NOTS TP 4304

OPERATION MANUAL FOR THE NOTS-NASA ROCKET-MOTOR ACOUSTIC TEST FACILITY
STEADY-STATE RESONANCE TESTS WITH FLOW

by

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ABSTRACT. Steady-state resonance tests with through flow and a sonic nozzle throat condition were run on the NOTS-NASA acoustic-loss test facility to establish and record the instrument hookup schematics, instrument settings, system calibration procedures, and data reduction techniques. This report is intended as a manual for operating the facility for this type of test. With this knowledge, the facility may be used to measure experimentally the acoustic chamber losses of scale-model rocket chambers. The loss coefficients that are determined may be used in comparing various internal motor geometries before full-scale motors are built and tested, with a possible saving of time and money.

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FOREWORD

This report presents operating techniques for the NOTS-NASA Rocket Motor Acoustic Test Facility at China Lake, California. The work was supported by NASA Work Order 6030.

This report is transmitted for information only and does not represent the final judgment of the Center.

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INTRODUCTION

This report is a manual for operating the NOTS-NASA rocket-motor acoustic-loss test facility for a specific type of test. This type of test determines the acoustic attenuation constant, α, for various model motor chambers having through flow and a sonic nozzle throat condition by determining the half-power bandwidth of the chamber response curve. These tests have been termed "Steady-State Resonance Tests with Flow."

The history of the system development, the theory behind the testing method, the use of various complimentary testing techniques, and the potential used to which the system can be put are described in Ref. 1-9.

This report is designed as a step-by-step manual beginning with a discussion of the test hardware and ending with possible ways of plotting the final data. Each section has been checked in the laboratory during the writing. Unnecessary circuitry has been removed, calibration procedures have been established, and the final instrument settings, test procedures, and data reduction techniques recorded. This should make it possible to run the facility routinely and, thereby, greatly enhance its use.

TEST APPARATUS

The experimental apparatus used in making these tests consists of a model motor chamber, a steady air supply capable of maintaining sonic flow in the nozzle of the model, a variable-frequency oscillating air supply to drive the chamber, and instrumentation to detect and record the resulting chamber behavior.

The model chamber is pressurized by flow through a high impedance porous metal plate at the forward end of the model. Flow through the plate is maintained by a prechamber connected to a high pressure air storage system. The pressure is controlled by regulating valves. A schematic diagram of the air-feed system is given in Fig. 1.

The main air flow is regulated from the 2,800 psi storage tanks and manifolded to the motor prechamber through four lengths of No. 1509 0.375-inch Aeroquip hose. The hose is acoustically isolated from the prechamber by a second porous ring at the prechamber inlet. The smaller

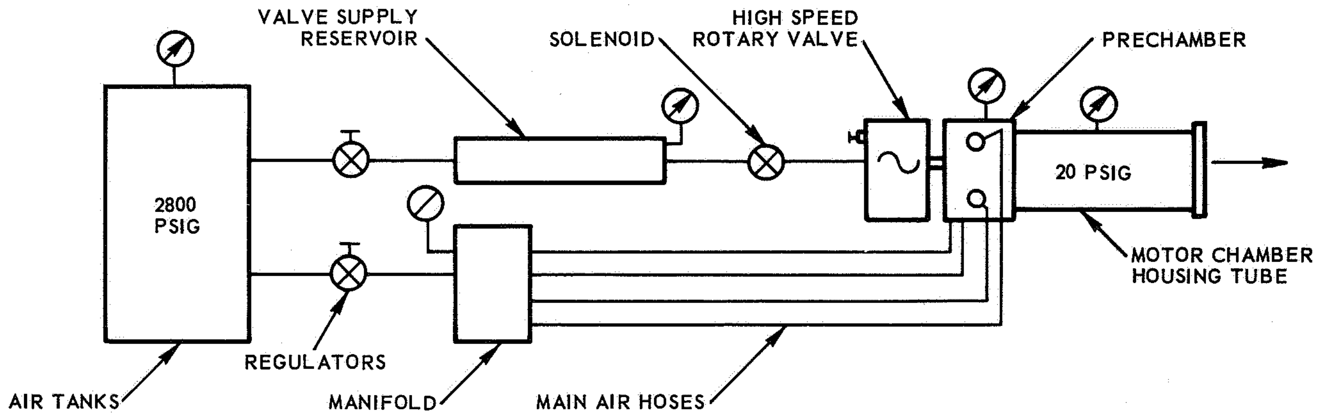


FIG. 1. Schematic of the Air Flow Feed System Used for Steady-State Loss Measurements.

volume of air for the modulated air supply is fed through a pressure regulator and a 35-foot section of 0.375-inch steel tubing to a spherical surge tank, through the rotary valve, and into the prechamber.

The Naval Ordnance Test Station (NOTS) designed rotary valve is used to produce a sinusoidal pressure forcing function in the prechamber. The valve consists of a rotating cylinder with a balanced slot arrangement driven by an air motor. The valve is designed to provide six cycles of alternate inflow and exhaust (to the atmosphere) per cycle of valve rotation, Fig. 2. The output wave form depends on the outlet and inlet pressure ratios and the orientation and shape of the rotor slots. Using this system, the prechamber driving frequency can be varied across a wide frequency range with a nearly sinusoidal wave form. The valve output is introduced at one end of the prechamber.

The prechamber is used to unite the steady and pulsating supply flows. A detailed drawing of the prechamber is given in Fig. 3, and a sketch showing the relations of the prechamber housing to the motor tube is given in Fig. 4. The oscillating flow from the rotating valve enters the prechamber cavity directly from an axial port at the head end. Four side ports located concentrically around the head of the prechamber are used to provide the main air supply. The steady air flow enters the prechamber by passing through an annular disk of porous, sintered stainless steel. This is done to acoustically isolate the prechamber from the main air-feed system and thereby minimize acoustic losses and supply line resonances.

The inside dimensions of the prechamber cavity form a cylindrical cavity approximately 2 inches in diameter and 2 inches in length. The natural frequency of this cavity is about 3,000 cps, several times any frequencies of interest during the tests.

The prechamber is separated from the test chamber by a second porous plate. This high impedance barrier is introduced so that the model chamber can be driven by the large amplitude oscillations in the prechamber without any appreciable feedback or reverse coupling from the chamber.

The model rocket motor is fitted to the outlet side of the prechamber assembly. Various model configurations have been studied in the past, see Ref. 2 and 5. Appendix A gives the specifications for new model designs. Appendix B gives the diameters of motor parts used to date.

There are two microphone ports on the prechamber block. One, for a Columbia microphone, is used to monitor the acoustic pressure oscillations in the prechamber cavity. The other, for a Bruel and Kjaer (B&K) microphone, is used to detect the acoustic oscillations at the head of the model chamber.

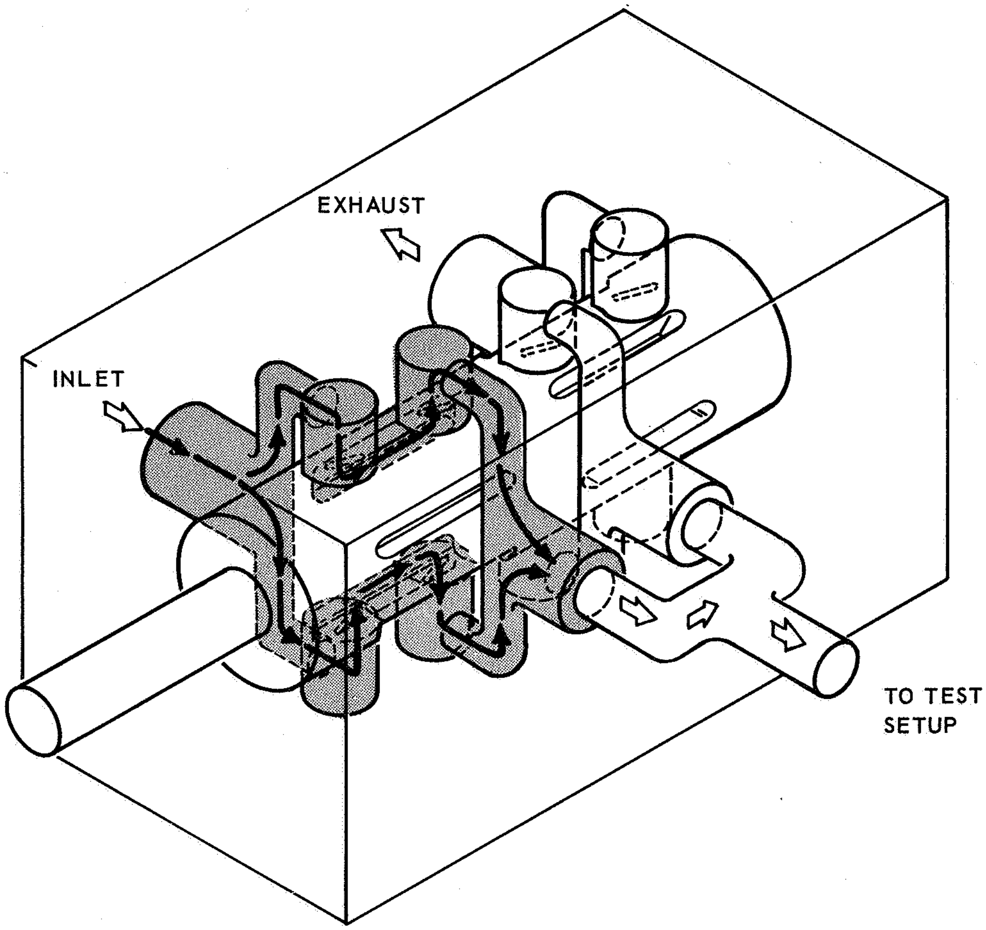


FIG. 2. The NOTS Designed Rotary Valve for Oscillating a Portion of the Incoming Air Flow.

