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PROJECT PYRO DYNAMIC PRESSURE ACCURACY EVALUATION

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74

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Charles M. Richey

FOREWORD

This is a final report of an accuracy study on Project Pyro pressure measurement instrumentation. This study was conducted by the Research and Evaluation Section of the Facilities Division at the Air Force Rocket Propulsion Laboratory, during the period August 1967 through August 1968, under in-house project number 921000AMU. The work was accomplished at the request of the Liquid Propellant Blast Hazards Study (Project Pyro), AF 04(611)-10739, and was under the direction of Mr. Charles M. Richey. Acknowledgement is given to Mr. Roger Benedict, Instrumentation Engineer for Project Pyro, for the help received in designing the charge source (see para 3.1.2) and in conducting the tests at the Pyro Test Area. Acknowledgement is also given to Mr. Edwin Winslow of the AFRPL Calibration Section for his investigation of the Reference Cable (see para 3.1.1) and for his help in carrying out the tests at the Pyro Test Area and to Lt. Roy Eastland of the Programming and Analysis Section for handling the processing of the accuracy data.

This technical report has been reviewed and is approved.

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ABSTRACT

An accuracy study was performed on the pressure measurement instrumentation of Project Pyro (Blast Hazards Testing) located at Test Area 1-90 at the Air Force Rocket Propulsion Laboratory (AFRPL), Edwards AFB, California. This report presents the methods, techniques, problems, results, and conclusions of this accuracy study. A pseudo end-to-end technique was employed to obtain the data with the results being presented to a 95% confidence level (approximately $\pm 2\sigma$). For frequencies between 50 Hz and 6000 Hz and amplifier gain positions 2 through 20, the bias was found to be -5.6% with an uncertainty of ±6.7%.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

ILLUSTRATIONS

TABLES

SECTION I

INTRODUCTION

Project Pyro tests were carried out at Test Area 1-90 at the Air Force Rocket Propulsion Laboratory (AFRPL). The primary results obtained from these tests were temperature and pressure data associated with the blast wave formed from the intentional explosive destruction of a variety of test articles under various conditions. This evaluation is concerned only with the instrumentation used to measure the blast pressures.

Because of the highly destructive nature of the initial shock front, measuring its rise time and amplitude (peak overpressure) is very important and therefore the pressure instrumentation should be capable of high-response measurements (up to 20,000 Hz). Piezoelectric pressure instrumentation was used exclusively in order to insure the required dynamic response. Frequency modulation (FM) recording techniques were used in recording the data on magnetic tape which was then speed-scaled during playback and the data recorded on oscillograph paper. This visual record was then shipped to the URS Corporation in Burlingame, California, for analysis. URS was the prime contractor for NASA on the Blast Hazards Program.

Since the Pyro data leaves the AFRPL as an oscillograph record, the accuracy program makes use of end-to-end measurements that include this visual record. However, when considering dynamic pressure measurements, true end-to-end tests cannot be performed because of the lack of an accurate and usable high-frequency pressure generator. Therefore, for the purposes of this study, modified end-to-end tests were performed. That is, the pressure transducers were removed from the system and a simulated sine wave signal was fed into the pressure transducer amplifiers and cable that precede the FM recording systems.

SECTION II

PYRO PRESSURE INSTRUMENTATION SYSTEM

2.1 TEST AREA

The Pyro test area consists of a test pad located 1080 feet from the instrumentation control station. Radiating from the pad are three lines of instrumentation 120° apart (see Figure 1). The transducers are located from 2.8 feet to 600 feet from the intersection of these lines of instrumentation, and the amplifiers and signal conditioning apparatus associated with each pressure transducer are housed in underground concrete boxes approximately 50 feet behind each transducer position. The amplifiers then each drive from 600 to 1800 feet of RG-62/U instrumentation coaxial cable, which terminate at a patch panel in the control station.

2.2 INSTRUMENTATION SYSTEM

The pressure instrumentation system consists basically of the transducers, amplifiers, cable and the tape recorders.

2.2.1 Pressure Transducers

The Pyro project requires a high-response pressure system that will respond to approximately 20,000 Hz in order to follow the pressure rise of the initial shock wave. Piezoelectric transducers were chosen because of their response characteristics and Kistler Instrument Corporation transducers were selected because of their extended frequency range and their comparative ease of operation over other available types. The system in general uses 27 transducers to measure overpressure (side-on) and stagnation pressure (head-on). Five Kistler models have been in use during the project and they are the 601A, 601H, 603A, 606A, and 701A. Their sensitivities vary from 0.3 picocoulombs (pcb)/psi to 5 pcb/psi which allows pressure measurements from 1 psi to 3,000 psi. These transducers are housed in stream-lined blast-proof enclosures so that the shock wave will be affected as little as possible. They undergo periodic

