufacturers have known that acoustic vibration from jet engines can cause fatigue failures; in 1954 came the first intimation that high noise may be causing some of the mystifying failures in airborne electronic equipment; and few months ago (late 1956) designers of a turbo-prop engine discovered that standing sound waves over-heat turbine blades."

What has happened since this 1956 article predicted that the nation's R & D organizations may soon have to spend millions of dollars collectively to provide sonic facilities, in which jet engine and aerodynamic high intensity noises can be duplicated for testing new equipment and components.

As early as 1954 it will be recalled that M. B. Levine and Fred Mintz, then of Armour Research Foundation, showed that some of the mysterious malfunctions in airborne electronic and electromechanical equipment might actually be caused by high noise levels. Thus, three years ago, these authors showed that ruggedized military types of vacuum tubes exhibited undesirable microphonics in a noise environment of 130 DB, some failing at noise levels as low as 120 DB.

The experiments on sensitive relays in high intensity noise environments at Armour Research also indicated trouble areas. Tests using 130 DB noise at 1100 CPS excitation caused relay contacts to open sufficiently to cause trouble in some airborne control circuits. Dr. W. Fricka of Bell Aircraft (Reference 2) noted excessive microphonic output in Type 5814A electron tubes at an average SPL of 140 DB between 700 and 1600 CPS.

Now what has been done in the airplane and missile test laboratories to duplicate this new sonic environment? First we must ask, what environments exist within the scope of modern missiles; from subsonic, low-altitude test parameters to the high-mach (M = 4 to 6) missiles with ballistic trajectories peaking at 300 to 500 miles above the earth? No one answer exists since each missile with its own peculiar resonances and structural responses will provide its own environment. For the sake of simplicity, this paper will consider three basic sonic environments and discuss some practical acoustical test facilities that have been developed within the past two years to duplicate high intensity noise in the laboratory.

1. High level noise due to propulsion or rocket sources, primarily tonal in the low frequencies (100 to 400 CPS) and up to 170-180 DB intensities.
2. Aerodynamic acoustic excitation caused by transonic or supersonic velocity of missiles on which there are discontinuities in structure or skins causing shock waves or turbulent boundary layers. This may be of lesser intensity (that is 130 to 150 DB) but with higher frequencies (to 10 or 15 kilocycles).
3. A third environment may exist in sensitive electronic and microwave equipment in which midintensity (that is, 130 to 140 DB) acoustic excitation may be imposed by either propulsion or aerodynamic noise sources or their harmonics to the high frequency spectrum (that is, 10 to 40 kilocycles).

It is evident that no one high intensity sonic test facility will cover the above three environments effectively. Currently the electromagnetic loudspeaker in plane-wave tubes or resonant chambers may provide discrete-frequency sweeps or "white noise" exposures up to 150 to 155 DB. Sirens, air "whistles," jet engines, and rockets may provide the "tonal" or specific frequency sources from 155 to 175 DB or higher.

## TYPICAL SPECIFICATIONS

Several manufacturers of airborne equipment have attempted to outline sonic environmental criteria to which subcontractors are asked to subject components. Since each contractor has a specific missile or airplane in mind, little similarity exists between the specified acoustic laboratory environments. Several examples may be interesting.

One manufacturer of a supersonic bomber has determined, by test, the frequency spectrum and noise intensity at each location where electronic equipment is carried. Operating components in these areas must withstand the specified exposure without equipment malfunction or damage.

Another airplane prime contractor has released acoustic test requirements as follows: "Acoustical noise tests shall be conducted concurrently with vibration tests.

"These tests are applicable to selected items of equipment mounted on the engine or in the airplane at stations within 6 feet of the nearest point of the engine.

"WHITE (BROAD BAND) NOISE TESTS. The test specimen shall be functioning in accordance with the provisions of the component detail specification. Means shall be provided for complete and continuous monitoring of the functional performance of the test specimen during the entire test period, as described in the detail specification. The test specimen shall be exposed for a period of 10 hours to noise whose spectrum is continuous and uniform as a function of frequency from 75 to 10, 000 CPS. (Uniformity of the noise spectrum is defined as follows: In each octave band, 75/150, 150/300... 4800/10,000 CPS, the noise level shall be uniform within ± 3 DB.) The overall sound pressure level shall be 155 DB $^{+0}_{-2}$, above a reference level of .0002 microbar. At the completion of the tests, the test specimen shall be thoroughly inspected to assure that no damage, malfunction or defects result from the tests.

"SPECTRUM NOISE TESTS. In addition to the "white noise" tests above, discrete frequency (spectrum) noise tests shall also be conducted. The test specimen shall be subjected to sound pressures of 150 DB $^{+0}_{-2}$ above a reference level of .0002 microbar at discrete frequencies swept from 75 to 10, 000 CPS at an exponential rate of 10 minutes per octave. At the discretion of the contractor, the spectrum noise tests may be conducted in lieu of the white noise tests described above, if the spectrum sound pressure level is increased to 155 DB $^{+0}_{-2}$.

<u>Note</u>

> It is suggested that during development of a component the vendor conduct initial sweep surveys at relatively low levels and then progressively increase them so as to enable detection of incipient malfunctions and failures; e.g., 135, 140, 145 and 150 DB."

What are the justifications of the round figures of 150, 155, and up to 180 DB glibly tossed around the missile industry? Have tests determined the magic number 155 DB? And what about the frequency spectrum? Should it be "white noise,"

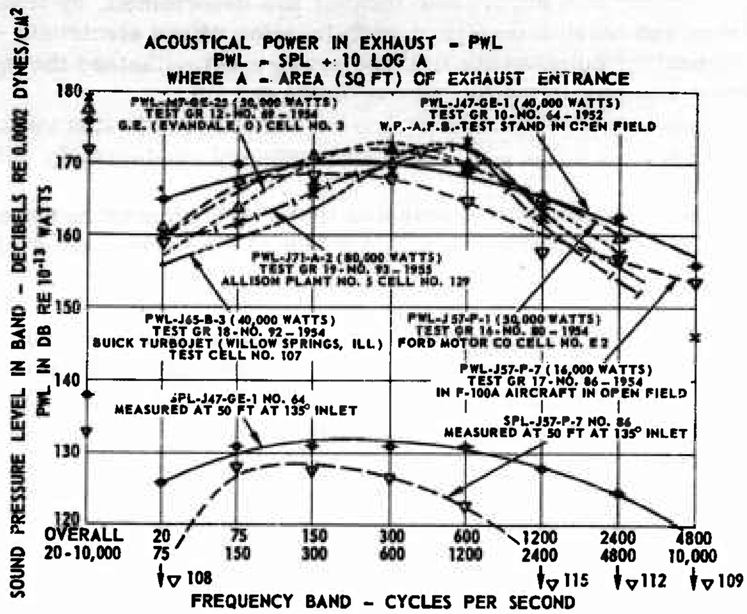



*Figure 1. Turbo-Jet Noise Data.*

with uniformity in each octave band to ±3 DB, or would a "broad-band" spectrum resembling the conventional turbojet rounded curve be more useful? Or should discrete frequency sweeps be used? A test engineer usually prefers empirical facts, so the writer plotted several of the jet engine acoustical power levels (PWL) and sound pressure levels (SPL) compiled by Bolt, Beranek, and Newman, Inc. (1956) in W.A.D.C. Technical Report 54-401. (Reference 5)

This test data is shown in Figure 1. It will be noted that, at maximum power output (16, 000 to 80, 000 watts), the conventional J-47, J-57, J-65 and J-71 turbo-jets give acoustical power levels peaking at 170 DB at 300 to 600 CPS. Similarly the sound pressure levels at 50 FT to 100 FT from the jets round off near 130 DB in the same frequency range.

But how about electronic equipment near the large multiple rockets in today's giant missiles? Figure 2 is the writer's guess of the SPL that may exist near (5 FT) dual rockets (155 DB) in the 300-600-1200 CPS region. At 30 FT from the rocket exit plane the high frequencies will be attenuated rapidly, so the major energy may be below 150 CPS and peak a little above 140 DB. To those interested in overall levels (20-10, 000 CPS), at 5 FT the reading may be 165 DB and 145 DB at 30 FT.

In the test laboratory where everybody is thinking of new "gadgets," such as powerful electronic drivers, sirens, air whistles, etc would it be out-of-order

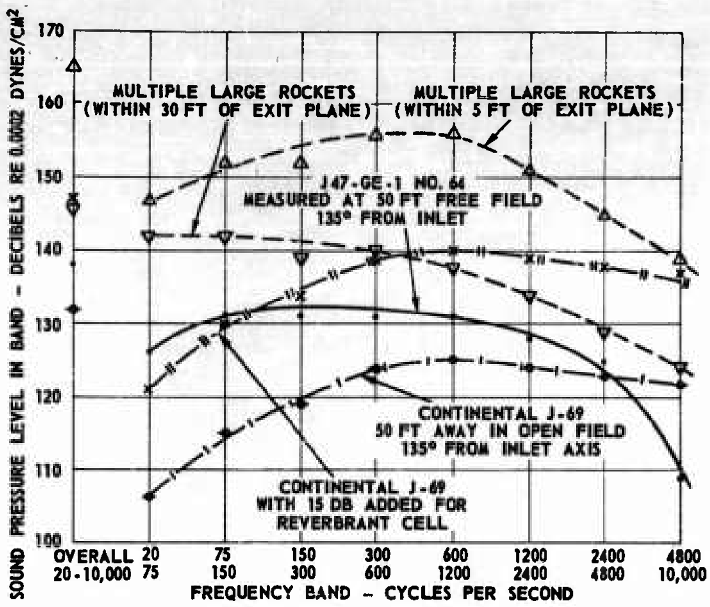



*Figure 2. Typical Sound Pressure Levels, Turbo-Jet and Rockets.*

to mention that the normal engine test facility may offer some help. Such a reverberation chamber could be used for testing electronic parts, missile systems, and maybe structures under "sonic fatigue?" Figure 3 shows such a possibility at the Seaplane Ramp at Convair, San Diego. An extra work bench placed along one wall near the jet exhaust, which would be loosely connected to the exhaust muffler, may be exposed to 150 to 170 DB of noise in a frequency spectrum identical to the flight article. Specimens and components attached to the benches could be operated and electrically monitored from the control room to determine possible weaknesses and time duration to malfunction.