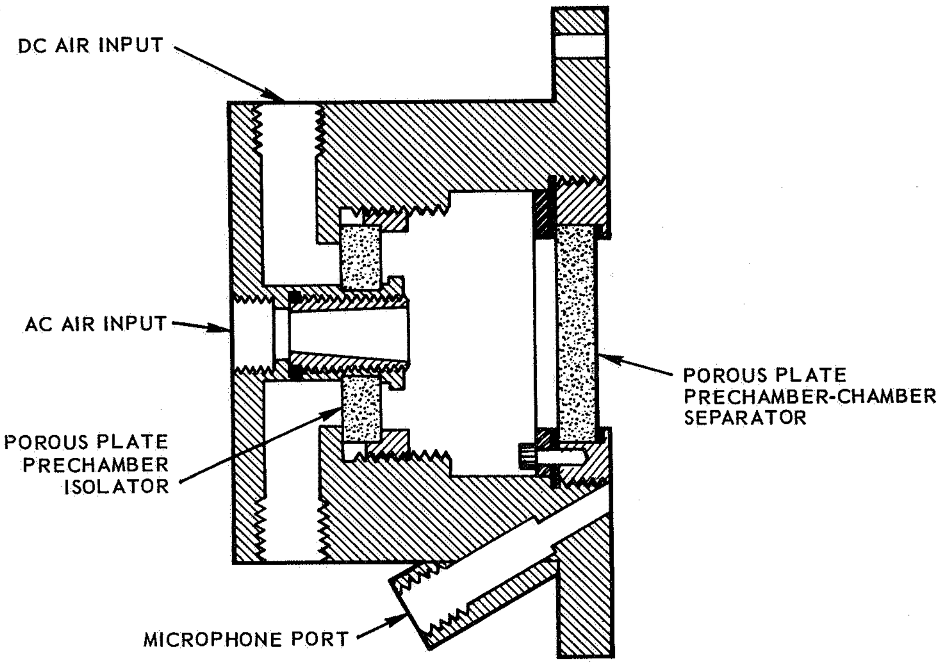


FIG. 3. Cross-Sectional View of the Prechamber Assembly Used to Unite the Steady and Pulsing Flows Prior to Entering the Model Chamber.

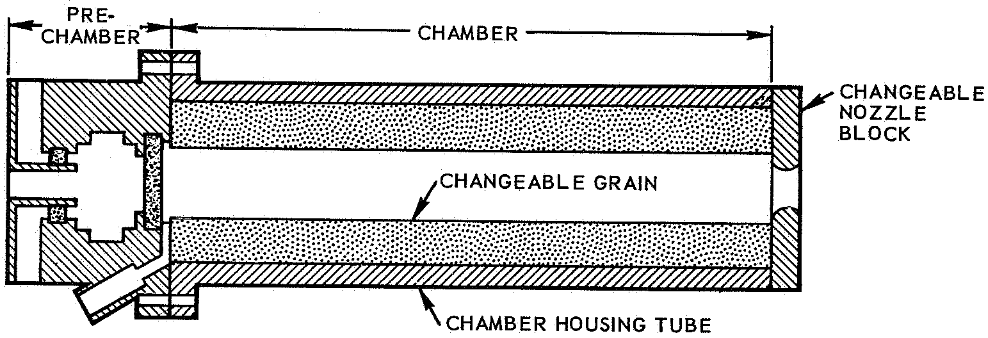


FIG. 4. Cross-Sectional View Showing the Relation of the Prechamber to the Model Chamber Tube. Grain pieces are slid into place on removal of the nozzle end plate.

Figure 5 shows the test setup with a particular model motor housing tube attached to the prechamber together with various grain and nozzle pieces.

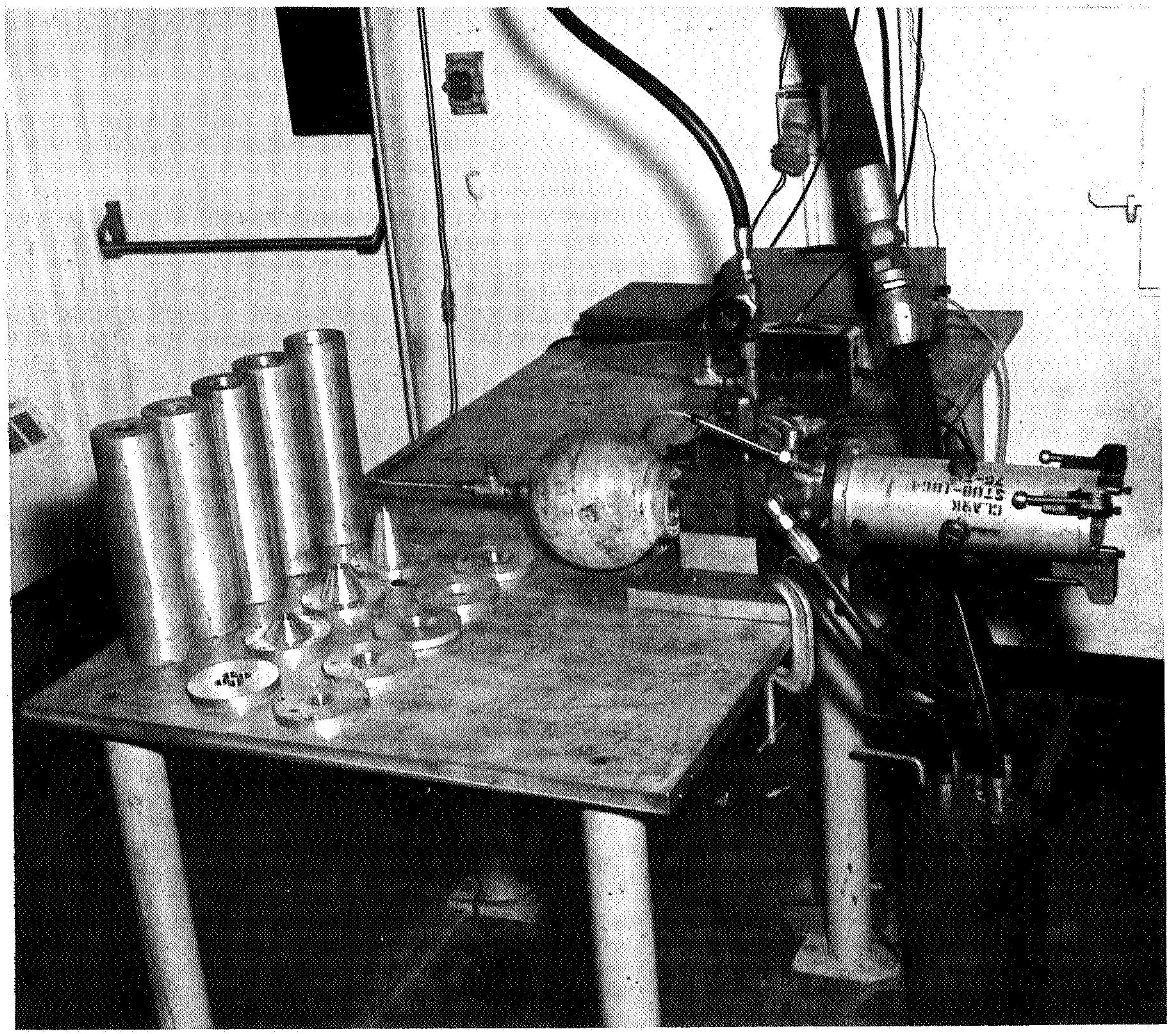


FIG. 5. Photograph of Test Hardware With a Model Motor Housing Tube Attached to the Prechamber Together With Various Grain and Nozzle Blocks on Table.

INSTRUMENTATION

A block diagram of the instrumentation circuits used for the steady-state resonance tests with flow is shown in Fig. 6. Figure 7 shows the actual instrumentation racks.

The system involves essentially three separate channels of data processing:

1. Frequency conversion system
2. Prechamber acoustic pressure data system
3. Chamber acoustic pressure data system

Frequency Conversion System. The X-axis of the X-Y plotter, which shows driving frequency, is driven by a DC signal proportional to the acoustic driving frequency. To do this, pips from the photodiode are amplified by the photocell amplifier and applied to the input of the sine converter. The output of the sine converter, a DC voltage proportional to the frequency, drives the X-axis of the X-Y plotter. On a separate output, the sine converter also produces a sine wave of the same frequency as the incoming pips for use elsewhere in the system. A digital frequency meter is used to obtain precise frequency measurements. A B&K variable frequency oscillator is used for calibration and will be discussed later.

Chamber Acoustic Pressure Data System. The B&K microphone is connected to its companion power supply, then to a Columbia amplifier. The amplified output is passed to a Spectral Dynamics tracking filter. A reference frequency signal for the tracking filter is supplied as an AC signal from the previously mentioned sine converter. The output of the tracking filter is fed to three instruments. Oscilloscope channel "A" acts as a monitor of the AC chamber response. A B&K electronic voltmeter-amplifier rectifies the incoming signal to give a DC output which then goes to the red pen of the X-Y plotter to give a direct linear trace proportional to the chamber response. The third branch from the chamber B&K microphone is taken through a circuit to compensate or normalize for the lower driving power of the rotary valve at higher frequencies.