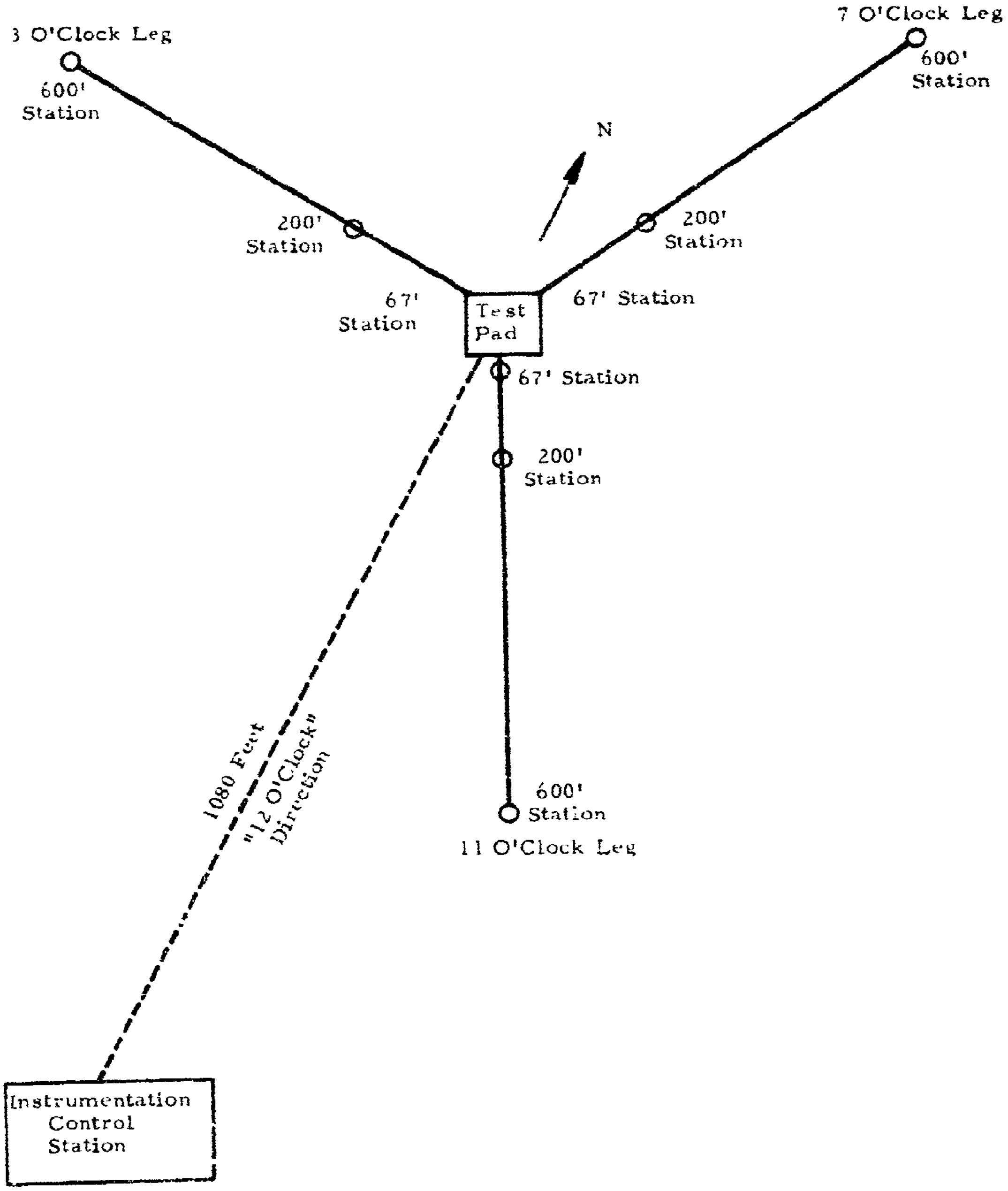


Figure 1. Pyro Test Area 1-90

static calibrations by applying known pressure steps to each transducer and recording their output as amplified by a calibrated charge amplifier.

2.2.2 Amplifiers

The Kistler Model 566M109 charge amplifiers are used for signal conditioning of all blast pressure measurements. These amplifiers are protected from the elements and the force of the blast by being placed in underground concrete boxes. They are complete in themselves requiring only input, output, calibration, power, and remote grounding connections. The amplifiers drive the RG-62/U coaxial cable and are periodically removed from their test locations and calibrated with a 1000-Hz reference signal. Records are kept of the calibration and are used by URS in their calculations. The amplifiers have gains of from 0.25 mv/pcb to 100 mv/pcb.