Should engine runups be difficult to schedule and "too short" to put accelerated life tests on components in the test cell, a small turbojet, commercially available, may offer an economical solution. If a Continental J-69 or Fairchild J-44 jet be available, possibly through bailment or service contracts, a rather simple engine test cell could be designed for good reverberation characteristics. The J-69 has been used as an example in Figure 2. Free field acoustical measurements at 50 FT and 135 DEG from the inlet exhaust plane may give the

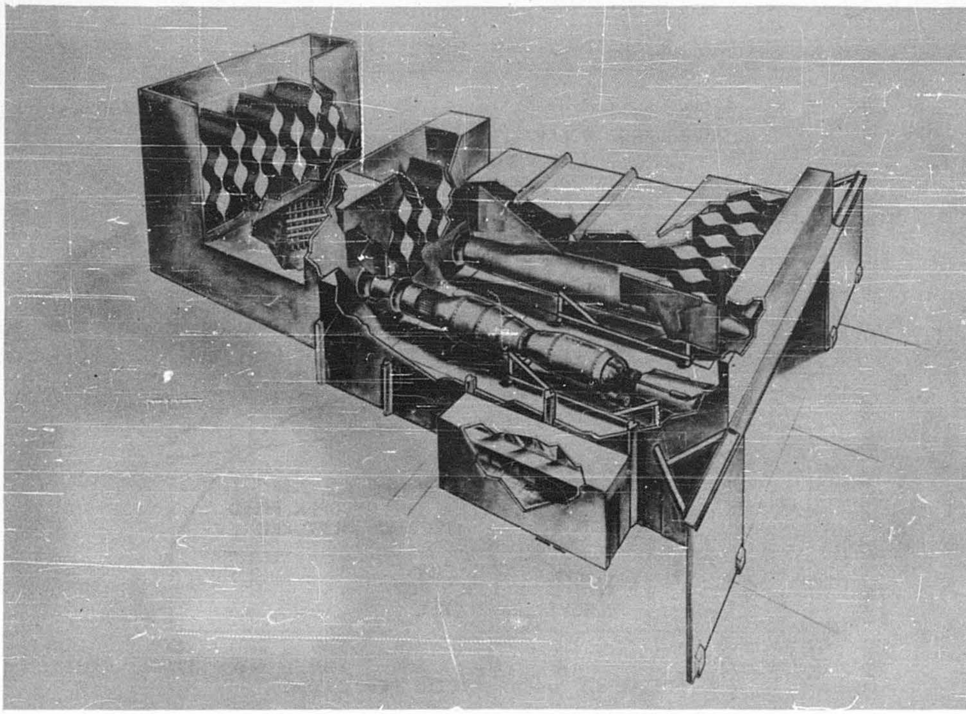


*Figure 3. Convair-San Diego, Jet Test Facility, Seaplane Ramp.*

characteristic flat curve peaking at 125 DB at 600-1200 CPS. With 15 DB extra throughout the spectrum provided by a reverberant cell, levels of 140 DB are possible for long periods of time at negligible cost. Such an engine may consume 18-25 LB/SEC of air, and with a 50 to 1 air-to-fuel ratio, the jet fuel consumption may be only 0-3 to 0-5 LB/SEC or approximately 200 GAL/HR. This may not be any more costly than the 2000 to 4000 CFM of air needed by some modern sirens, and with more realistic frequency spectra.

## ACOUSTICAL FACILITIES

Probably the best method for a commercial test laboratory to meet this new acoustic environment challenge is (1) to review the recent test literature, (2) inspect some of the sonic facilities now available, (3) determine how much investment can be made in acoustic testing of specific types of components, and (4) then to purchase or build the facility. The demand for new and different test environments will change rapidly in the next few years and new sources of high intensity noise will be developed. So an investment, once made, may be required to be modified by added funds to higher intensities and frequencies before complete returns on the investment can be obtained.

| NAME | SENSITIVITY DB | FR | RANGE | MAX DB | MIN DB | °F MAX TEMP | TEMP COEF DB/°F | CAP UUF | COST WITH CALIB |
|---|---|---|---|---|---|---|---|---|---|
| W-E 640-AA | -50 FROM 10CPS -12KC; -90 AT 100KC | 8KC | 10CPS-100KC | 150 | 30 FROM 10CPS - 12KC; 12 FROM 600 - 1200CPS | APPROX 300°F | .004 DB/°F | 50 UUF | $650.00 |
| TOKYO RIKO MR-103 | -56 FROM 10CPS -12KC; SHOULD BE SAME AS ABOVE AT 100KC | 8KC | 10CPS-100KC | SHOULD BE SAME AS ABOVE | SHOULD BE SAME AS ABOVE | APPROX 400°F | .0013 DB/°F | 50UUF | $225.00 |
| ALTEC 21 BR | -55 TO -115 | 9-30KC | 5CPS-20KC* | 155-214 | 50-100** | 350°F | 0.012 DB/°F | 5 UUF | $125.00 |
| MASSA M-125 | -92.5 | 40KC | 20CPS-35KC | | | 160°F | | 120 UUF | $225.00 |
| MASSA M-213 | -102 | 140KC | 20CPS-120KC | | | 150°F | | 12UUF | $425.00 |
| OMEGA 32 | 30 DYNES/CM² 100PSI | 162KC | 0-105KC | 100PSI | 30 DYNES/CM² | 200°F | | .3 UUF | $625.00*** |
| PHOTOCON 364 | | 7.5KC | 0-50KC | 160 | 80 | 250°F | | 18 UUF | $300.00 |
| PHOTOCON 320A | | 120KC | 0-15KC | 200 | 120 | 250°F | | 18 UUF | $300.00 |

*UNCOMPENSATED
**THRESHOLD SPL
***INCLUDES EXCITER AND AMPLIFIER

*Figure 4. Microphone Data, M.T.S. at Convair-Pomona, 4 June 1957.*

The attached bibliography will aid the newcomer in this acoustic environment in determining current practices.

A few sonic laboratory facilities are now in operation, many more are in development. This paper can cover only a few that have come to the author's attention within the last year.

One common denominator of all these acoustical laboratories that will need to be resolved at an early date is the proper microphone to measure the environment. A symposium of microphone manufacturers, calibrators, and users was recently held at Convair-Pomona, to determine test characteristics of some of the more common microphones. A summary of the findings of this meeting is given in Figure 4. As with the sonic facility, each user will have to pick the microphone that best fits his test needs and budget. Figure 5 covers some of the more common microphone characteristics as compiled by the Bolt, Beranek, and Newman Co., Inc. of Cambridge, Mass. and Los Angeles. The specifications shown are not intended to indicate manufacturers' statements but are given as practical guides to the selection of equipment for the purpose intended. A more critical evaluation of this list (Figure 5) is being made by B.B. & N. and is to be made available in the near future. A very complete study of the Altec 21 BR series microphones has been made by Mr. J. Hilliard (Reference 3).

CONVAIR-POMONA, PLANE-WAVE AND RESONANT TUBES. As early as 1954, engineers in Convair-Pomona, made "captive flights" of missiles to study the effects of vibration and noise. The primary objective of these tests was to measure sound intensities in and around the missile during rocket burning. The

| MANUFACTURER | ALTEC | | | | | AR* | CHESA-PEAKE | GULTON | PHOTOCON | | | TOKYO RIKO | SHURE | | WE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TYPE NUMBER | 633A | 21BR 150 | 21BR 200 | 21BR FLUSH MOUNT | 21BR PIN HOLE | BC10C | AB 330S | P600 | 304A | 354A | 364A | MR103 | 9898 | 98B99 | 640AA |
| SENSITIVITY-DB RE 1V/UBAR | -85 | -55 | -85 | -60 | -75 | -116 | -110 | -100 | -88 | -24 | -42 | -50 | -60 | -60 | -50 |
| IMPEDANCE CAP IN UUF | 30 OHMS | 6 | 6 | 6 | 6 | 8000 | 3000 | 400 | USE WITH DG400 DYNAGAGE | | | 50 | 2000 | 1000 | 35 |
| MAXIMUM SPL DB RE 0.0002 U BAR | 110 150 | 140 | 170 | 145 | 160 | 244 | 250 | 170 | 190 | 140 | 160 | 140 | 140 | 140 | 140 |
| MINIMUM SPL DB RE 0.0002 U BAR | 15 | 25 | 55 | 30 | 45 | 80 | 74 | 70 | 55 | 10 | 10 | 10 | 20 | 20 | 10 |
| TEMPERATURE MAXIMUM °F | 150 | 500 | 500 | 500 | 500 | 200 | 450 | 200 | 6000-$H_2O$ COOL 400 W/O $H_2O$ COOL | | | 400 | 110 | 110 | 400 |
| STABILITY VS TEMPERATURE | FAIR | POOR | GOOD | FAIR | FAIR | GOOD | GOOD | GOOD | EXCEL-$H_2O$ FAIR WITHOUT | | | EXCEL | POOR | POOR | GOOD |
| OPERATION IN HIGH HUMIDITY | GOOD | POOR | POOR | POOR | POOR | EXCEL | GOOD | FAIR | | GOOD | | FAIR | FAIR | FAIR | FAIR |
| FREQ RANGE CPS ±1 DB RE 400 CPS RANDOM INCIDENCE | 200 TO 600 | 20 TO 3000 | 20 TO 10000 | 20 TO 3000 | 20 TO 5000 | 1 TO 4000 | 1 TO 1000 | 20 TO 2500 | 1 TO 4000 | 1 TO 500 | 1 TO 5000 | 10 TO 4000 | 20 TO 2000 | 20 TO 4000 | 10 TO 4000 |
| FREQ RANGE CPS SLOPE 1½ DB PER ⅓ OCTAVE RANDOM INCIDENCE | 100 TO 600 | 20 TO 10000 | 20 TO 12000 | 20 TO 10000 | 20 TO 5000 | 1 TO 4000 | 1 TO 1000 | 20 TO 4000 | 1 TO 10KC | 1 TO 700 | 1 TO 10KC | 10 TO 10000 | 20 TO 2000 | 20 TO 5000 | 10 TO 10000 |
| DIFFRACTION 5 DB NORMAL TO GRAZING ABOVE - CPS | 5000 | 8000 | 8000 | 8000 | 8000 | 6000 | 1500 | 6000 | 7000 | 3000 | 7000 | 7000 | 3000 | 6000 | 7000 |

*ATLANTIC RESEARCH CORPORATION.

*Figure 5. B.B. & N. Microphone Summary.*

end result of these investigations was to provide a method whereby similar sound pressures could be simulated in the laboratory under controlled conditions.

2 Foot Diameter Plane Wave Tube. A contract was placed with the California Sound Products Inc., in Hollywood, nearly two years ago for a "Plane Wave Tube" to investigate electronic components under sonic environments. Close teamwork has existed during the past year of testing by Convair-Pomona Engineering Test Laboratories, California Sound Products Inc., and the Altec-Lansing Corporation. Mr. J. Hilliard of the latter organization has done much to keep the Convair-Pomona facility up-to-date.

Two laboratory areas have proven of value at Pomona. One is formed by an insulated tunnel two levels below the concrete centrifuge pit, for initial trials of sirens, whistles and electronic drivers without acoustical attenuation. After the noise generator has been developed in this remote-control cell, thus protecting the operator and neighbors, it is installed in one of the chambers in the Acoustic Laboratory shown in Figure 6.