Prechamber Acoustic Pressure Data System. The relative driving power is measured by a Columbia microphone mounted in the prechamber wall. Its signal is amplified by Channel #2 of the Columbia amplifier and monitered at this point by oscilloscope channel B.

The normalization referred to above is done at this stage. The chamber response signal mentioned above is divided by the prechamber driving signal from the Columbia microphone to obtain a final normalized chamber response curve. To do this, both signals are fed through an X/Y calibrator, the use of which will be discussed later, into individual log converters. The use of log converters permits the signals to be, in

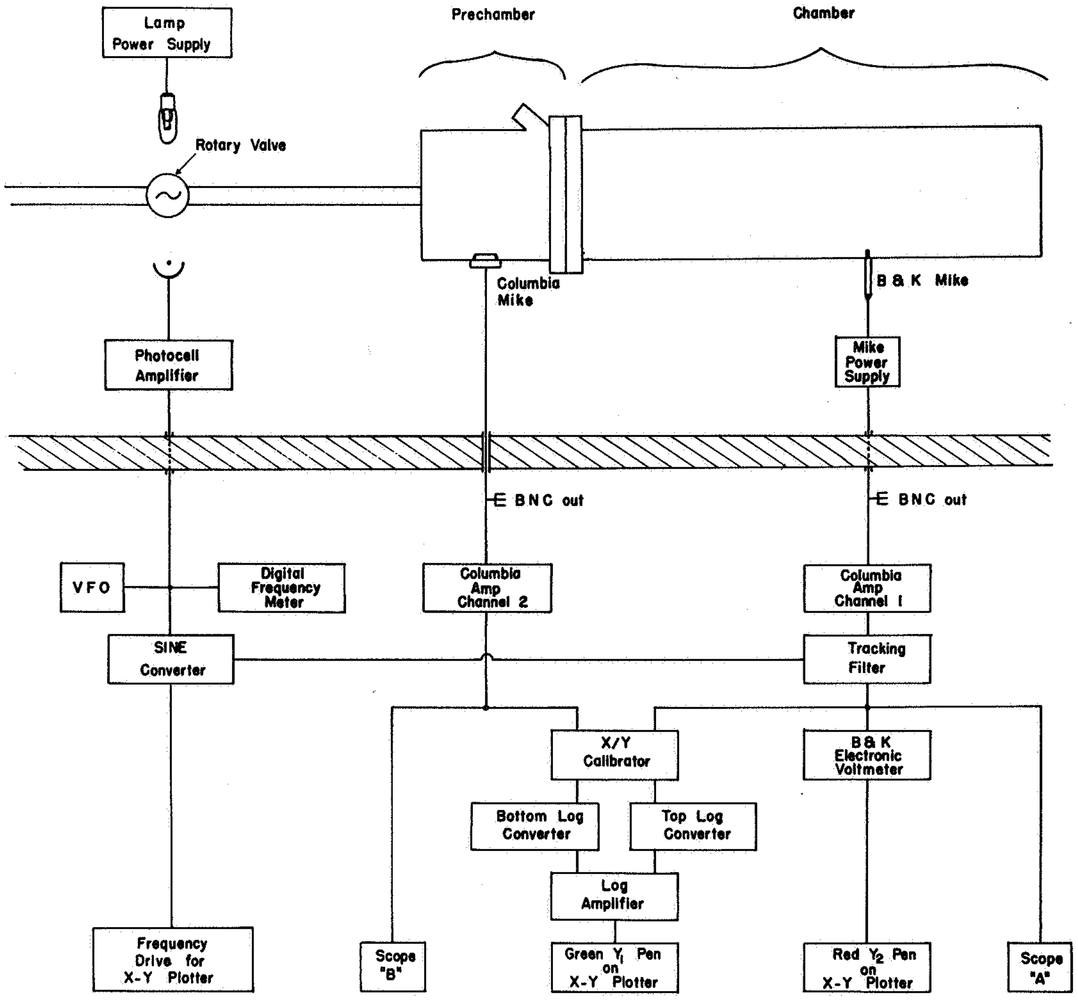


FIG. 6. Block Diagram of Instrumentation Circuits for Steady-State Resonance Tests With Flow.

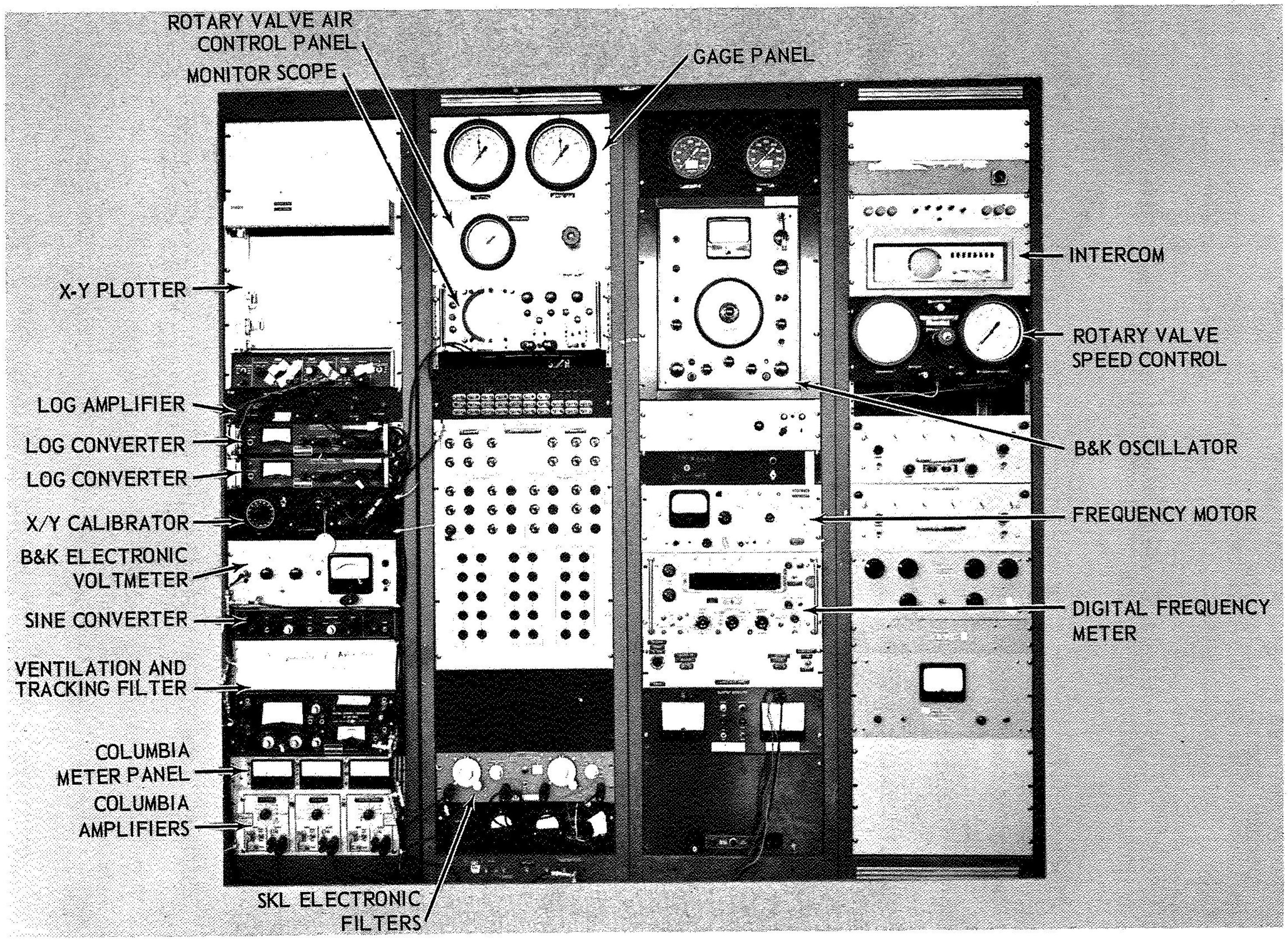


FIG. 7. NOTS-NASA Instrumentation Racks.

effect, subtracted rather than actually divided. The log functions are subtracted in the log amplifier unit and the output used to drive the green Y_1 pen of the X-Y plotter.

INSTRUMENT SETTINGS AND CALIBRATION

As discussed in the Instrumentation Section, three electrical circuits are used in the steady-state resonance tests with flow. These are: (1) frequency circuit, (2) prechamber acoustic pressure circuit, and (3) chamber acoustic pressure circuit. A block diagram showing these three circuits simultaneously is given in Fig. 6.

In the following subsections, recommended starting instrument test settings are given. Due to the large variation in internal motor geometries that is possible, the gains of various amplifiers will have to be adjusted at the resonance point to obtain maximum circuit sensitivity at the time of testing. The settings that are given are fairly representative of past motor work.

Also given are individual circuit calibration procedures. These settings must be made prior to running a test so that the resulting X-Y plotter traces can be reduced.

FREQUENCY CIRCUIT FOR COLD-FLOW, ROTARY VALVE TESTS

1. Circuit Diagram

   For block diagram of frequency circuit, see Fig. 8.