2.2.3 Cable

The charge amplifiers located in the field are connected to the recording electronics in the Instrumentation Control Station by RG-62/U coaxial cable. The shortest length of cable is about 635 feet and the longest is over 1800 feet. Because of the extreme cable lengths involved, it was important that they be included in the overall system evaluation so that their effect on frequency response would be included. Also, the extreme differences in cable lengths between various instrument locations could create phase shifts large enough to be investigated. Determining the phase shift between the channels tested was an objective of this study.

2.2.4 Recorders

All pressure data are recorded on three Ampex FR-1200 14-track instrumentation recorders. Each recorder has 12 FM-record modules and two direct-record modules. The recorders are run at 120 inches per second (ips) with an FM center frequency of 108,000 Hz. This provides a recording bandwidth from d. c. to 20,000 Hz. The data tapes are taken to the AFRPL data reduction center where the tapes are speed-scaled and recorded on oscillograph rolls which are then sent to URS for analysis.

SECTION III

TEST APPARATUS AND PROCEDURE

3.1 EQUIPMENT

The following laboratory test equipment was utilized during accuracy tests conducted on the Pyro instrumentation:

a. ATEC 6B45 Frequency Counter, Serial number FE2206.

b. Fluke 803B AC/DC Differential Voltmeter, Serial number 2797.

c. Fluke 823A AC/DC Differential Voltmeter, Serial number 274.

d. Hewlett-Packard 200CD Sine Wave Generator, Serial number 15908.

e. Hewlett-Packard Variable Power Supply, Serial number 15200464.

Other necessary equipment included a "black box" charge source designed to simulate a piezoelectric transducer, and 1,200 feet of calibrated RG-62/U coaxial cable. Both of these items will be discussed in detail.

3.1.1 Reference Cable

A parameter at the onset of this study was the possible time lag or phase shift between the various pressure locations on the pad. This could be an important consideration during investigations of blast shock-wave propagation if the time lag was great enough. In order to test for phase changes, a reference frequency source is necessary. However, since the frequency generator was to be located on the test pad and the data was to be recorded 1,080 feet away in the blockhouse, a cable with known phase characteristics to bring the reference back to the blockhouse was necessary. A cable 1,200 feet in length (RG-62/U) was calibrated for response and phase shift from 10 Hz to 100,000 Hz by the AFRPL Calibration Section. The cable was calibrated while terminated in its characteristic impedance of 90 ohms (see Figures 2 and 3). Unfortunately, due to