The primary Convair sonic facility, as shown in Figure 7, consists of two 8 FT long sections of concrete sewer pipe, approximately 2 FT in diameter, forming a 16 FT long tube. The active end of the chamber, approximately 2 FT

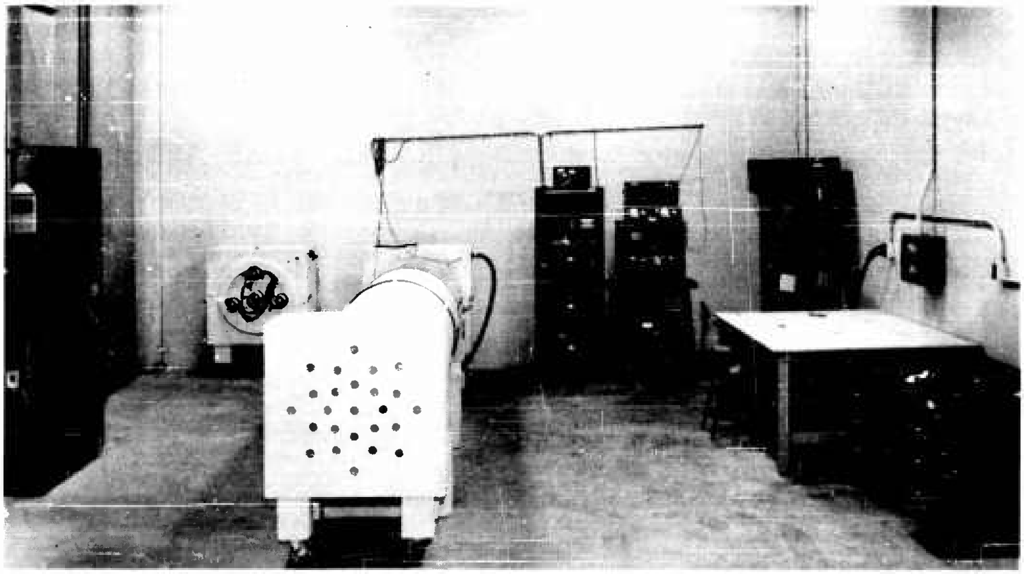


*Figure 6. Convair - Pomona, Acoustical Laboratory.*

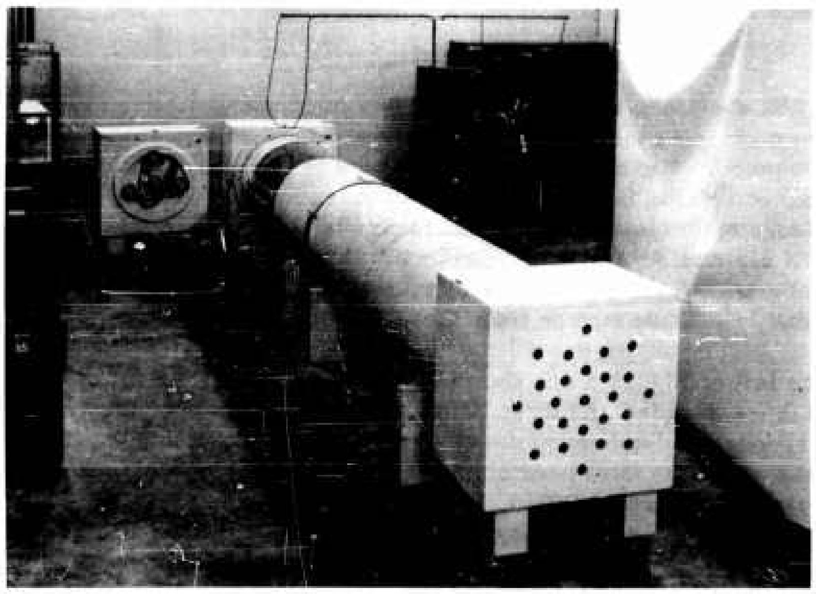


*Figure 7. Convair - Pomona, Large "Plane Wave Tube".*

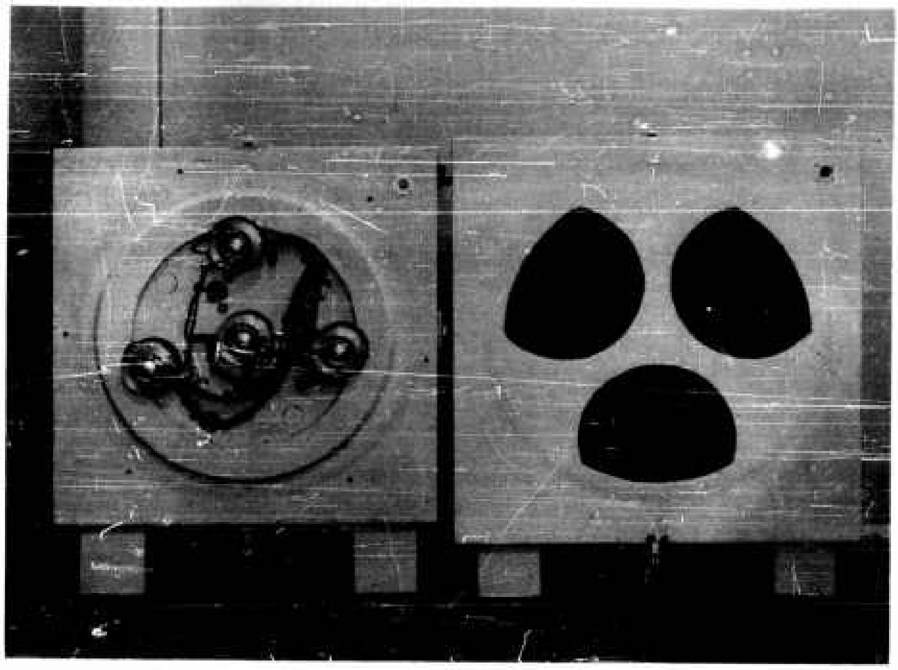


*Figure 8. Speaker Enclosures.*

from the test specimen area, consists of two interchangeable loudspeakers' enclosures: one containing low frequency "woofers" and the other mid- and high frequency speakers. The opposite end of the tube is sealed by an acoustical termination box, containing fiberglas insulation.

In Figure 8, the low frequency enclosure is shown on the right, containing three 15 IN air-cooled Altec 515 speakers. During some tests three 15 IN RF-475 Stromberg-Carlson low-frequency speakers have been used. The results of the frequency response curves from these two sets of speakers have proven similar.

On the left of Figure 8 are shown the original set of four Altec 802C drivers for the high frequencies and three Altec 288C transducers for the mid-frequencies. With the recent development of the air-cooled 200 watt Altec 290C drivers, a set of these new units have been obtained and tests will be continued as higher powered amplifiers are installed.

Figure 9 shows the frequency spectrum using the Altec 802C transducers to beyond 20 KC, whereas the Altec 288B and Stromberg-Carlson RF-475 units are compared in the region of 1 to 3 KC. During the "sweep frequency" tests at discrete frequencies in this large tube, the speakers change over at 5000 CPS and 700 CPS.

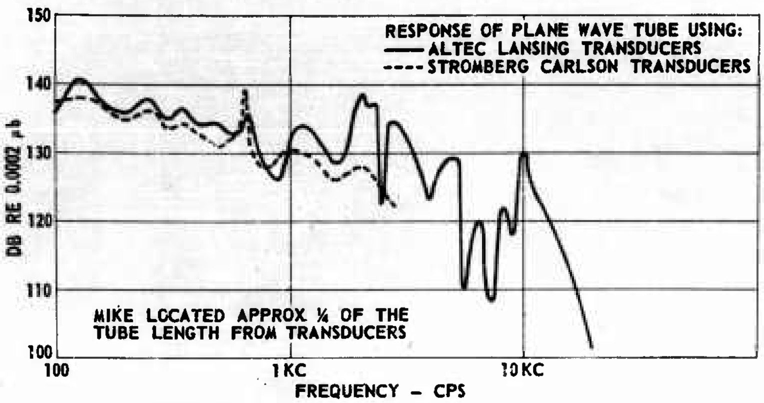



***Figure 9. Frequency Response Curves of Plane Wave Tube.***

The control console to the right of Figure 10 includes a logarithmic amplifier built in the Convair-Pomona Laboratories and a Brush recorder for rapid records. In the base is the new Altec 260 watt power amplifier, which can be augmented by additional laboratory amplifiers to meet the speaker demand. The remainder of the test instrumentation in the foreground is used to evaluate commercial klystrons in acoustic environments.

A novel means of visual inspection of the test specimen area has been provided by California Sound in Figure 11. A cut-out portion of the concrete pipe is covered with a 1 inch plexiglas viewing window, sealed in rubber. This provides for rapid access to the specimen, and yet provides approximately 30-40 DB sound attenuation for the operator. Signal cables from the test specimen may be "led out" over the rubber seal or through ports provided.

Convair has run some acoustical attenuation studies, shown in Figure 12, in which microphones are placed inside and outside of the cone.

The ease with which tests may be made on vendor's components is illustrated in Figure 13. In this instance the specimen is supported on damped wooden rods and wires in the 2 FT test area and the signals are monitored by instrumentation on the nearby cart. The plexiglas enclosure would, of course, be "on" during the acoustical survey.

<u>8 Inch Diameter Resonant Tube.</u> The second Convair sonic facility is shown in Figure 14. This is an 8 FT long section of 8 IN. diameter concrete sewer pipe. An Altec 290C or Jim Lansing 375 driver is adapted to the left end by means of a cast aluminum exponential horn. Small specimens, similar to relays, vacuum tubes or mounted in bases, can be attached to the rigid angle fixture on the face of the wooden plunger. With the signal wires passing back along the rod, the output of the specimen may be monitored at various resonance