2. Cold-Flow Test Settings

   a. Lamp power supply: On 6

   b. Lamp and photocell: Aligned with hole in rotary valve drive wheel

   c. Photocell amplifier: Switch on ON

   d. VFO: Disconnect or on OFF except to calibrate

   e. Digital frequency meter: ON

   f. Sine converter: On AC Input, Auto Triggering, Positive slope. DC signal from rear panel, AC signal from front panel

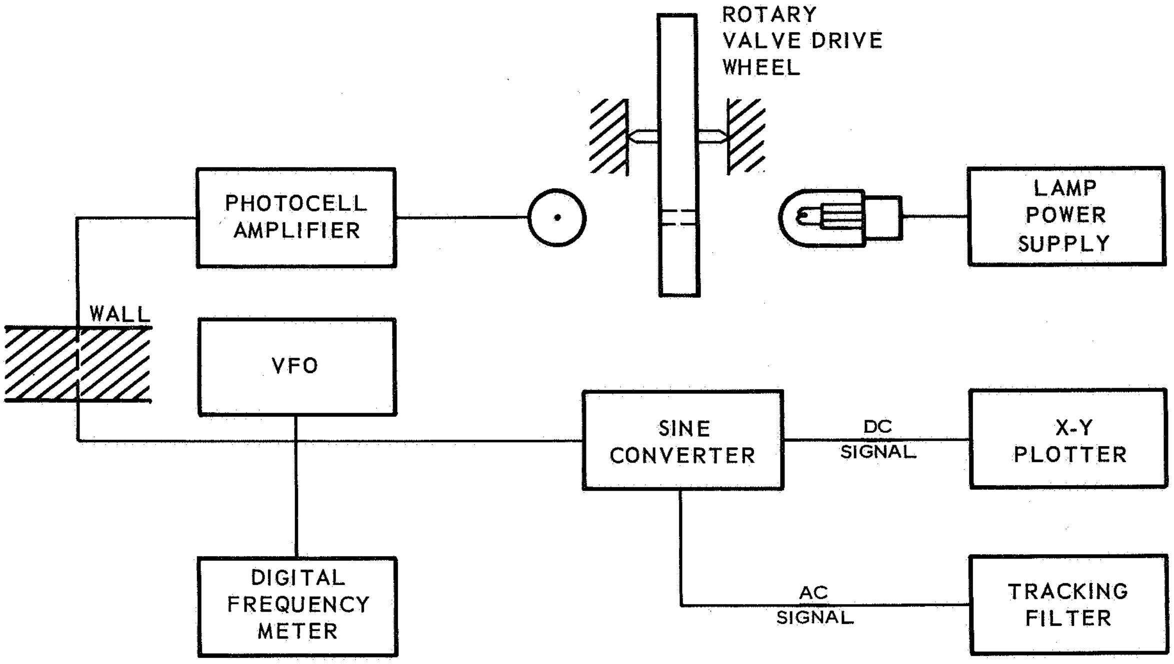


FIG. 8. Block Diagram of Frequency Circuit for Cold Flow, Rotary Valve Tests.

g. Tracking filter: AC signal to Tuning Input

h. X-Y plotter: DC signal to rear panel, X-axis channel. Calibrate at 100 and 1,000 cps as described below

3. To Calibrate

Turn X-Y plotter to STANDBY. Plug VFO into circuit and set at 3 volts output and 1,000 cps. Set X channel on plotter to 0.1 volt/division variable. Put in graph paper. Disconnect VFO, put plotter on RESET, and set zero point at desired location using the Input Zero Knob. Put plotter on STANDBY, replace the VFO input, put plotter on RESET. Pen should move about 10 inches across paper. Adjust with variable potentiometer in center of Range Knob to give exactly 10 inches displacement. Check for 1 inch at 100 cps. Put on STANDBY, disconnect VFO. Now ready to test.

ACOUSTIC PRECHAMBER PRESSURE CIRCUIT FOR COLD-FLOW, ROTARY VALVE TESTS

1. Circuit Diagram

A block diagram of the acoustic prechamber pressure measuring circuit is shown in Fig. 9.

2. Initial Instrument Settings

a. Columbia Amplifier (Channel #2)

Range selector:	X 10
Red knob:	Full clockwise
Meter switch:	10 volts
Front-Rear selector:	Front and Rear
Shunt switch:	Zero

b. Scope B

Sweep rate:	10 msec/cm
Sensitivity:	0.1 v/cm
Power:	ON

c. X-Y Calibrator

Selector:	BYPASS
Range:	1/1
Power:	OFF
Variac level:	10

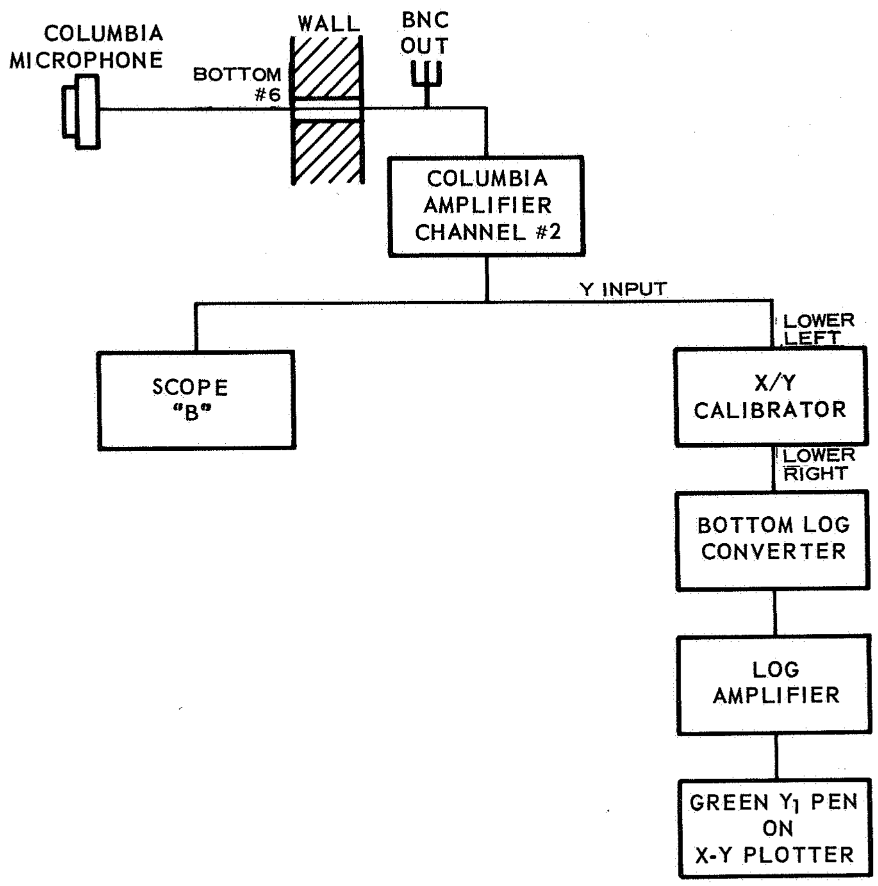


FIG. 9. Block Diagram of Acoustic Prechamber Pressure Circuit for Cold Flow, Rotary Valve Tests.

d. Bottom Log Converter

Input selector:	AC
Attenuation:	20 dB
Scale factor:	5 dB/inch

e. X-Y Plotter, Green Y_1 Pen

Range selector:	10 mv/division
Fix-variable:	Fixed

CHAMBER PRESSURE CIRCUIT FOR COLD-FLOW, ROTARY VALVE TESTS

1. Circuit Diagram

A block diagram of the acoustic chamber pressure circuit is shown in Fig. 10.

2. Initial Cold-Flow Test Settings

a. Microphone Power Supply: ON

b. Columbia Amplifier (Channel #1)

Range selector:	X 1 (0 dB) red knob full clockwise
Front-Rear selector:	Front and Rear
Shunt switch:	Zero
Meter switch:	20 volts

c. Tracking Filter

Power:	OFF, STBY, or ON
Volt range:	10 volts
Multiplier:	1
Filter:	OUT Channel #1 for 1½ cps pass Channel #2 for 10 cps pass