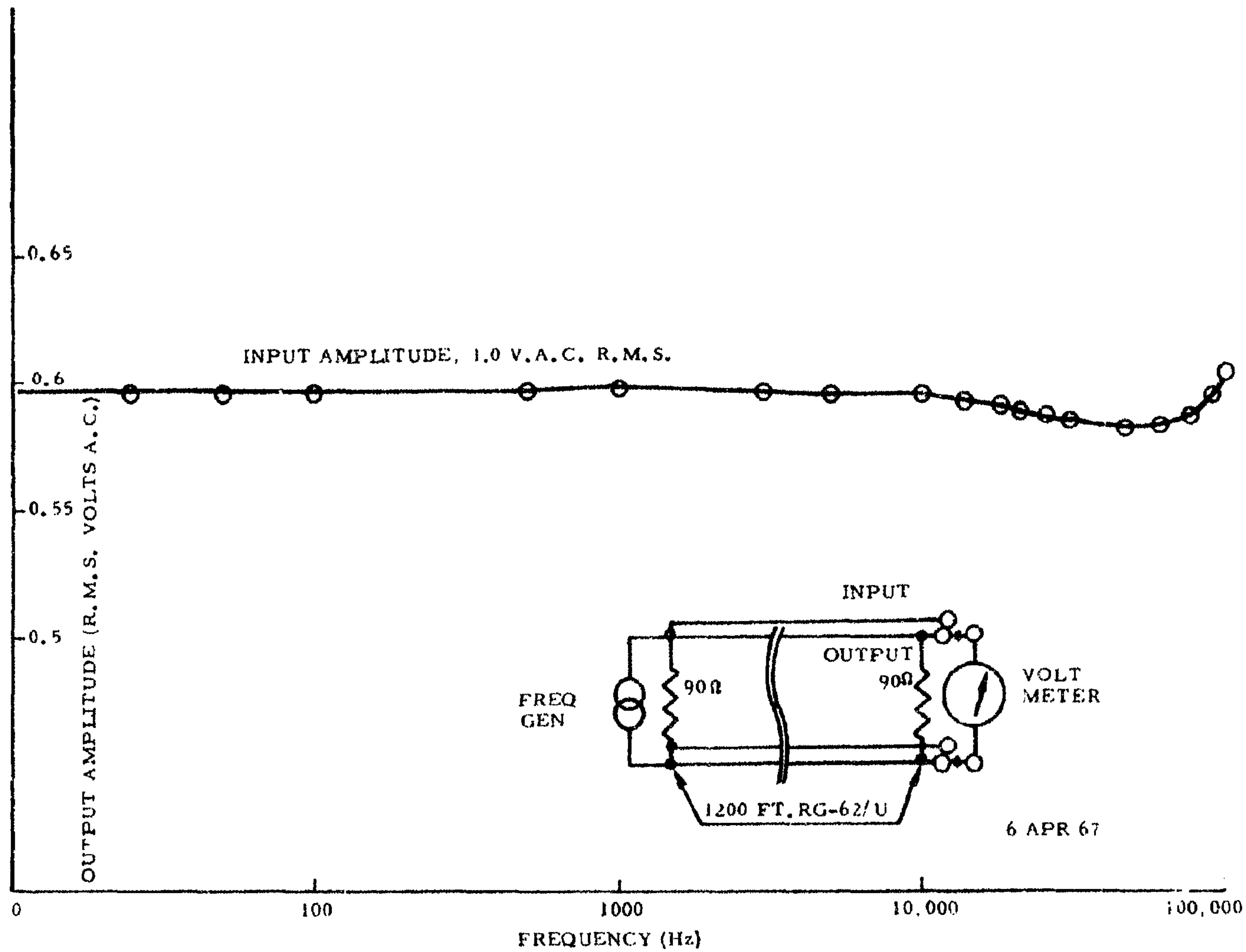


Figure 2. RG-62/U Cable Response Test

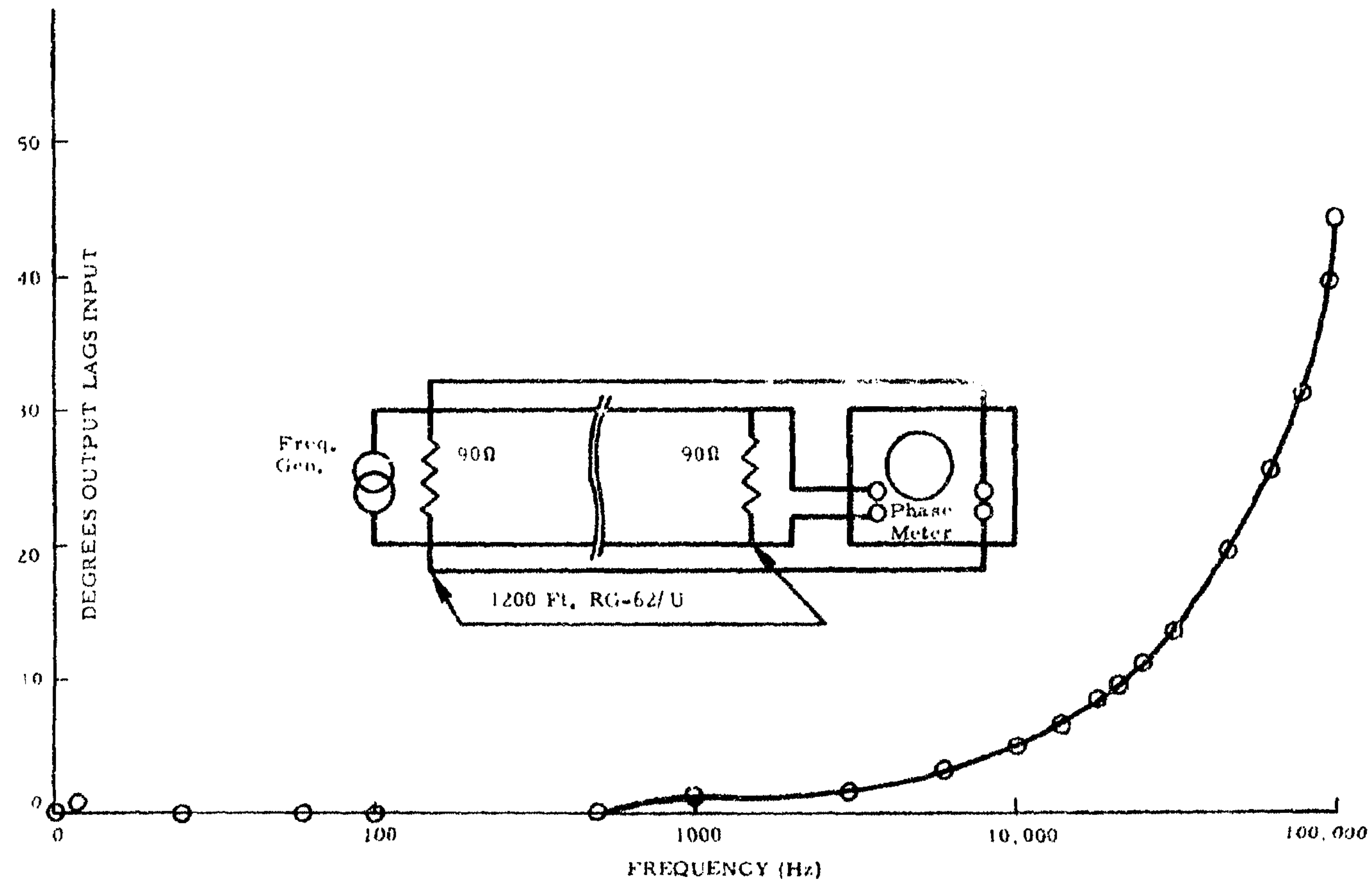


Figure 3. RG-62/U Cable Phase Test

data reading problems, which will be explained later, the phase portion of this study had to be discontinued.