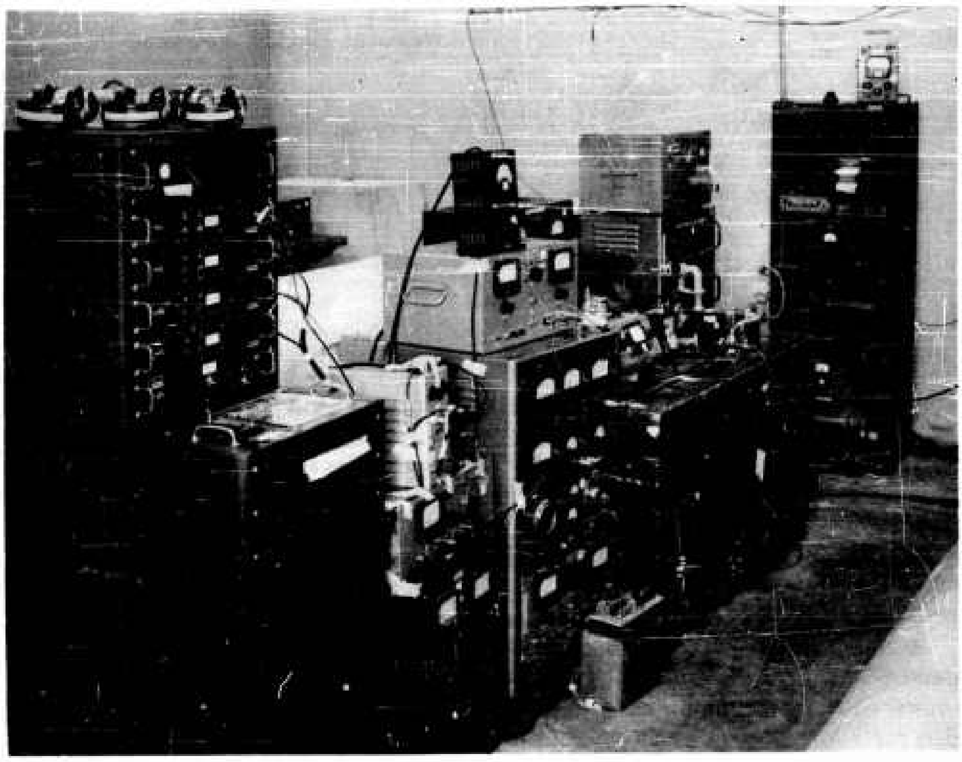


*Figure 10. Klystron Evaluation Under Sonic Environments.*

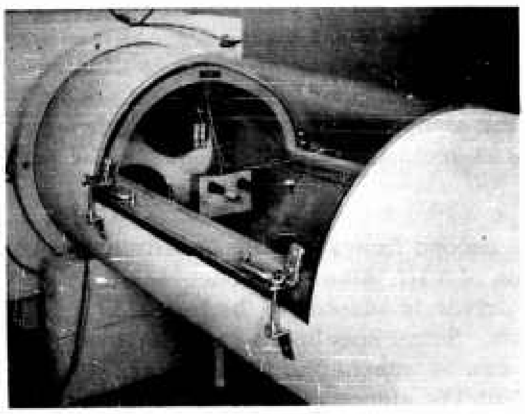


*Figure 11. Test Area Viewing Window in Plane Wave Tube.*

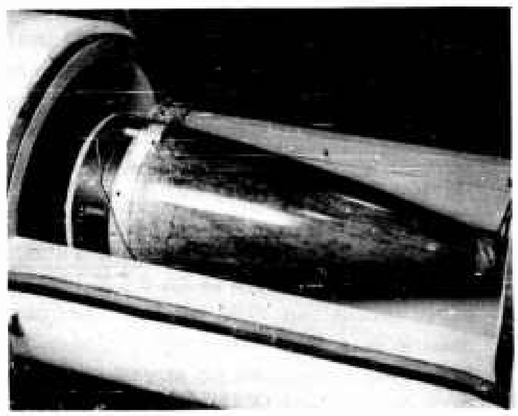


*Figure 12. Cone Attenuation Studies.*

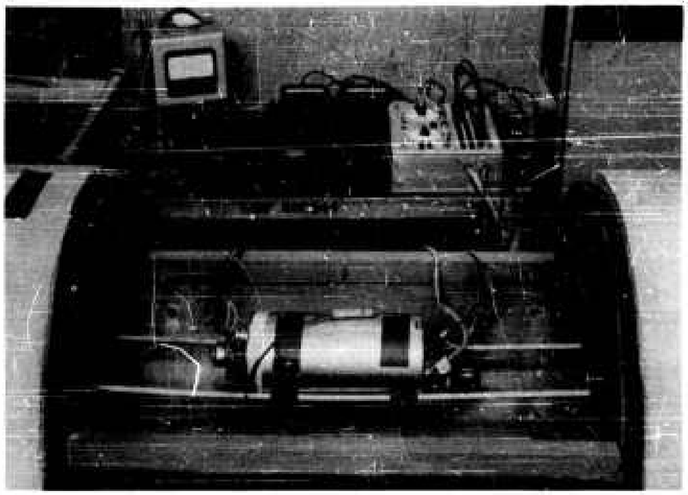


*Figure 13. Outside Vendor Test.*

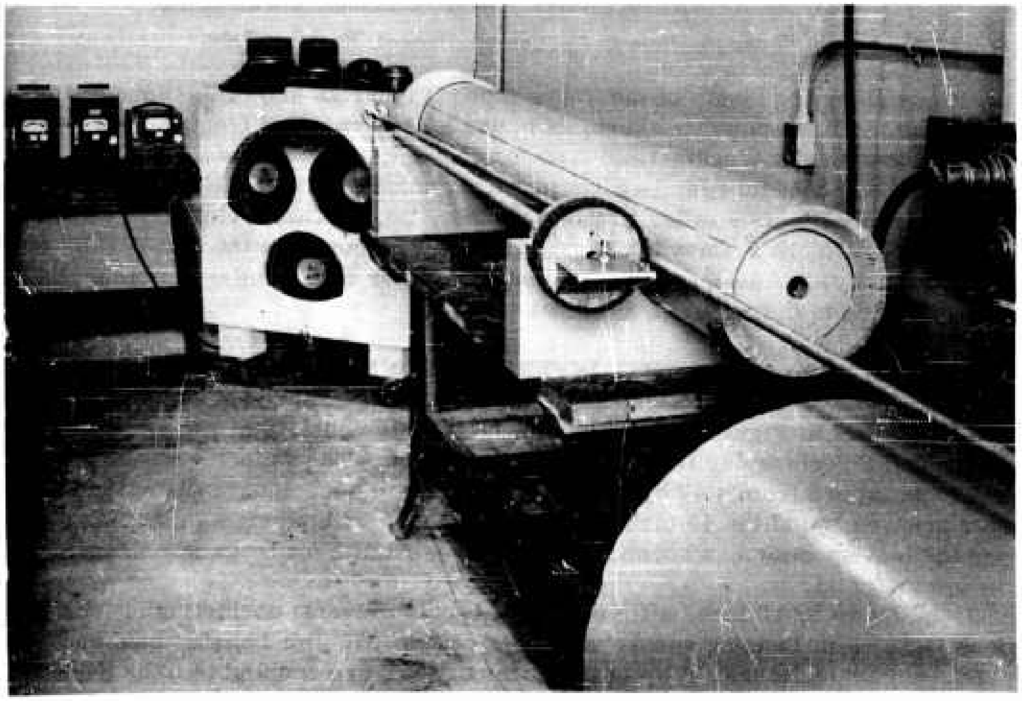


*Figure 14. Convair-Pomona Resonant Tube.*

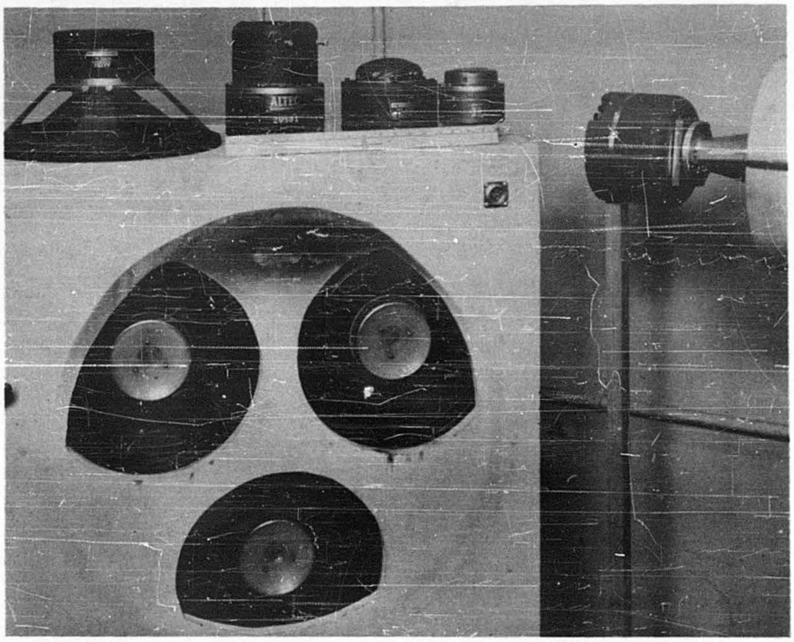



*Figure 15. Horn End of Convair-Pomona, Resonant Tube.*

positions along the length of the 8 inch pipe. Figure 15 shows the horn end of the tubes. The various speakers, covering a wide range of frequencies, are shown above speaker cabinet.

This resonant tube facility has just been completed and tests are in progress. It is hoped that tests similar to those made by Dr. Werner Fricka of Bell Aircraft Corp., Buffalo, N.Y. may be carried out so as to compare the test results obtained in his rectangular wooden resonant chamber with similar specimen test results made in this circular concrete pipe.

ROTOTEST LABORATORY INVERSE EXPONENTIAL HORNS. Rototest Laboratories, of Los Angeles, has recently completed the random (white) noise facility shown in Figure 16. Basically the facility consists of two exponential horns and a rectangular intermediate test section. The welded steel horn on the right tapers from a 40 by 40 inch panel to the 8 inch square (64 square inch) test area. Beyond the 40 inch long test chamber, with plexiglas front for viewing the test specimen, a second plywood exponential horn feeds into acoustic wedge material.

On the 40 by 40 inch baffle there are twenty drivers; consisting of four 12 inch D-131 Jim Lansing speakers and sixteen No. 375 Jim Lansing medium-frequency transducers. Two of the latter drivers are coupled into the back plate by two short exponential horns.

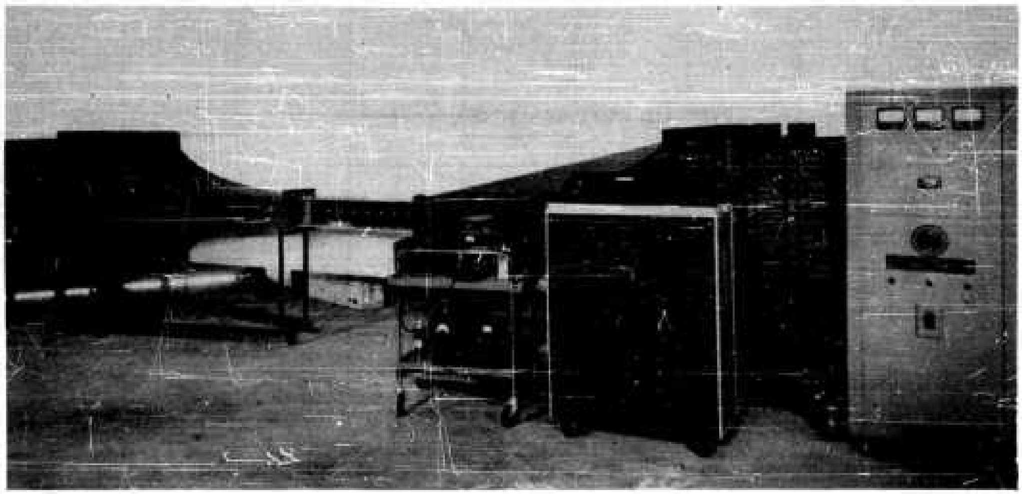


*Figure 16. Rototest Inverse Exponential Chamber.*

Power for the drivers are provided by nine McIntosh standard 60 watt amplifiers; one amplifier for each pair of transducers, with a 2 kilowatt power supply standby.

To date, Rototest and the Jim Lansing representative are stressing the "white noise" approach in compliance with their customers' requests. It is understood that recent tests have given fairly even acoustical power in each octave, as shown in Figure 17, and an overall sound level of approximately 150 DB.

ALTEC-LANSING'S UNSYMMETRICAL CHAMBER. Several months ago, the Altec-Lansing Corp. completed a high sound pressure level chamber in their Beverly Hills Laboratory, under their Director of Engineering, Mr. J. Hilliard. Figure 18 shows a picture of the concrete chamber, with four A.L. 802C speakers attached through short horns. The 25 by 27 by 23 inch box is made of reinforced concrete walls 1 inch thick, with non-parallel sides to reduce standing waves. The inside of the walls are coated with lacquer to reduce absorption. Altec uses four of their recently developed 290C loudspeakers, driven by four 260-watt amplifiers. The drivers shown in the picture are the Altec 802C high frequency drivers. It has been established that by using four Altec 290C units with a total power of 800 watts, that a sound pressure level of 156 DB can be produced. Higher SPL can be achieved by additional power and speakers. Either a sine wave (discrete frequency) or an octave-band power source can be used in the chamber and the maximum variation with position within the chamber does not exceed 3 DB.