d. Scope A

Power:	ON
Sensitivity:	1 v/cm
Sweep rate:	10 msec/cm

e. B&K Electronic Voltmeter

Power:	ON
Amplifier dial:	3 volts (-10 dB)
Meter switch:	RMS to right

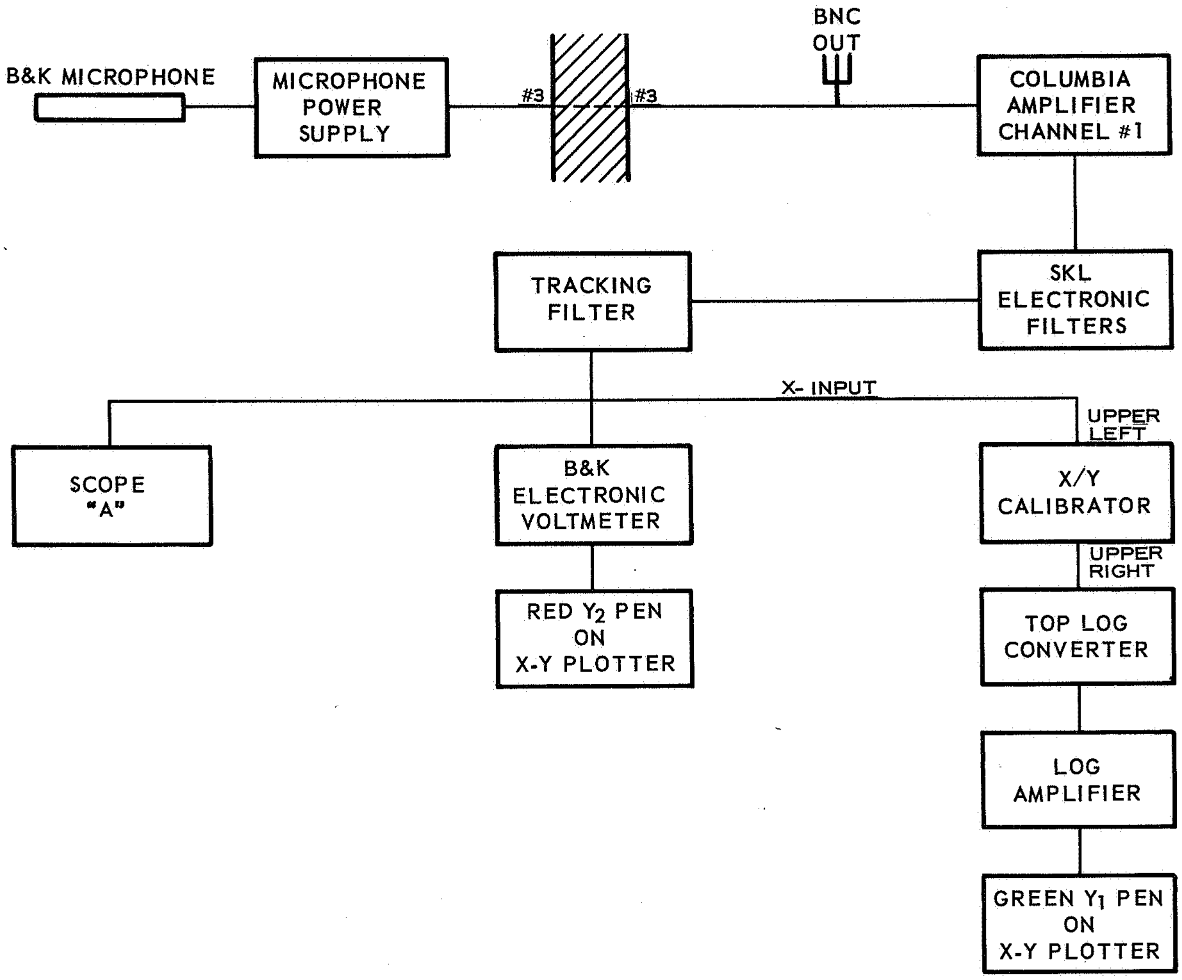


FIG. 10. Block Diagram of Acoustic Chamber Pressure Circuit for Cold Flow, Rotary Valve Tests.

f. X-Y Plotter - Red Y_2 Pen

50 mv for low Q chambers
0.1 v/div for high Q chambers
Fixed
Turn clockwise to make less sensitive

g. X-Y Calibrator

Power: OFF
Ratio: 1/1
Function switch: BYPASS
Variac level: 0

h. Top Log Converter

Power: ON
Input selector: AC
Attenuation: 40 dB
Scale factor: 5 dB/inch

i. Log Amplifier

Scale Factor: 5 dB/inch
Function Knob: X/Y
Position Knob: Do not touch

j. X-Y Plotter - Green Y_1 Pen

Sensitivity: Adjust as necessary
Fixed
Turn clockwise to make less sensitive

3. Cold Flow Test Adjustments

a. Adjust vertical zeros on X-Y plotter to put red pen about 1 inch from bottom of page and green pen about 3 inches from bottom of page.

b. Turn on air and take to resonance.

c. Check pens and all amplifier meter dials for either sufficient deflection or pegging. Change above intial settings accordingly. To increase deflection use amplifier gains and/or variable pen deflection knobs. If pens peg--decrease X-Y plotter range knobs (clockwise). If meters peg--decrease B&K voltmeter gain or both log converter attenuations.

4. Calibration of Red Y_2 Pen

a. Remove B&K microphone. Put on windscreen. Place microphone in B&K calibrator unit using adapter.

b. Lay calibrator and microphone on rubber mat. Check that adapter and microphone are snug.

c. Turn calibrator on to MEASURE. This gives approximately 122 dB at 200 cps.

d. Observe signal on Scope A - should be a good sine wave.

e. Plug VFO into the frequency circuit.

f. Put X-Y plotter on RESET. Pull input if green pen is pegging.

g. Turn B&K voltmeter attenuation knob counter clockwise until red pen lifts about half way up sheet.

h. Put X-Y plotter on Sweep and use VFO to make about a 1-inch horizontal line.

i. The decibel level of this line is the sum of

(1)	Calibrator output	+ 122 dB	
(2)	Present B&K test setting	- (-50 dB)	40 dB
(3)	Normal B&K test setting	+ (-10 dB)	
(4)	Line level	+ 162 dB	

j. Change B&K attenuation by 10 dB and make a second horizontal line. Since for a ratio of intensities of 2 to 1 the decibel change is approximately 3, a 10 dB change means multiplying or dividing the signal by 10.

k. Can now extrapolate to get other points.

l. Return B&K to normal (-10 dB) setting, plug in the Y_1 pen signal, unplug VFO, turn off calibrator, insert microphone.

5. Calibration of Log Ratio System - Green Y_1 Pen

a. Put log converter outputs into log amplifier panel input: B&K on left, Columbia on right. Put log amplifier X/Y output into green Y_1 pen.

b. Turn switch in rear of X-Y plotter from Normal to Potentiometer.

c. Set Y_1 range switch to 0.5 mv/inch. Fix-variable switch to Fixed.

d. Set 5 dB/inch on both log amplifier and log converter panels (3 settings).

e. Set 20 dB attenuation on both log converters.

f. On X/Y calibrator panel. Turn power ON. Set selector switch to CAL., ratio to 1/1, Variac level to 10. Adjust Variac so that meter needles are at mid-range on both log amplifiers.

g. Plug VFO into frequency circuit.

h. Set Y_1 pen at 4-inch line by use of Zero knob.

i. Adjust Scale Change switch on the X/Y log amplifier panel to give a 4-inch change between the 1/1 and 10/1 mark. This gives 5 dB/inch.

x 10 = 20 dB
x 100 = 40 dB

j. Go through calibration steps as follows. Use VFO to have Y_1 pen make 1-inch horizontal mark at each step. Step heights for X/Y calibrator ratios of 1/5, 1/2, 1/1, 2/1, 5/1, 10/1. Note which are which. Remove paper and save. Results will look like Fig. 11.

k. Turn X/Y calibrator selector knob to BYPASS, power OFF, turn switch at rear of X-Y plotter to NORMAL, and unplug VFO from frequency circuit.

l. Turn on air and take to resonance. Change the dB attenuation switch to give about 3/4 scale deflection on the top B&K log converter and about $\frac{1}{2}$ scale deflection on the bottom Columbia log converter. Record new dial settings (for example 40 and 30 dB respectively).

TEST OPERATING PROCEDURES

Once instrument settings have been made and individual circuits calibrated (see previous section), the system is ready for use. The outline below lists the actual steps involved in running a test.