3.1.2 Charge Source

True end-to-end tests of the Pyro pressure system. including the transducers, could not be conducted because of the need for a high-frequency sinusoidal pressure generator. Such a generator is, at the present, unavailable. However, end-to-end tests from the charge amplifiers were performed. And in order to simulate the input characteristics to the charge amplifiers that the transducers present, an active charge source was designed by the Pyro Instrumentation Engineer and the Author (see Figure 4). The charge source is basically an emitter-follower circuit that provides isolation from the sine wave generator input and presents approximately 90 ohms output impedance to the reference cable. The emitter-follower output voltage is placed in series with capacitors (on the order of 100 picofarads (pf) to provide charge to the charge amplifiers (q = capacitance voltage (CV)). Outputs were provided so that six charge amplifiers could be driven simultaneously.

3.1.3 Voltmeter

An 823A Fluke differential voltmeter was used to monitor and maintain the output voltage from the charge source. This voltmeter is accurate to better than ±0.5% of the reading from 20 Hz to 30,000 Hz and from 0.1 volts to 500 volts. The Fluke voltmeter is periodically calibrated (every 6 months) by Precision Measurements Equipment Laboratory (PMEL) to the manufacturer's specifications, using standards traceable to the National Bureau of Standards.

3.1.4 Other

The ATEC, Inc. frequency counter was used to monitor the Hewlett-Packard sine wave generator whose output was used to drive the charge source. A portable Tektronics oscilloscope was used to monitor the wave form to guard against distortion.

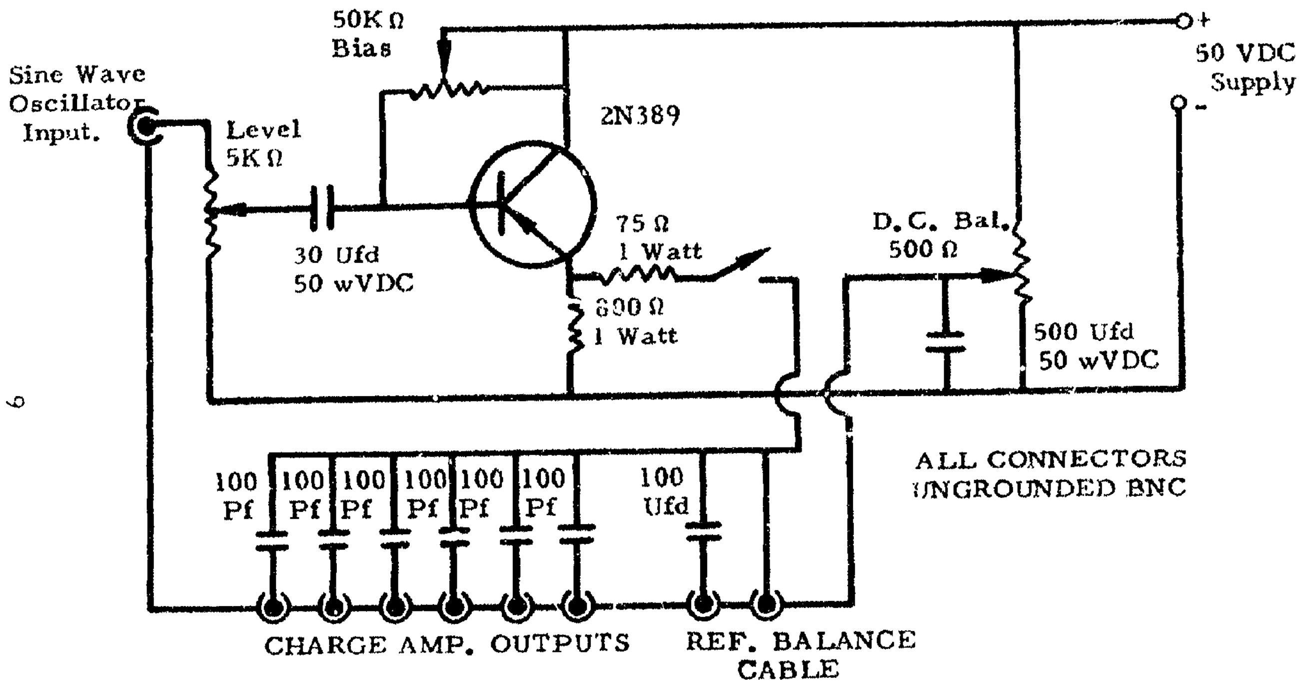


Figure 4. Charge Source

3.2 PROCEDURE

The following paragraphs outline how the equipment was set up and utilized, how the data was taken, and how the test was conducted. Problem areas that arose are also discussed.