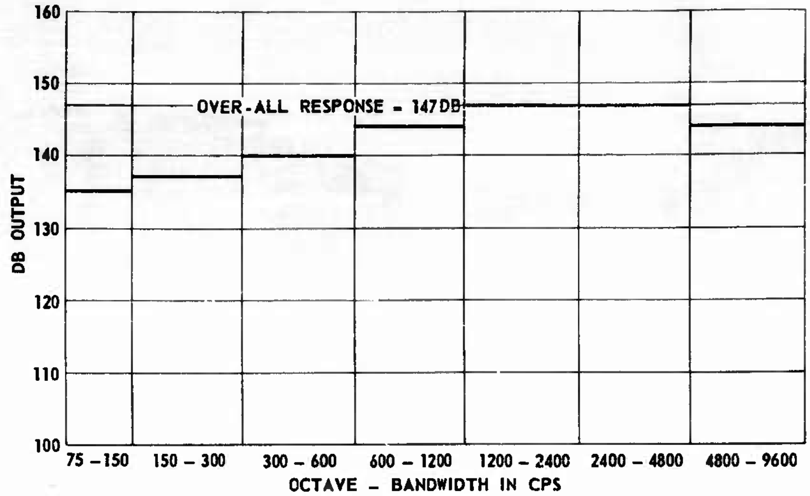



**Figure 17. Rototest Octave-Band Response of Acoustic Facility.**

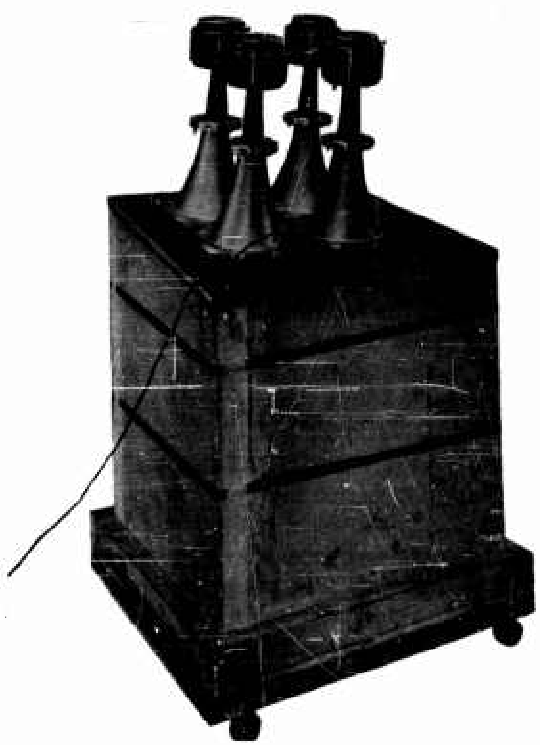


**Figure 18. Altec Acoustical Chamber.**

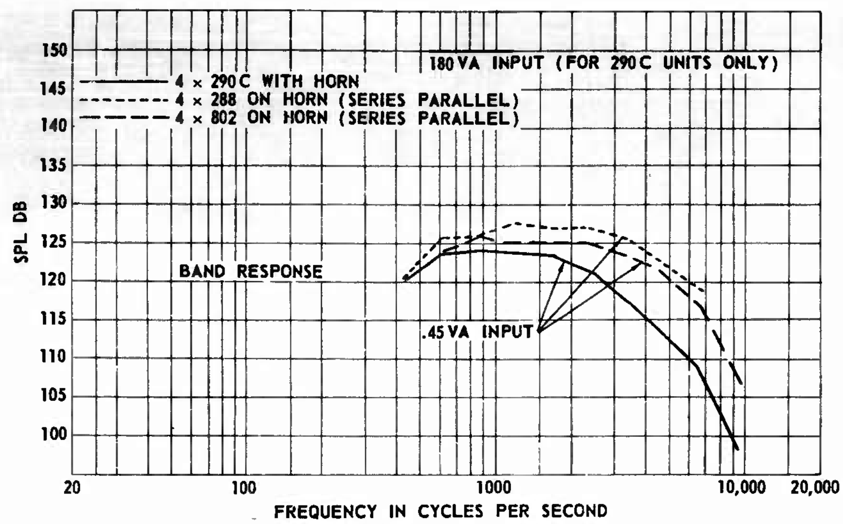



*Figure 19. Octave-Band Response of Altec Chamber.*

Figure 19 shows the response curve of the chamber with three different sets of speakers, four each. The Altec 288B is shown on top with the dotted line, below that is shown the dashed line of four Altec 802C speakers, and finally below that the four Altec 290C units. It should noted that the speaker input on each of these sets of speakers was 0.45 volt-ampere. At the top of Figure 19 is shown that four Altec 290C speakers have developed 150 DB using 180 VA input.

NORTHROP ACOUSTICAL TEST FACILITIES. In a well-presented paper (Reference 4) recently, Mr. D. Skilling of Northrop Aircraft Corp. reviewed the acoustical environmental testing of that Company since 1955. The first facility consisted of four "Dynojets" (small pulse jets used to fly model aircraft) in a 6 FT high by 7 FT wide jet engine muffler tunnel, lined with brick. Approximately 135 DB was obtained on these small pulse jets but their valve life was a matter of only a few minutes.

The "Dynojets" were replaced by four helicopter pulse jets, 4½ IN. diameter by 48 IN. long. It was necessary to keep the test specimen remote from the jets while starting them, due to the violent explosions that were present at times before the jet achieved proper running conditions. All controls for the jets were located in a control room outside the tunnel, some 50 FT from the pulse jets.

Some testing of small components began early in 1956. The maximum obtainable sound pressure levels on these specimens was 143 DB. When it became necessary to develop 150 DB on the components, the muffler tunnel was modified.

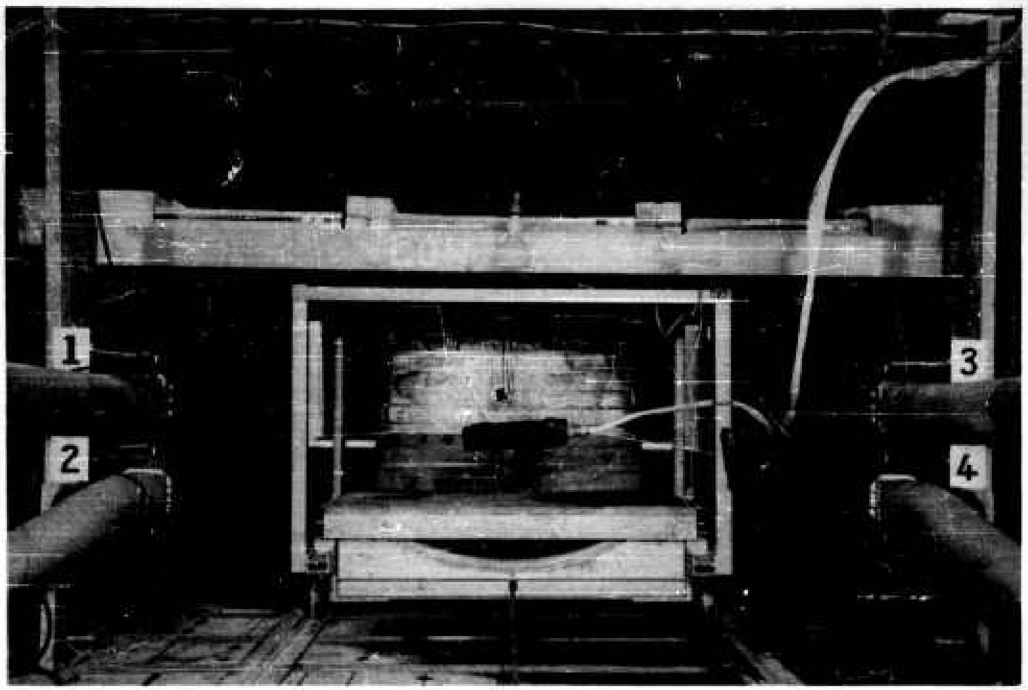



*Figure 20. Northrop's Pulse-Jet Test Facility.*

The vertical pairs of jets were located within 1 foot of each other and a false brick ceiling and back was installed, as shown in Figure 20. The specimen was suspended on a spring mount, in the remotely-controlled cart, so that the natural frequency in any of the three principal axes was less than 2 CPS. A method of throttling the jets was devised so that SPL from 136 to 154 DB could be controlled.

Figure 21 shows a 1/3 octave-band analysis of the pulse jet spectrum. It can be noticed that a fundamental frequency of 120 cycles appears, as well as the first and third harmonics of 120 CPS.

Another Northrop acoustic facility was required to produce a broad-band spectrum at 130 DB, with long duration. A so-called "Interim 130 DB Facility" shown in Figure 22 was developed. The chamber is constructed of 3/4 IN. plywood and is approximately 5 FT square, and 4 FT high. The plywood walls were covered with aluminum foil tape in an attempt to make the chamber more reverberant.

A suitable low frequency driver was provided in the box base by a 42 IN. diameter aluminum cone, $9\frac{1}{2}$ IN. deep and rolled of .090 IN. aluminum. This cone is driven by an MB-C5 vibration shaker, through its 5 KW power supply.

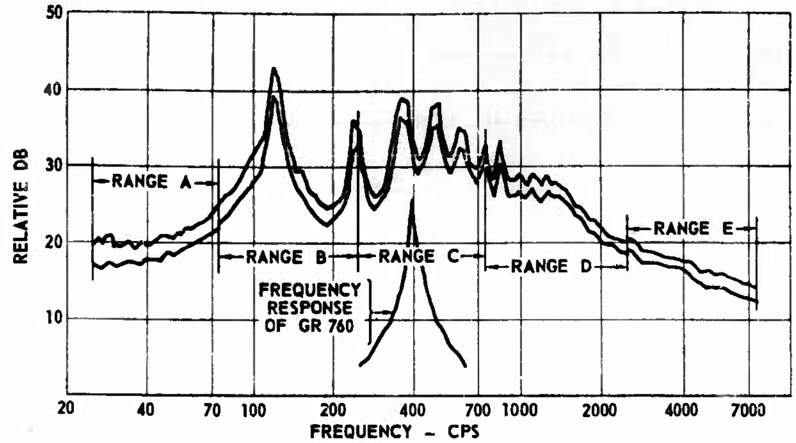



**Figure 21. Frequency Response of Northrop Pulse-Jet Facility.**

**Figure 22. Northrop's 130 DB Interim Chamber.**

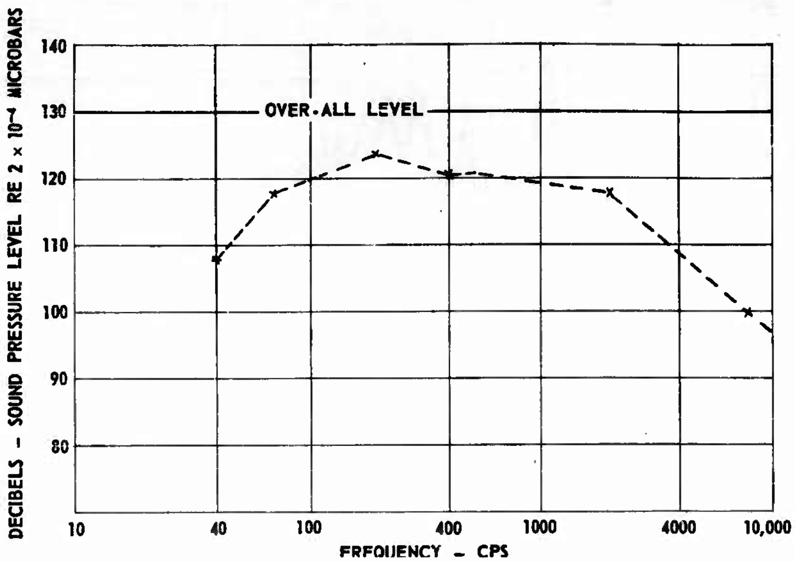



***Figure 23. Frequency Response Curve of Northrop Interim Chamber.***

Two 15 inch speakers in the chamber walls consisted of a University Triax 315 (50 watt) unit on the left and an Altec 515 on the right. The 315 speaker was driven by a 30 watt McIntosh amplifier and the 515 speaker by an Altec 256C amplifier (60 watt). The input signals to the shaker and the two speakers were separately recorded on a two-channel Ampex tape recorder. An electronic thermal noise source was constructed, using the random electron noise in a "thyratron" as a source.