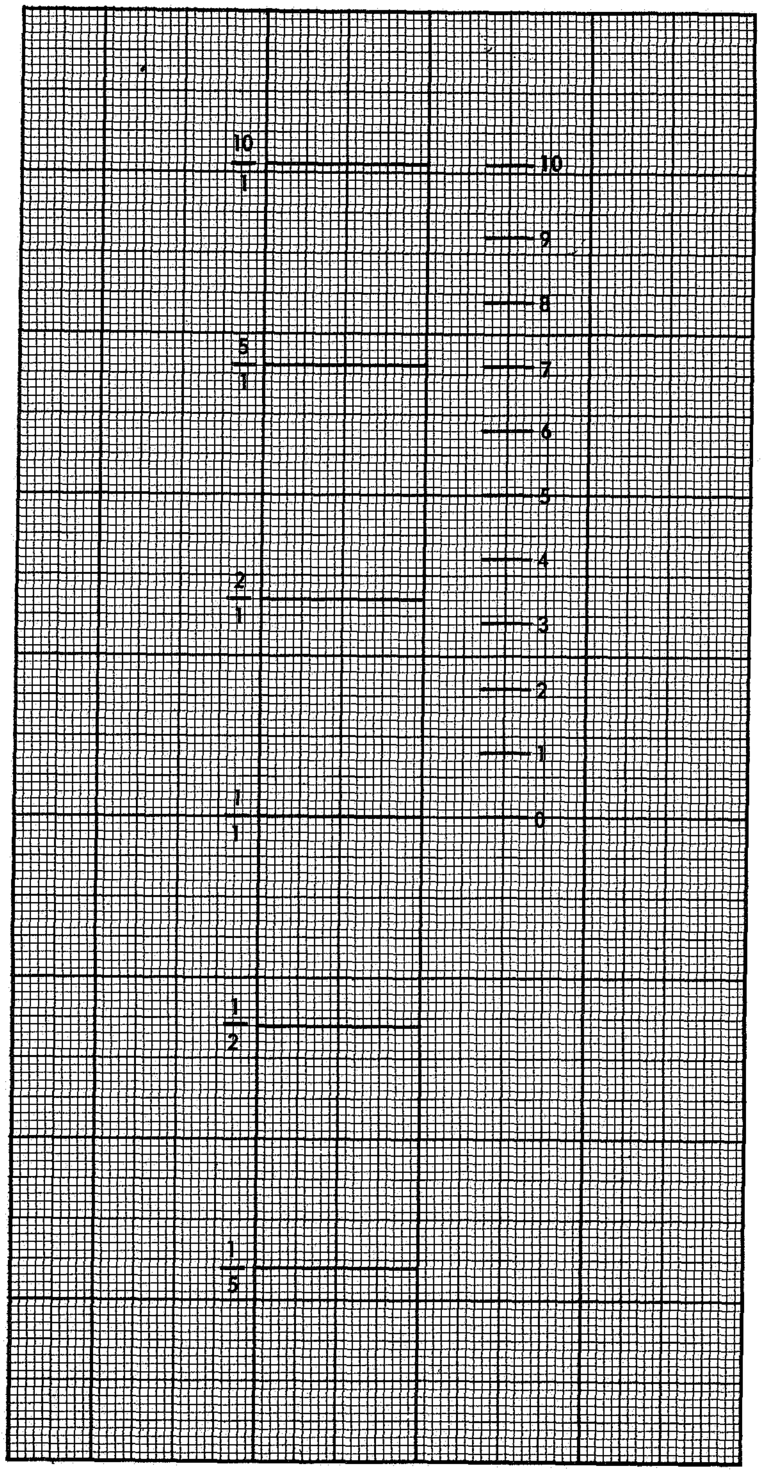


FIG. 11. Calibration Marks for the Log of Pressure Data and Sub-Division Marks to Obtain Log 0.707 = -0.151.

1. Instrument Warm-Up (15-minute minimum)

   A. Circuit breakers #1, #2, and #3 in Instrumentation Room and circuit breaker #1 in the rear of instrument rack #1. Set X-Y plotter and tracking filter on STANDBY. All equipment in rack #1 is left ON and turned ON and OFF by master circuit breaker behind rack #1.

   B. Turn ON AC strip in Bay 2. All equipment is left ON. Use wall circuit breaker--RHS light.

   C. Turn ON photocell amplifier power - small aluminum box by the test hardware. Use ON not STRAIGHT THRU position.

   D. Turn ON the 24-volt DC power supply in Group I. Breaker #5.

2. Selection of Porous Plate

   A. Two pieces of porous steel plate material are used in the prechamber assembly--see Fig. 3. One between the manifold and the prechamber and another between the prechamber and the chamber. The basic rule for choosing the porosity of these plates is to keep a 2 to 1 pressure ratio between the prechamber and manifold and keep a 5 to 1 pressure ratio between the prechamber and the chamber during any tests. Table 1 gives the porous plate porosities to be used with various nozzle sizes for these two locations.

   B. Assemble the model hardware. A list of the J's obtainable using 1-foot long grains and abrupt entry nozzles is given in Table 2.

3. Control Panel Operation

   A. Rotary Valve Pressure

      (1) Open large hand valve in bay to rotary valve supply regulator. Then set brown rotary valve hand control knob to give about 500 psi on the rotary valve pressure gage. This may have to go as high as 1,500 psi on large nozzle, high-J tests.

   B. Prechamber-Chamber Pressure

      (1) Pressure control is the left hand one of the five knobs. If unfamiliar with high pressure system, consult with technician in charge.

      (2) Adjust regulator to give about 25 psi in chamber.

TABLE 1. Porous Plate Porosities for Various Nozzle-Sizes

Nozzle size	Manifold-prechamber	Prechamber-chamber
Less than 3/8 in.	20 μ	20 μ
3/8 in. to 3/4 in.	20 to 40 μ	40 μ
3/4 in. to 1-1/4 in.	40 to 70 μ	60 μ

NOTE: Choose porous plate on basis of nozzle size. Basic rule is to keep 5 to 1 pressure ratio or greater between prechamber and chamber and 2 to 1 or greater between manifold and prechamber.

TABLE 2. J Values

Grain		A	B	C	D	E	F	G
Grain diam.		.9995	1.498	1.699	1.999	2.503	3.000	3.500
Nozzle		J = Area of nozzle throat/area of grain port						
No.	Diam.							
1	0.1265	.01601	.00713	.00554	.00400	.00255	.00878	.00013
2	0.2500	.06256	.02785	.02165	.01564	.00998	.06944	.05102
3	0.3750	.14076	.06266	.04871	.35191	.02244	.01563	.01147
4	0.4982	.24845	.11061	.08599	.06211	.03961	.02758	.02026
5	0.6250	.39102	.17407	.13532	.09775	.06235	.04340	.03188
6	0.9972	.99540	.44314	.34449	.24885	.15827	.11049	.08117
7	1.149	......	.58832	.45735	.33038	.21073	.14669	.10777
8	1.250	......	.69741	.54216	.39164	.24980	.17388	.12776
9	1.375	......	.84250	.65496	.47313	.30178	.21006	.15434

NOTE: When a model is assembled, first give grain letter then nozzle number, i.e., G-5 would mean a grain port diameter of 3.5 inches and a nozzle throat of 0.625 inch was tested resulting in a motor J value of 0.032.

C. Rotary Valve Speed Control

(1) Push black knob labeled IN TO LOAD in the fourth instrument rack to the IN position.

(2) Open the BYPASS valve.

(3) Set pressure to give desired maximum speed on the rotary valve - exceed 1,000 psi for only brief periods.

(4) Close BYPASS valve.

(5) Barely crack open the loading rate valve.

(6) Pull black knob out when ready to test.

D. To Run Test

(1) Set X-Y plotter on RECORD.

(2) Pull out black Rotary Valve Speed Control knob. Speed of the driving rotary valve will automatically decrease and make a test record.

(3) Read and record the pressures of the Chamber, Manifold, Rotary Valve Supply, and Prechamber. A sample test record form that has been used in the past is shown in Table 3.

(4) Put X-Y recorder on STANDBY before it goes off scale at the lower rotary valve speeds.

(5) Record pertinent test data on each graph sheet, see Fig. 12.

NOTE: For best test results and most accurate data reduction, high amplitude curves similar to the one shown in Fig. 12 are desired. To get such results, leave the X-Y plotter on STANDBY and increase the driving frequency to the resonance frequency. Then adjust the various amplifier gains to increase sensitivity--be careful not to overload (i.e. "peg") any of the amplifiers in doing this. Overloaded curves are no good.

DATA REDUCTION PROCEDURE

The test procedure outlined in the previous section results in two curves plotted against the driving frequency for a given J value or internal motor configuration. One, the linear red trace, gives the

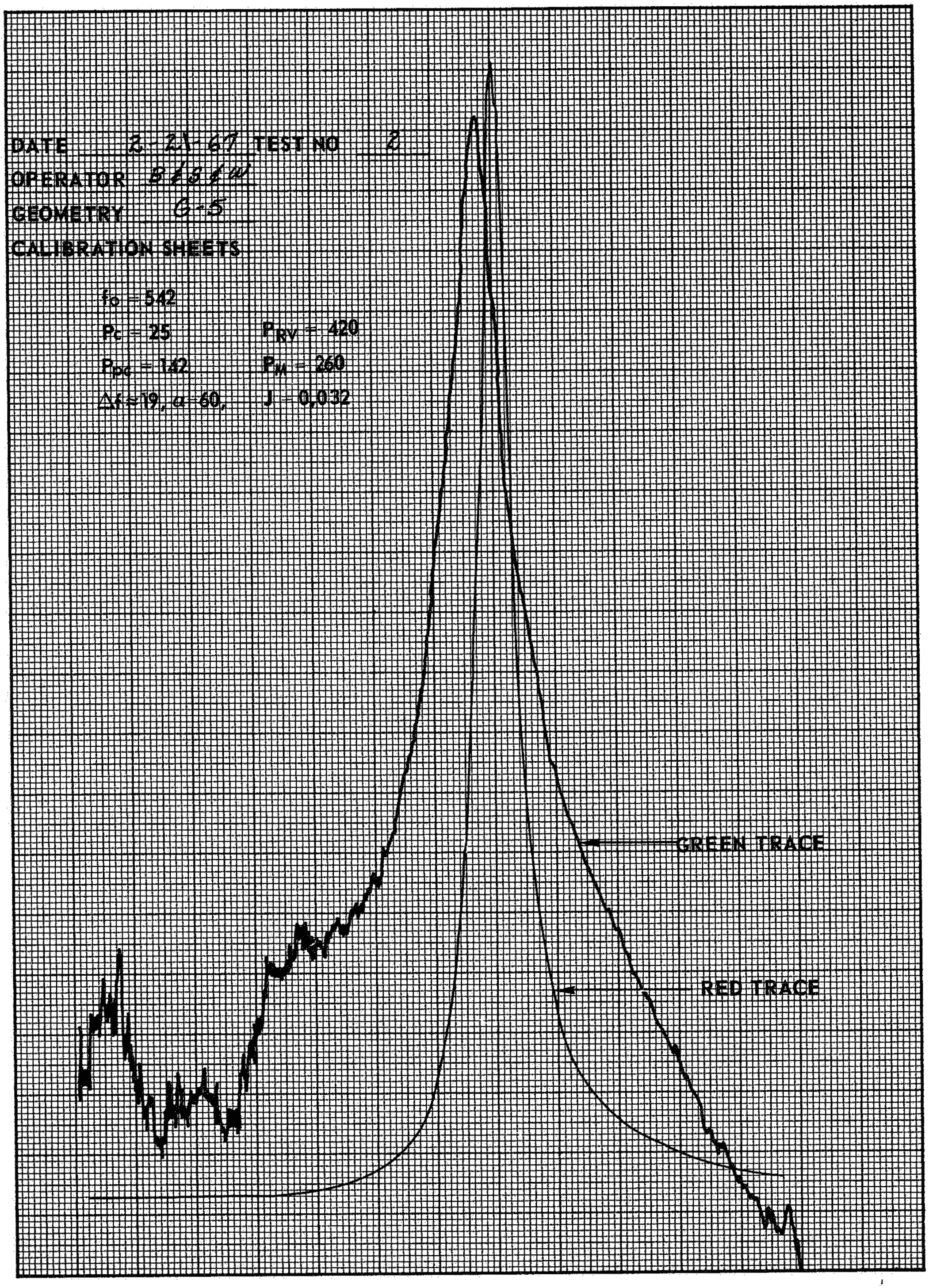
TABLE 3. Sample Test Record

Test date:
Operator's initials:

Purpose of test series

Geometry: 1-6 (i.e. nozzle #1, grain #6)

Test number	Geometry	Manifold pressure	Prechamber pressure	Chamber pressure	Rotary valve pressure	f_o	Δf	$\alpha = \pi\Delta f$	Comments on test
1	G-5	250	120	25	500	540	20	63	
2	G-5	260	142	25	420	542	19	60	
3									
4									



DATE 2-21-67 TEST NO 2

OPERATOR B & S & W

GEOMETRY G-5

CALIBRATION SHEETS

$f_o = 542$

$P_c = 25$ $P_{RV} = 420$

$P_{pc} = 142$ $P_M = 260$

$\Delta f = 19$, $\alpha = 60$, $J = 0{,}032$

FIG. 12. Typical Test Record From X-Y Plotter.

chamber response alone. The other, the green drive compensated (or normalized) logarithmic trace, gives the ratio of the chamber to the prechamber acoustic response. The alpha or temporal chamber damping constant is determined from each of these traces in the following manner.

Direct Chamber Response (Red Pen). The full amplitude of the red curve is measured from the zero line (see calibration of red Y_2 pen in Fig. 13) to the peak of the curve. This value is multiplied by 0.707 which gives the half-power amplitude. By counting the graph paper grid marks between the two points where the curve intersects the half-power amplitude line, the half-power bandwidth is determined. The half-power bandwidth is multiplied by 3.14 to obtain the value of alpha for the chamber tested.

Normalized Chamber Response (Green Pen). Use the green calibration lines between log 10/1 and log 1/1 to mark off ten equal increments. These increments are used to determine the log of 0.707 which is -0.151. The length of 0.151 is subtracted from the green pen trace at the resonance peak to determine the half-power amplitude. The bandwidth at this level is multiplied by 3.14 to arrive at the alpha value for the chamber tested.

PLOTTING OF DATA

The chamber damping constants obtained above are generally plotted against whatever variable was changed in the test. In some instances this is the J value of the motor and in some it is the total motor geometry or some particular geometry change.

As a check on proper system behavior, however, a plot of the damping constant versus J data for the extensively studied 1-foot chamber length model with various abrupt entry nozzles is given in Fig. 14. The line through the data is given by the equation:

$$\alpha = \frac{cJ}{L}$$

where "α" is in seconds^{-1}, the speed of sound c is in feet per second, the motor length L is in feet, and J is the ratio of the nozzle throat area to the grain port area. The speed of sound as a function of air temperature is given in Fig. 15. Calibration checks of the over-all system performance may be made and matched to these data prior to running new or unfamiliar geometries.

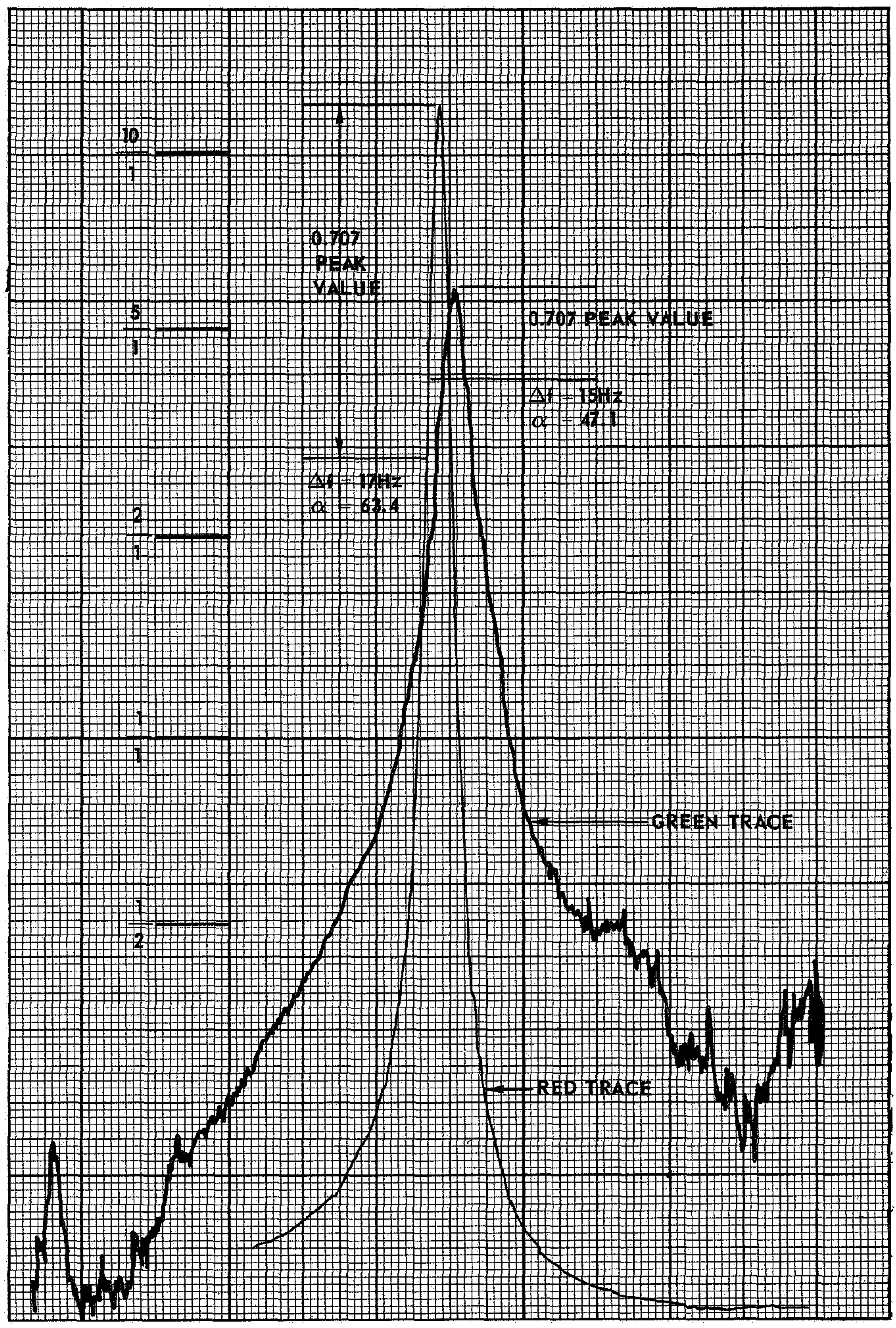


FIG. 13. Typical Test Record Showing Calibration Marks and how the Damping Constant is Obtained.