3.2.1 Equipment Dispersal

The reference cable was rolled out between the control station and the test pad; then the equipment was set up in a van to protect the equipment from the weather. The location of the van on the test site was determined by the location of the charge amplifiers. The amplifiers should be chosen at random, but since they are placed in the field at random, an area was selected that had six amplifiers within reach of the low-noise cable that was used to carry the signal from the charge source. Low-noise cable had to be utilized because standard RG-62/U cable was extremely noisy and too sensitive to weather changes, thus causing considerable signal drift. The equipment was loaded into the van and connected as shown in Figure 5. Because a charge amplifier is extremely susceptible to drift caused by charge leaking off, extra precautions had to be taken to insure absolutely clean connections between the charge source and the amplifiers. Freon degreaser was used liberally on all low-noise cable connections whenever any drift problems occurred.

3.2.2 Frequencies and Gains

This study was performed to determine the frequency response of the Pyro pressure instrumentation. The following amplifier gains were selected: 2, 5, 10, 20, 50 mv/pcb. The gain of 100 mv/pcb was not selected because it was seldom used by Project Pyro, and gains below 2 mv/pcb were not selected because enough drive voltage could not be obtained from the charge source. The following frequencies (Hz) were selected to adequately cover the frequency spectrum:

10	100	3000	10000	18000	30000
25	500	6000	12000	21000	
50	1000	8000	14000	25000	

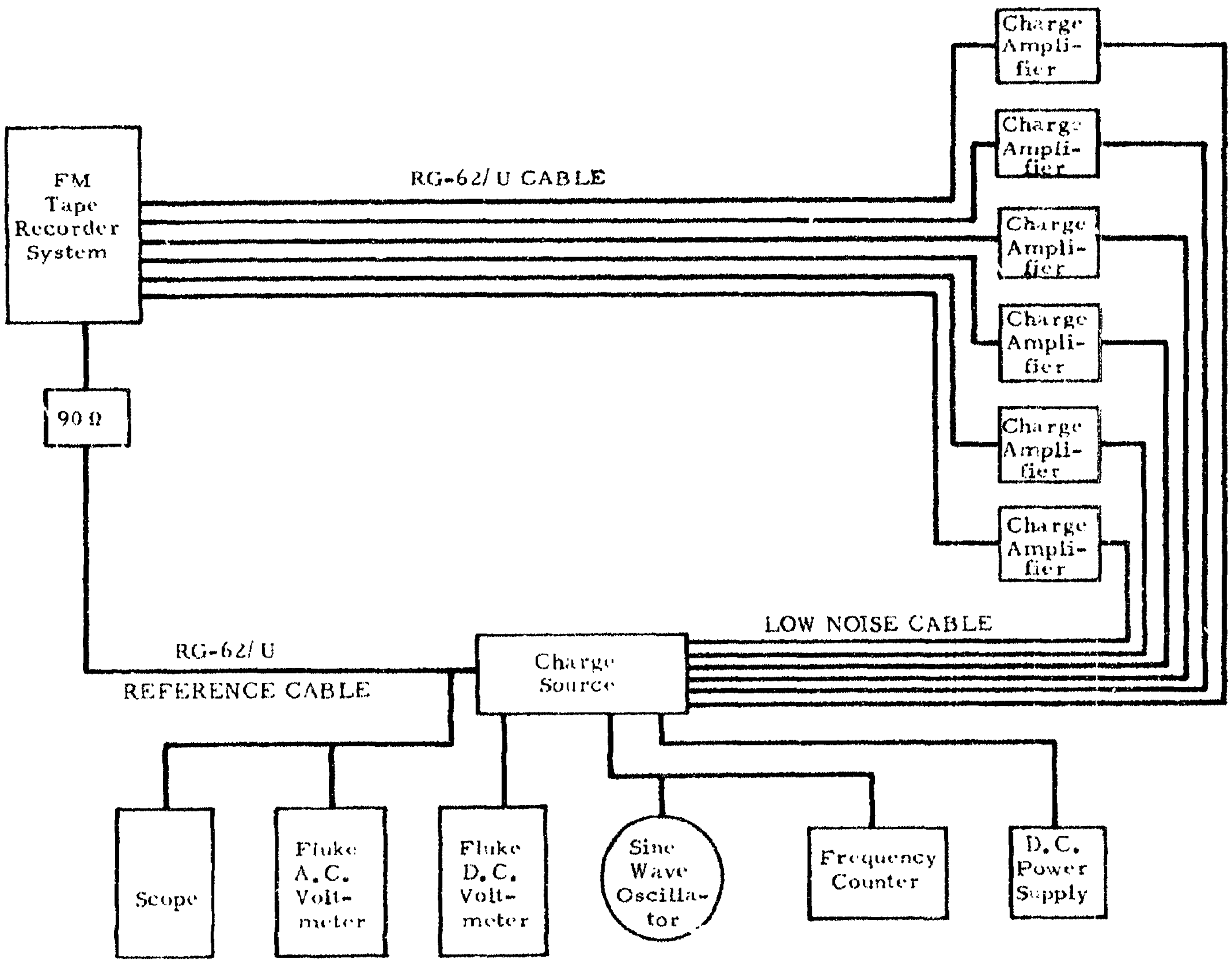


Figure 5. Equipment Layout

All adjustments that might affect the output voltage or wave form were readjusted for each frequency and gain setting.

3.2.3 Input Voltage Standard

A specific gain setting was chosen for each test and the charge source adjusted to obtain a 1-volt output from the charge amplifiers. Maintaining this 1-volt output is standard operating procedure for Pyro and was, therefore, followed during this study. The following amplifier gains and input voltages at the charge source produced a 1-volt output as shown below:

gain (g)	2	5	10	20	50
input voltage (e)	5	2	1	0.5	0.2

e = input (volts)

Q = charge (pcb)

g = gain (mv/pcb)

v = output (mv)

c = charge source capacitance (pf)

let: $v = 1000$ mv $\qquad c = 100$ pf

$g = 2$ mv/pcb

then: $v = gQ \quad$ or $\quad Q = \frac{v}{g}$

$$e = \frac{Q}{c} = \frac{v}{gc} = \frac{1000 \text{ mv}}{(2 \text{ mv/pcb})(100 \text{ pf})}$$

$$e = 5 \, \frac{\text{pcb}}{\text{pf}}$$

remembering that 1 pcb = (1 volt) (1 pf)

we see that e = 5 volts.

3.2.4 Charge Source