Figure 23 illustrates a typical response curve of the Northrop Interim Chamber. The frequency spectrum energy is such as to approximate the 130 DB overall level desired.

A new acoustic test facility has recently been installed in a room 6 feet high by 5 feet wide by 8 feet long in the rear of the pulse jet muffler tunnel by the Western Electro Acoustic Laboratory. Two speaker cabinets are used in this room. Each cabinet is made of 1 inch plywood and stands 6 feet high, is 3 feet wide and 4 feet long and contains five speakers. There are three Jim Lansing Model 130A 15 inch low frequency speakers, using front horn and reflex loading. There are also two Jim Lansing Model 375 high frequency drivers with dispersion horns built into the cabinets. The two tweeters, the high frequency units, are at the upper end of the cabinet with the three 15 inch speakers in the three lower sections. These high frequency units were especially made by the Moving Coils Division of Jim Lansing to handle the high power necessary to achieve the desired sound levels. Two Altec 260 watt amplifiers are used, one for the tweeters and one for the woofers. A Western Electro Acoustic Laboratory equalization and dividing network provides the 700 cycle cross-over between the two speaker systems. This unit also provides the bass and treble boost.. A Western Electro Acoustic Laboratory thermal noise source, using the random electron noise generated, this time in a carbon resistor, provides the input signal for the system.

Sound level measurements in this new "Sound Room" at Northrop Aircraft Corp. were made on a 1/3 octave band analysis. Although the overall levels are approximately 130 DB, as in the "Interim Chamber" (Figure 23), due to bass and treble compensation, a flatter characteristic spectrum is available as shown below:

OCTAVE NOISE LEVEL (DB) - A.S.A. STD REF. LEVEL .0002 DYNES/$cm^2$

| O.A. | 0-75 | 75-150 | 150-300 | 300-600 | 600-1200 | 1200-2400 | 2400-4800 | 4800-9600 |
|---|---|---|---|---|---|---|---|---|
| 130 | 102 | 112 | 114 | 115 | 114 | 114 | 114 | 116 |

DOUGLAS AIRCRAFT CO. — S.M. SIREN FACILITY. With the need for structural information on sonic fatigue on the "DC-8" jet transport, Douglas Aircraft Corp. has invested in a fine acoustical laboratory. Most structures for high sound pressure areas on the "DC-8" airplane have resonance frequencies in the neighborhood of 200 to 700 CPS. The new siren at Douglas has a frequency range of 50 CPS to 1000 CPS for the fundamental.

Figure 24 is a schematic diagram of the Douglas siren system. The test cell for structural elements is 5 FT long and has a 4 FT high by 1 FT wide cross section. Mr. P. Belcher described the Douglas tests and facilities so adequately before the I.A.S. Specialist Meeting in Los Angeles on 26 February 1957 (Reference 2) that details will not be given in this paper. Figure 25 shows the siren installed in the pit in the Douglas reverberation room. The flow restrictor, for varying the pressure, is a 15 IN. variable iris valve. Two compressors in series deliver 4000 cubic feet per minute at 5 PSI gage. The "chopper" is driven by a 30 horsepower motor which is a part of a Ward-Leonard control system, providing extremely stable frequency control under variations of line voltage and changes in load. Exhaust ports are acoustic treated so that the external sound pressure is 75 DB when the test chamber records 160 DB.

SOUNDRIVE ENGINE COMPANY SIREN INSTALLATION. Several large Los Angeles Aircraft manufacturers are renting the sonic facilities provided by Mr. Al Bodine, President of Soundrive Engine Co. in Pico Canyon, Newhall,

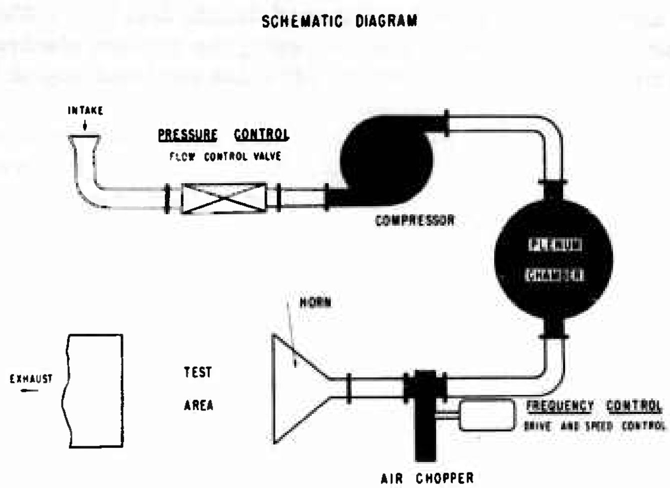



*Figure 24. Douglas Siren System, Schematic Diagram.*

Calif. just north of San Fernando. Figure 26 shows the test section with the standard 24 IN. square panel mounted, to check for sonic fatigue. It also shows that the entire face of the test section can be removed to mount a 4 by 5 FT structural test panel. Visible also are the plenum chamber, the chopper port disc and the terminating duct. Douglas Aircraft Co. conducted many of their DC-8 tests in this Pico Canyon facility while their acoustics laboratory was being constructed. Figure 27 shows the interior view of the same Soundrive test section. At the top and bottom are glass fiber batts, covered with perforated metal, to reduce vertical standard waves. Noise intensities above 160 DB may be maintained in this facility.

BELL AIRCRAFT CORP. (BUFFALO, N.Y.) RESONANT CHAMBERS. Dr. W. Fricka presented a full description of the Bell Aircraft "standing wave" chambers (Reference 2) at the I.A.S. Specialist Meeting in Los Angeles on 26 February 1957. Bell Aircraft has been a pioneer in the testing of small components under high sound pressures, using low acoustic power, by tuning the enclosure and using resonant amplification. Figure 28 shows the largest of several such "standing wave tubes," with a rectangular chamber of 1600 SQ CMS test section. Both end plates are removable. Altec drivers of different types are mounted on the piston plate which is fastened to the right rod. The box has wheels which run on rails and can be moved relative to the fixed driver support by the lead screw and

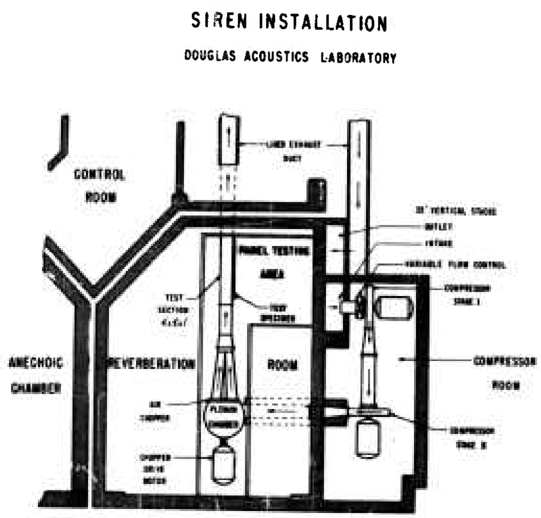




*Figure 25. Douglas Siren Installation in Acoustic Laboratory.*

Figure 26. Sound Drive Pico Canyon Siren Test Facility.

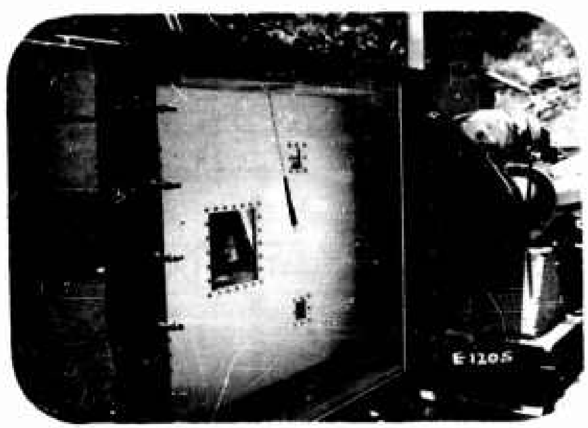



Figure 27. Sound Drive Siren Internal View.

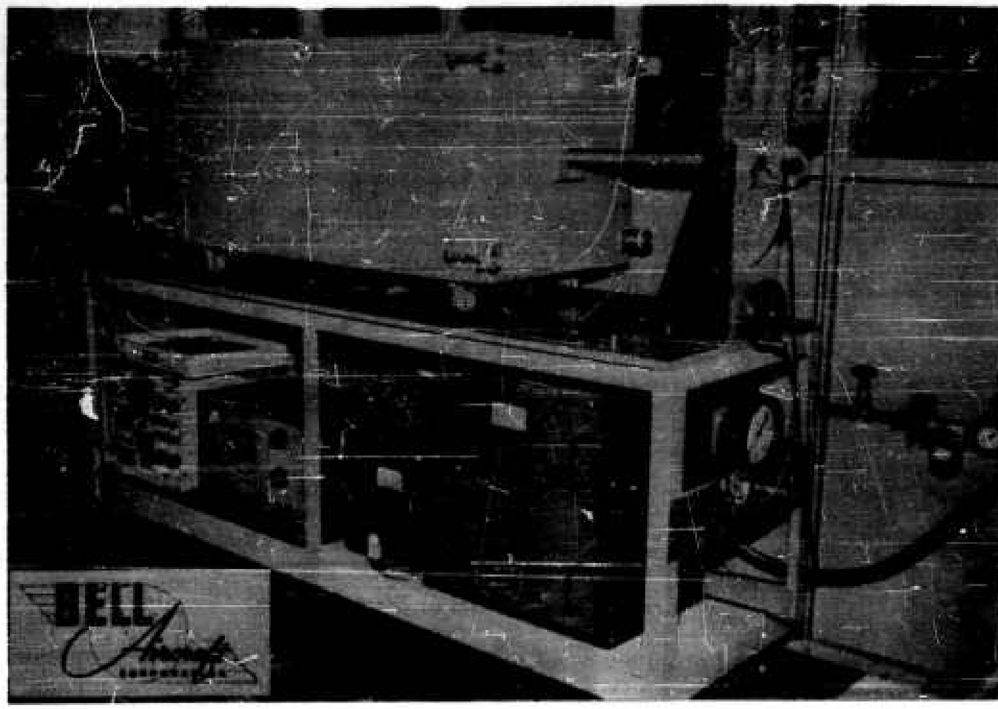


*Figure 28. Bell Aircraft Large "Standing Wave" Tube.*

the handwheel. A cable and a hose inside the rod provide power and air supply to the acoustic drivers. The left end plate supports the component to be tested. The associated electronic equipment is located below the test bench.