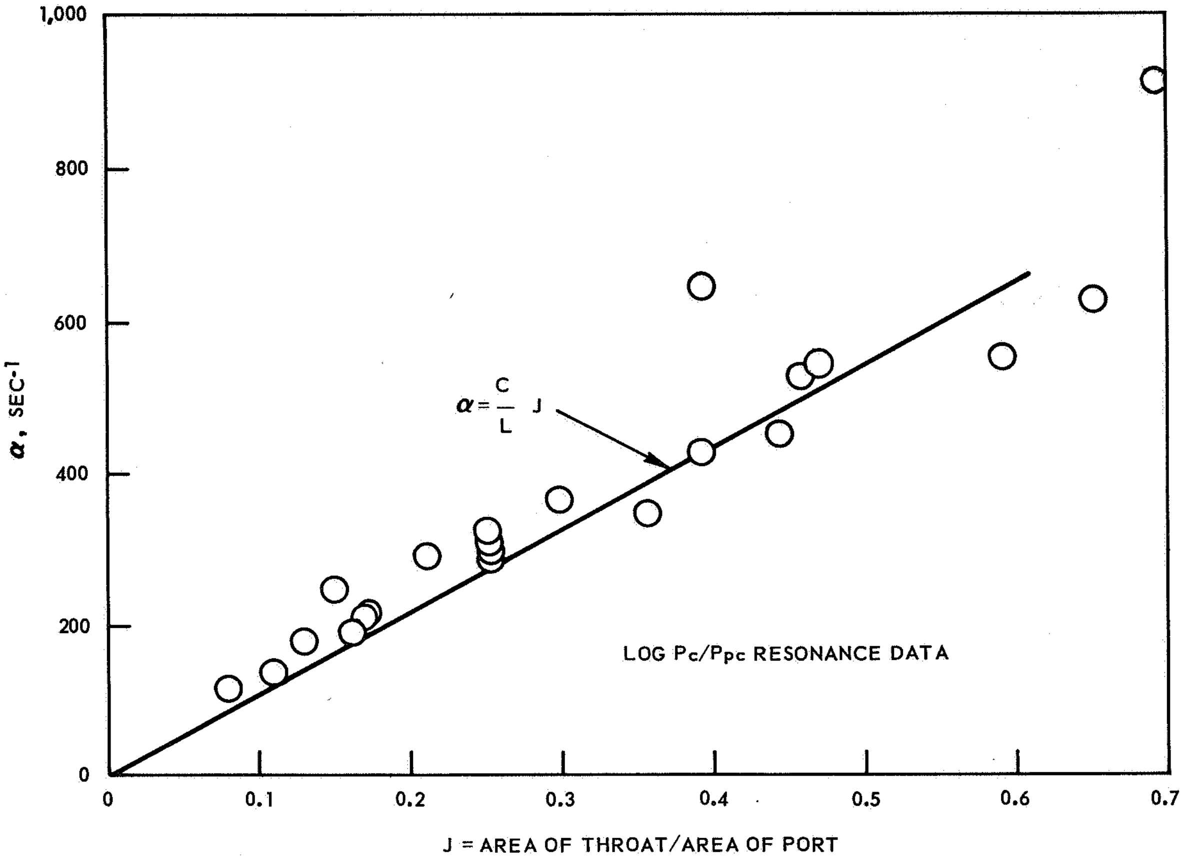


FIG. 14. Damping Constant Versus J for Abrupt Entry Nozzles.

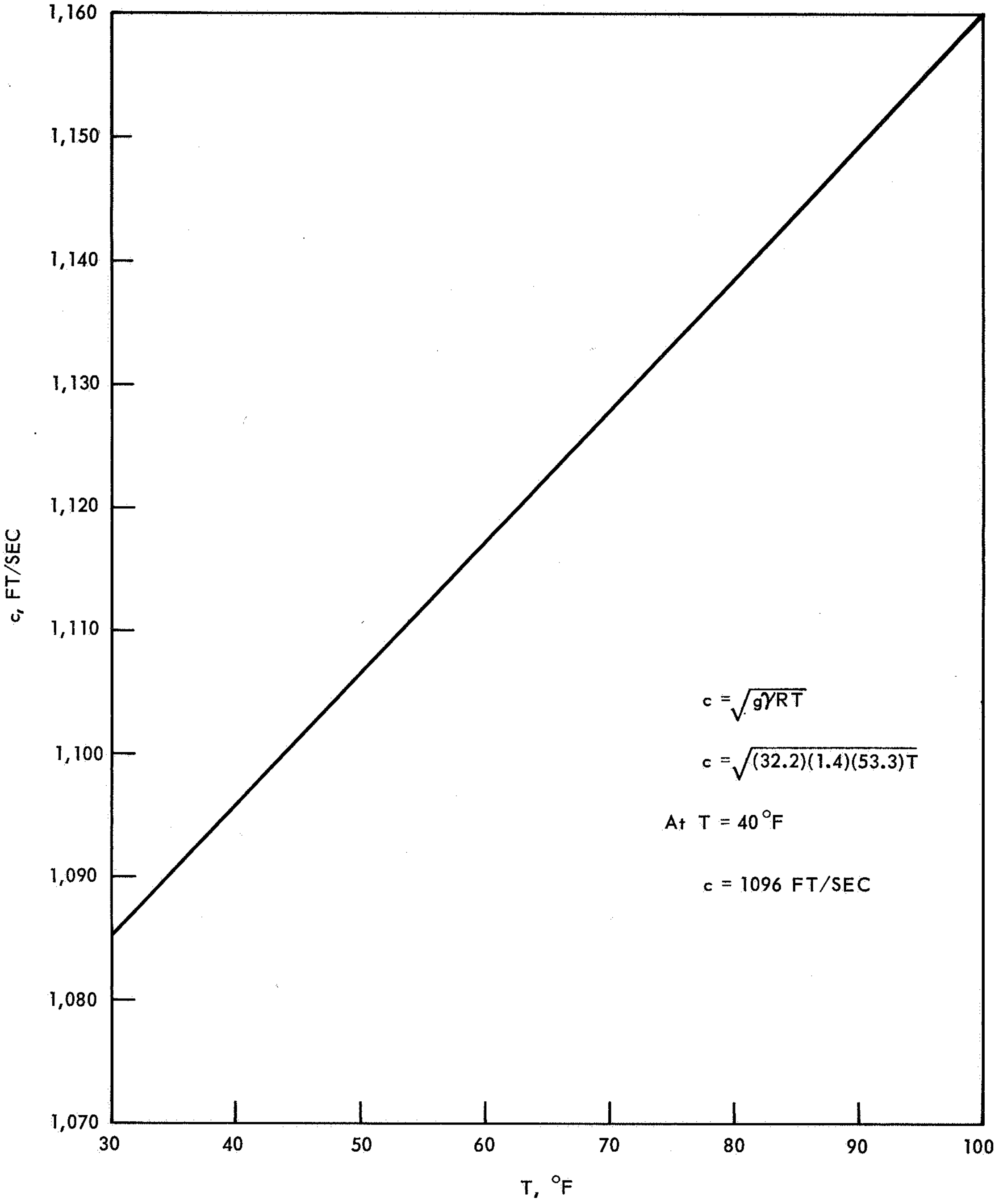


FIG. 15. Speed of Sound in Air as Function of Air Temperature.

CONCLUSIONS

The acoustic system and operating procedures presented enable resonance-type tests to be made of model motor chambers while maintaining a sonic nozzle throat condition. As shown in Ref. 5 and 8, such a nozzle boundary condition properly simulates the actual motor acoustic conditions.

To date, this system has been used for a variety of tests. Scale-model motors have been tested and the effects of various motor internal geometry changes noted thus indicating which geometry is potentially the most stable. Tests have been run on various nozzle configurations to determine the adequacy of present theoretical treatments. Other tests have been run to determine the effects of various nozzle throat boundary conditions.

Since such tests can be run easily, cheaply, and quickly compared with actual hot motor instrumentation and firings, the present system should often prove advantageous.

Appendix A

DESIGN DATA SHEET FOR NOTS-NASA ACOUSTIC-LOSSES-EVALUATION-SYSTEM MODELS

1. The models to be tested should be designed to mate with the NOTS acoustic driver prechamber. The mating section is a 6-inch diameter, flat-face flange with a 1-inch face, and has six 5/16-inch diameter by 3/4-inch long studs equally spaced on a $5\frac{1}{4}$-inch diameter bolt circle. The mating model should have a $\frac{1}{2}$-inch thick flange, with mating clearance holes and a gasket seal. All joints should be pressure-tight for 20 psi service.

2. The model chamber should have a heavy wall (not less than $\frac{1}{4}$-inch thick) to eliminate losses through the wall. A chamber of $4\frac{1}{2}$ inches external diameter is convenient to work with. Motor length and internal diameter should be scaled linearly. (Most of NOTS tests have been run in a $3\frac{1}{2}$ inch ID by $\frac{1}{2}$-inch thick aluminum chamber, using cylindrical slip inserts to vary the internal diameter to give port areas equivalent to zero, 1/3, 1/2, and full-burn times.) Internal star perforations need not be scaled and can be replaced by cylindrical bores having the same port areas.

3. Nozzles should be scaled by area to give the same ratio of grain-port to nozzle area throughout the entry section. This requirement will change the angle of the nozzle entry section. Accuracies of 20 percent should be satisfactory. Nozzle throat diameters should be in the range $\frac{1}{4}$-inch to $1\frac{1}{4}$ inches. Nozzle shapes after the sonic throat will not affect losses so that nozzles can be cut off sharply, roughly 1/8-inch aft of the throat section.

4. Roughly, 10 to 15 tests of a simple model can be run in 1 day. The test series should be planned to occupy approximately 1 week, consisting of 1 to 2 days of setup and 3 to 4 days of tests.

Appendix B

RELATION OF OLD AND NEW PART NUMBERS TO NOMINAL DIAMETERS

Nozzles

Old	New	Diameter
5	1	0.1265
4	2	0.25
3	3	0.375
2	4	0.5
1	5	0.625
A	6	1.0
1.1	7	1.15
B	8	1.25
C	9	1.375

Grains

Old	New	Diameter
1	A	1.0
2	B	1.5
1.7	C	1.7
3	D	2.0
4	E	2.5
5	F	3.0
6	G	3.5

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The system that is reported here was initially designed and assembled by the late R. O. Slates. The present work has attempted merely to simplify certain of the instrument circuitry and set down operating instruction that will enhance the use of the system.

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Steady-state resonance tests with through flow and a sonic nozzle throat condition were run on the NOTS-NASA acoustic-loss test facility to establish and record the instrument hookup schematics, instrument settings, system calibration procedures, and data reduction techniques. This report is intended as a manual for operating the facility for this type of test. With this knowledge, the facility may be used to measure experimentally the acoustic chamber losses of scale-model rocket chambers. The loss coefficients that are determined may be used in comparing various internal motor geometries before full-scale motors are built and tested, with a possible saving of time and money.

14. KEY WORDS	LINK A		LINK B		LINK C	
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