The level and bias controls on the charge source and the output of the sine wave generator were adjusted to produce the desired input to the amplifiers while maintaining a clean sine wave as observed on the oscilloscope. The d. c. potential across the capacitors (balance) was adjusted to eliminate any constant charge that would otherwise be present at the charge amplifier input. This d. c. potential and the sine wave input amplitude were monitored with the Fluke voltmeters. The input voltage from the charge source (monitored at the reference cable output) was held to within ±0.001 volts of the required voltage for each test. This was checked and readjusted prior to recording each group of data.

3.2.5 Frequency Counter

The frequency counter was used to monitor the input frequency and it was kept to within 0.5% of the chosen value.

3.2.6 Reference Signal

The data for this study was recorded using the standard techniques developed for recording the Pyro test data. This includes placing a reference signal on each FM recorder channel used. This is done because to reduce the oscillograph data, the deflection constant in inches per volt must be known. At Pyro this reference signal consists of a d. c. voltage applied to each charge amplifier through its calibrate input, which is then amplified and subsequently measured at the recorders prior to being put on tape. This reference voltage, which is applied to each channel simultaneously in three steps, is measured by a digital voltmeter and automatically printed out to insure accuracy. This method of injecting the reference signal insures against a major system failure prior to a test. This reference signal was placed on tape on each of the six channels tested just as for a standard Pyro test. The accuracy test was then conducted for each amplifier gain by recording several seconds of data for each of the frequencies (see para 3.3.2).

3.3 DATA REDUCTION

3.3.1 Oscillograph Playback

The recorded tape was taken to the AFRPL Data Playback/ Reduction Center where the recorded signals were placed on oscillograph paper. For the purposes of this accuracy study, the recorder playback speed was the same as that used for Pyro tests, 7.5 inches per second. However, the oscillograph paper speed was varied to allow the most advantageous reading of the sine wave accuracy data. From 10 Hz through 100 Hz, 1 inch per second (ips) paper speed was used. From 500 Hz to 3000 Hz, the speed was 25 ips and from 6000 Hz to 30000 Hz, a speed of 160 ips was used. The very high speed of 160 ips for the majority of the selected frequencies resulted in a great deal of oscillograph paper per run, generally more than one full roll (475 feet). Six pressure channels were recorded plus one reference channel from the reference cable for phase shift determinations. In order to maintain easy readability of the data on the oscillograph paper, only four channels of information were played back at a time, three pressure channels and the reference channel. The zero step and voltage reference steps that were placed on tape once for each gain were placed at the beginning of each new set of channels on the oscillograph paper.