The sound field around the component under test is not uniform and for each specimen an average value is assumed. Bell Aircraft Corp. has tested many components such as relays, electronic tubes, telemetering units, gyros, barometric switches and amplifiers.

It is interesting to note that, with the flat-sided "standing-wave" tube, modal patterns of cork dust exist in the chamber and are unique for a given frequency and dimension. At the points of maximum velocity, corresponding to minimum pressure, the cork dust drifts to the region of maximum pressure. Between 200 and 5000 CPS a sound pressure level of 160 DB can be obtained. At higher frequencies up to 10 KC the value drops to 145 DB.

Figure 29 shows the microphonic outputs of one of the sound sensitive tubes (CBS-Hytron Type 5814A). Of 20 electron tubes tested, this tube was the most affected by 140 DB. It has 2 maxima under acoustic resonance, at 800 and near 3000 CPS.

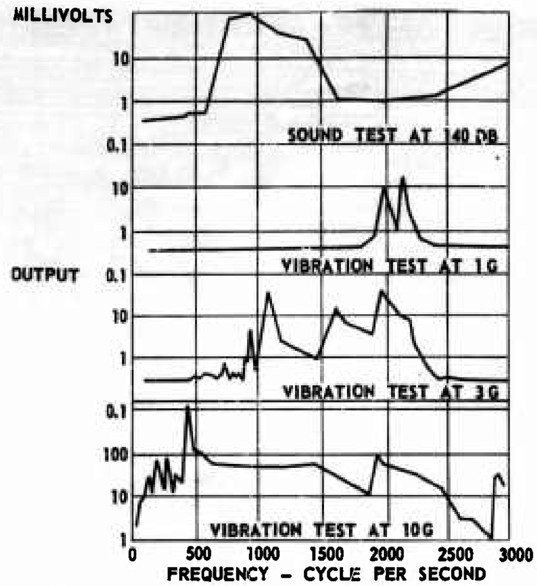



***Figure 29. B.A.C. Tests on Electron Tubes.***

The question has often been asked if microphonic outputs in electron tubes could not be similarly excited by mechanical as well as by acoustical means. Mechanical vibration of this tube had other results. Vibration at 1g did not have any influence at 1000 and 3000 CPS. It had, however, small outputs between 2000 and 2200 CPS. At 3g's the peak appears at 1100 CPS but does not reach the critical limit chosen as a malfunction criterion of 75 millivolts for microphonic output. At 10g's, a broad spectrum with a sharp peak at 500 CPS is generated which exceeds 75 millivolts.

Bell Aircraft Corp. has initiated an extended program in cooperation with the Army's Evans Signal Corps Laboratory to establish a relationship between sonic and mechanical vibration excitation.

## Part II
## CONVAIR "SOUND CABIN" TEST FACILITY

A paper on sonic environmental testing would not be complete without discussing the effects of jet engine noise on airplane and missile equipment. A request was received from a large aircraft manufacturer, recently, for heretofore unpublished test information on early Convair "Sound Cabin" research. Inasmuch as the writer holds Patent application No. 708,206 on "Method and Apparatus For Acoustical Testing," filed 6 November 1946, it may be that public discussion of the "Sound Cabin" principle of testing may aid the harassed jet plane manufacturers and provide a tool for "ground testing."

In 1946 and 1947 the writer presented some papers on aircraft acoustical problems and possible solutions (References 12, 13, 14, 15). Only the master copy exists of much of the test information on the 1945 Sound Cabins No. 1 and No. 2 in San Diego. Upon request, this ground survey method of conducting tests in high intensity noise environments will be briefly reviewed.

Figure 30 shows the simplicity of this acoustical test method of using a discarded fuselage section, in this instance, the nose portion of an XB-32 which had survived explosive decompression and gunfire tests in 1945 and had thereafter been patched and repaired. Sound Cabin No. 1 was mounted on a suitable wheeled stand which could be rolled with ease to the engine propeller or turbojet being tested.

The "Sound Cabins" also fill the need for an economical means of comparing soundproofing materials and insulation methods. Two sound cabins were used in 1945 and 1946 on various engine-propeller and jet-engine combinations. The bare, 137 inches long by 87 inches high by 96 inches wide, Sound Cabin No. 2 was modified, in cabin interior arrangements, to represent a soundproofed forward 56 inch long baggage compartment and a rear 81 inch long passenger cabin with its prescribed soundproofing treatment. Sound Cabin No. 1 was maintained as a single calibrated chamber (94 inches long by 72 inches high by 103 inches wide), with padded end bulkheads, in which experimental wall soundproofing could be evaluated. Sound cabins are valuable research tools, not only in saving expensive flight time, but in providing a reproducible test method for full-scale tests of soundproofing.

Tests made in these cabins indicate that ground tests frequently agree with flight results within several DB throughout the octave-band spectrum. In other instances, a calibration factor may be necessary to convert from ground to

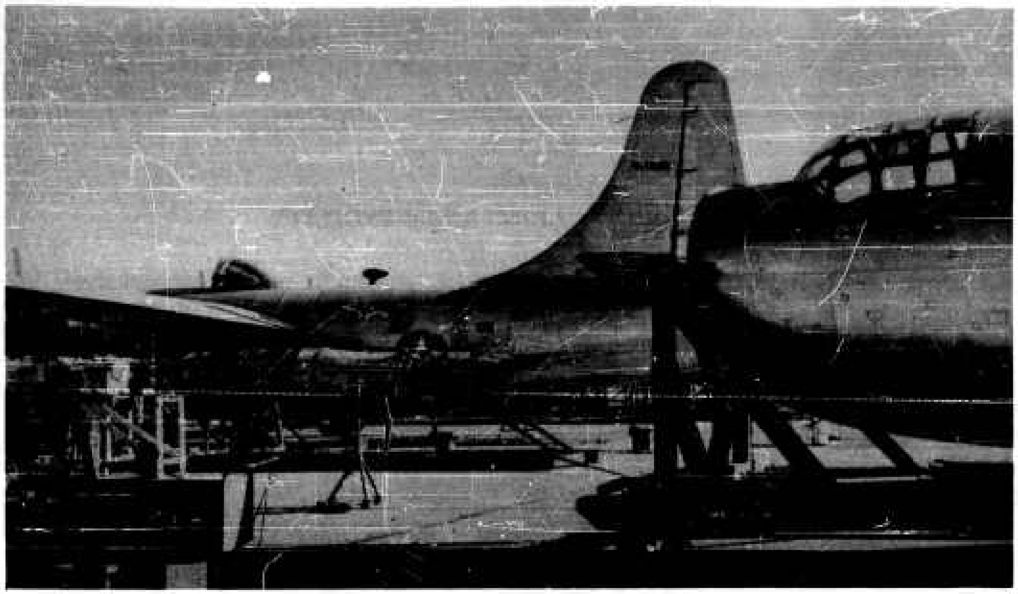


*Figure 30. Convair Sound Cabin No. 1 Survey Near G.E. TG-180 Turbo-Jet.*

flight predictions, depending upon the airplane configuration.. A calibration test between "Sound Cabin" and airplane is sometimes necessary. Since tests are made before and after soundproofing in the same "cabin" and with the same test equipment, the noise attenuations are truly comparable.

Sound Cabin No. 2 was taken from the rear fuselage portion of a salvaged Convair plane in 1946. It was relatively easy and inexpensive to cut off this section with an acetylene torch, place two heavy wooden bulkheads one at either end, mount it on a portable stand, and roll it up to the engine for testing. By using the actual noise source in question, and a full-scale fuselage structure, many of the questionable phases of acoustical laboratory tests have been eliminated. A closer approximation to flight conditions can thus be maintained than has been possible, prior to 1945 and 1946 when this original research was conducted, other than the expensive operation of soundproofing the complete flight article.

The propeller and engine exhaust noises and their effects on functional electronic equipment and on personnel as determined in the last ten years (References 12 to 16) cannot be dismissed today without a look at the probability of greater noises in the future, when jets power the airlines and rockets boost experimental aircraft and high-mach missiles.

In 1946, some noise surveys were performed around one of the first operational turbo-jets built in this country – a General Electric TG-180. The first delivered engine was mounted on a test stand, shown in Figure 30, for evaluation

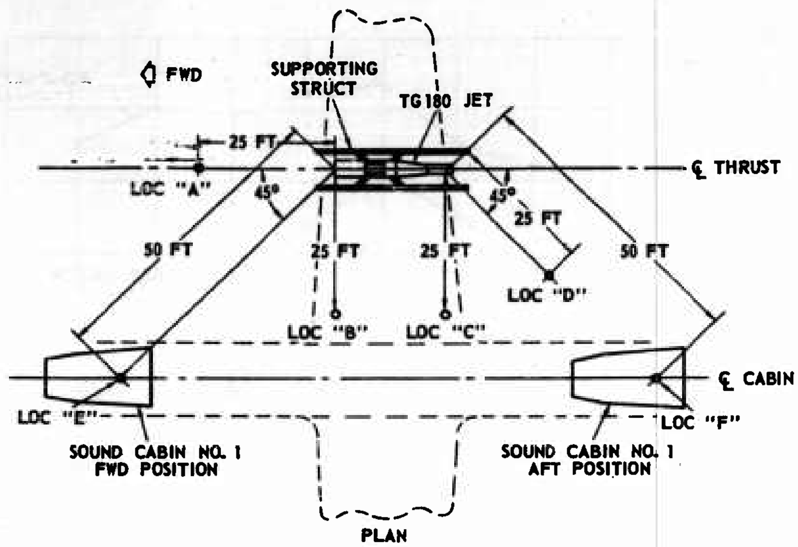
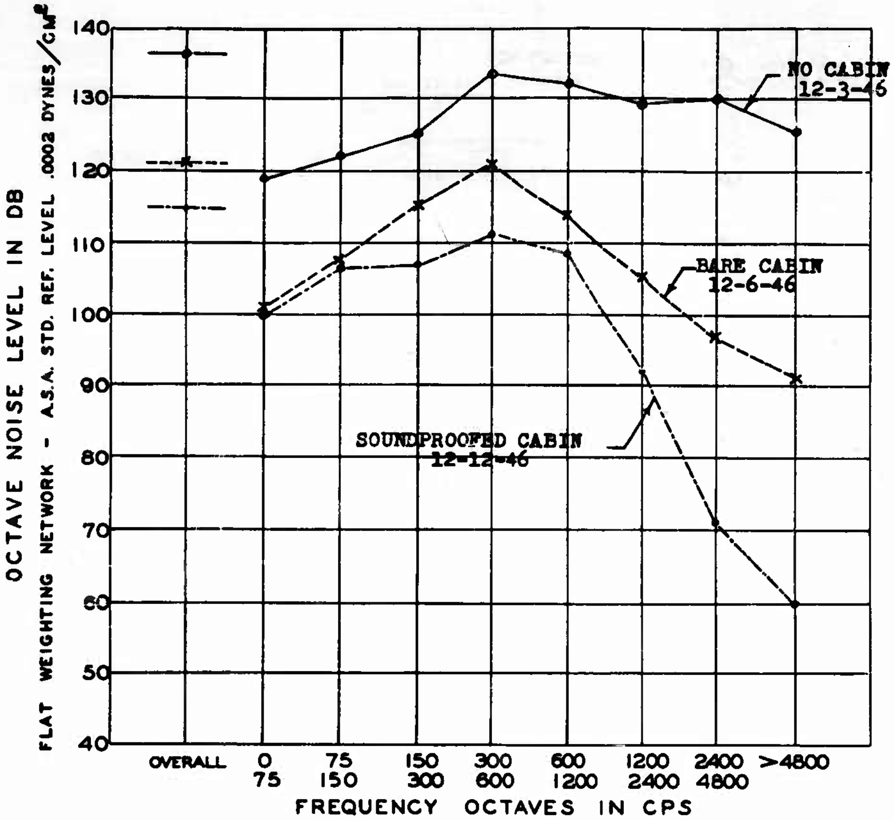



*Figure 31. Convair Sound Cabin No. 1 in Rear Position Near Turbo-Jet.*

runs prior to being flown in an experimental bomber. Convair Sound Cabin No. 1 was used adjacent to this turbo-jet so as to predict noise intensities that might be present in passenger cabins of future jet-liners. The "Cabin" was placed at 50 FT from the jet engine on the assumption that jet-powered planes, 10 or 15 years after these 1946 tests, would have large fuselages with turbo-jet or turbo-prop engines located well out on the wings. Two locations were chosen for the "cabin" acoustic investigations, as shown in Figure 31. One of these represented the pilot's or forward passenger location in a large airliner, 50 FT from the jet inlet and 45 DEG forward. The second represented rear passenger cabin seat locations on tomorrow's "Los Angeles-London Express," 50 FT from the jet exhaust and 45 DEG aft.

The octave noise levels varied from 116 DB overall and 108 DB "Hiband" at a location 25 FT forward of the impeller housing on the centerline of thrust at maximum turbine RPM of 7700, to 138 DB overall and 135 DB "Hiband" at a spot 25 FT from the jet exit, 135 DEG from thrust axis.

The measurements at the 1200 — 2400 CPS octave band was termed "Hiband" octave by the writer in 1946 for these early Convair acoustic surveys since it is easier to make one reading on a portable noise level meter in "rushed" flight tests rather than three readings at the 600-1200 CPS, 1200-2400 CPS, and 2400-4800 CPS octaves and averaging these three readings, as suggested by Leo Beranek. The end results are within 1 decibel of the same value, however, in most noise spectra from engines, jets and rockets, and the curves over these




SOUND CABIN NO. 1 - 50 FEET FROM JET EXIT AT 135° (LOC. E).

7700 RPM

SOUND CABIN SOUNDPROOFED: 2" XAA-PF, 2 V-FILMS, SUNTAN TRIMCLOTH, AND CARPET NO. 8. MICRO. NO. 1.

*Figure 32. Effects of Sound Cabin No. 1 and Cabin Insulation on Turbo-Jet Noise.*

octaves are linear. The term "Hiband" was used in the early 1940's at Convair-San Diego, to indicate the maximum speech interference octave band of 1200-2400 CPS. The 1946 test readings in this paper were made either on the E.R.P.I. RA277F Frequency Analyzer, E.R.P.I. RA 363 Filter Set, W.E. 633A Microphone and Sound Apparatus Co. FR-137 Recorder or on the more portable equipment consisting of a General Radio 759B Sound Level Meter, W.E. 633-A Microphone and the Convair-Cook "Hiband" Octave Filter. Reference 15 gives more details on the circuitry and use of the "Highband" Filter.

Figure 32 summarizes the turbojet noise at 7700 RPM at a location 25 FT aft of the jet exit, 135 DEG from the thrust axis. It is interesting to note that while the overall levels were attenuated from 136 DB to 121 DB and 114 DB by introduction of Sound Cabin No. 1, first bare and then soundproofed (0.22 PSF), the "Hiband" levels were reduced from 129 DB to 105 DB and 93 DB respectively. Thus, an .032 IN. 24S-T aluminum alloy-sheet wall, stiffened with 1/2 by 1 by 1/2 by .050 IN. stringers at 6 1/4 IN. spacing on 1 by 2 3/4 by .065 IN. belt-frames, at 24 IN. spacing, is capable of reducing outside noise levels throughout the octave range as shown below.

| Condition. | Overall | 75-150 CPS | 300-600 CPS | 1200-2400 CPS | 2400-4800 CPS | Above 4800 CPS |
|---|---|---|---|---|---|---|
| By Bare Cabin | 15 DB | 14 | 13 | 24 | 33 | 35 |
| Soundproofed Cabin (.22 LB/SQ FT) | 22 DB | 16 | 23 | 36 | 59 | 66 |

The turbojet-noise surveys were made with due knowledge that a nacelle over the jets would tend to reduce the impeller noise, or at least localize it with certain directional characteristics.

Figure 33 shows the convenience of this "Sound Cabin" method of surveying propeller noise or turbojet effects on occupants or equipment within aircraft fuselages or large missiles. The exterior noise may be observed by the test engineer, salesman, prospective customer or aircraft executive and then by entering the cabin and closing the side door, the degree of acoustical comfort, soundproofing effectiveness, or equipment operation may be judged.

In summary, the aircraft and missile manufacturers now are faced with a new test environment, that of high intensity noise (sonic), which may exist to the detriment of the proper functioning of electronic equipment or passenger comfort. The few tests made to date in "Sonic Test Facilities" in a few laboratories in this country indicate that electronic equipment, such as electron tubes, relays, barometric switches, microwave units and various sensitive control and guidance components may be effected by high intensity or high-frequency noise. Laboratory test facilities to meet this challenge are sorely needed at a low cost, as soon as possible. Reasonable "sonic testing" specifications based on flight results are needed. More industry-wide communications on these test problems and discussions of test facilities now available to meet the sonic challenge is recommended. The questions and answers following this meeting and letters sent to the writer will do much to "clear-the-air" and help the industry meet this new "sonic barrier" by adequate tests.

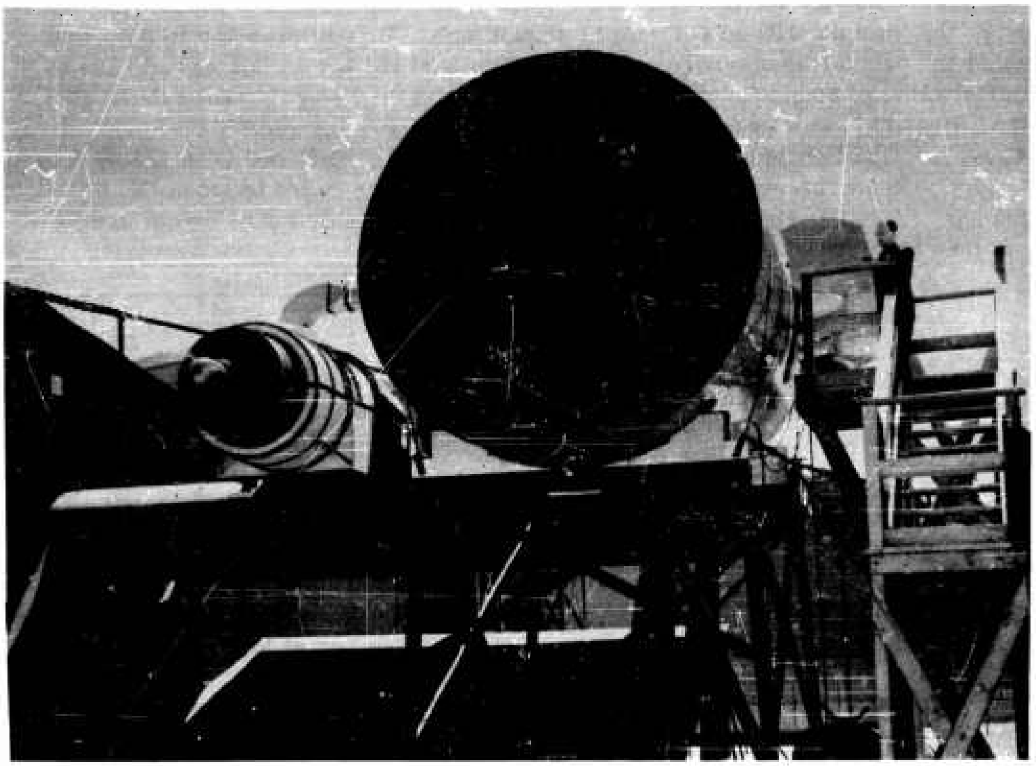


*Figure 33. Support Structure of an Engine Test Stand.*

## BIBLIOGRAPHY HIGH INTENSITY ACOUSTICS


Reference

1. M. Mandel — "New Sound Barrier: Obstacle and Opportunity," — "Research and Engineering," September 1956.

2. R. June, P.M. Belcher, Dr. W. Fricka, K.R. Jackman. — "High Intensity Acoustical Test Facilities — Loud Speakers and Sirens" — presented at the Los Angeles I. A. S. Specialist Meeting, February 26, 1957.

3. J.K. Hilliard — "Part I. — Condenser Microphones for Measurements of High Sound Pressures." Part II. — Generation of High Intensity Sound Using Loudspeakers." Papers presented at the General Electric Acoustics Symposium, Schenectady, N.Y., February 7, 1957.

4. D. Skilling — "Acoustic Testing at Northrop Aircraft Corp.," presented at the Los Angeles Section of the Society of Experimental Stress Analysis, U.C.L.A., Los Angeles, May 24, 1957.

5. N. Doelling, D.M. Mercer and Staff of Bolt, Beranek and Newman, Inc. — "A Compilation of Turbojet Noise Data" — W. A. D. C. Tech. Report 54-401, July 1956.

6. A.A. Regier — "Noise, Vibration, and Aircraft Structures," presented at the 24th Annual I. A. S. Meeting, New York, January 23-26, 1956.

7. Dr. W. Fricka — "A Stationary Wave Resonant System to Produce High Sound Pressure Encountered in Missiles," presented at American Rocket Society Fall Meeting, Hotel Statler, Buffalo, N.Y. September 24-26, 1956.

Reference

8. M.M. Miller — "Sound and Furor — The Jet Noise Suppression Age," presented at the S.A.E. National Aeronautical Meeting, Hotel Statler, Los Angeles, October 2-6, 1956.

9. B.A. Rose — "New Tools to Lick Aircraft Equipment Noise Problems," presented at the S.A.E. National Aeronautical Meeting, Hotel Statler, Los Angeles, October 2-6, 1956.

10. C.B. Brahn — "How to Prevent Tube Failures from Noise and Vibration," Aviation Age, February 1957.

11. L.B. Martin — "Vibration Tube Testing," Electronic Design, February 1, 1957.

12. K.R. Jackman — "Aircraft Acoustical Problems and Possible Solutions," — Parts 1, 2, 3, and 4 - by K.R. Jackman in "Aviation," July, August, September and October 1946.

13. K.R. Jackman — "A Review of Advances in Silencing Aircraft," by K.R. Jackman, — preprinted for and presented at the A.S.M.E. Semi-Annual Convention, Chicago, Ill., June 16, 1947.

14. K.R. Jackman — "Research Toward Greater Airline Passenger Comfort," by K.R. Jackman, preprinted for and presented at the I.A.S. Annual meeting, N.Y.C., January 27, 1946.

15. K.R. Jackman — "Greater Comfort for the Airline Passenger — Part I — Cabin Silencing," by K.R. Jackman in "Aero Digest," October 1948.

16. R.A. McFarland — "Human Factors In Air Transport Design," 1946 McGraw-Hill Book Co., Inc. (Graph on "Aircraft Comfort" on p. 279).

UNCLASSIFIED