3.3.2 Data Point Selection

To increase the accuracy of the measured data taken from the oscillograph paper, 11 points per channel per frequency were measured. This gave 10 differences for both the X coordinates (phase) and the Y coordinates (amplitude). (See Figure 6.) Note that the charge amplifiers invert the signal and therefore the reference channel trace is at least 180° out of phase with the other channels. Hand reduction of the accuracy data was contemplated until it was realized that two groups of over 1,400 points each would be required for each gain setting.

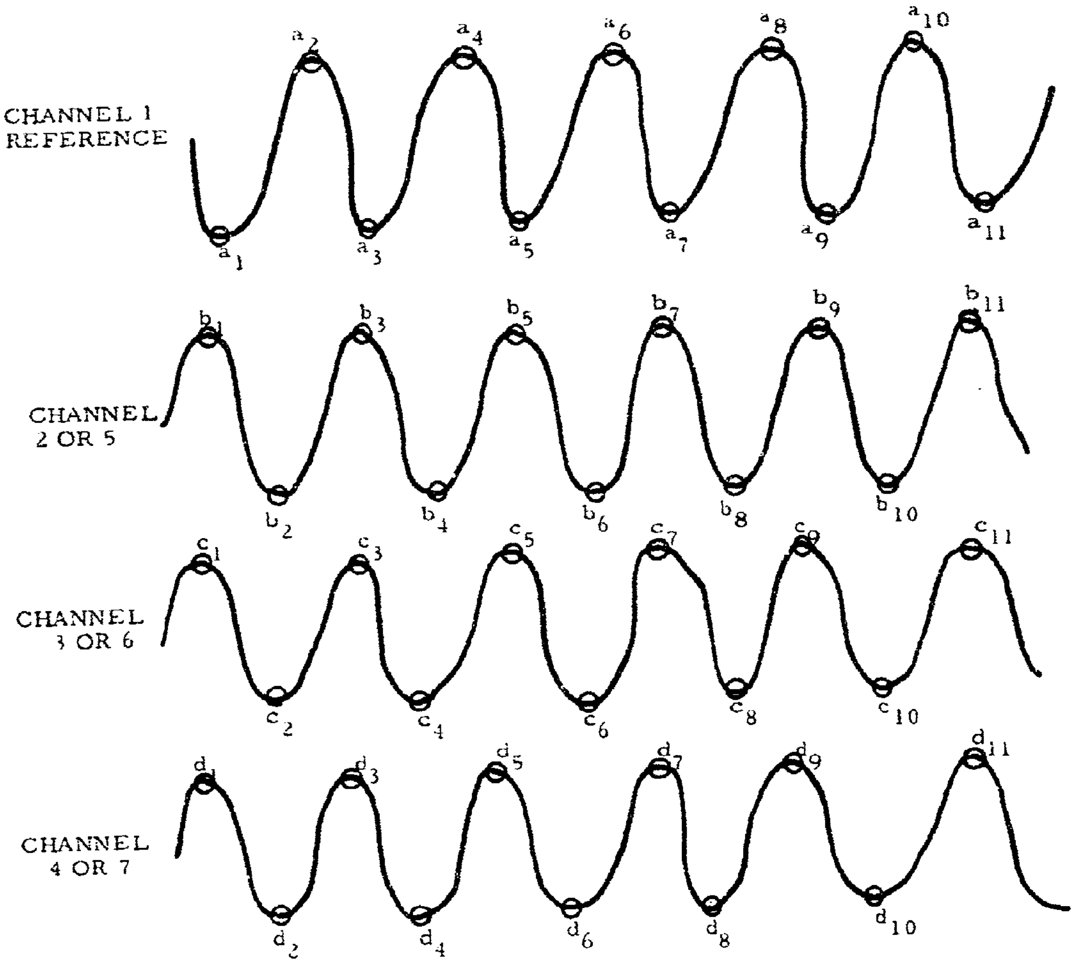


Figure 6. Oscillograph Data

3.3.3 Telecordex 099

Computing and Software (C&S), the AFRPL Data Services contractor, was given the task of reading the data points on the oscillograph paper using the Telecordex 099. This instrument was chosen because of its high resolution of 792 counts per inch in both the "x" (horizontal) and "y" (vertical) directions and because it locates a point simultaneously in both directions. The Telecordex 099 puts the data on IBM cards in a computer usable format. This data was subsequently processed and printed by the computer under the direction of the AFRPL Data Analysis Section.

3.3.4 Phase Shift

Initially, phase shift in degrees was included in the format but it was found that it was a parameter that could not easily and accurately be obtained from the data. This problem resulted from the fact that the oscillograph paper could not be accurately aligned on the "099" consistently. The phase measurement would have resulted from observing the horizontal displacement of a given channel's output as compared to the reference channel (channel 1) at the top of the oscillograph paper (see para 4.1.2). Since this involved measurements across the entire paper (top to bottom), very accurate horizontal alignment of the paper was necessary, but could not be obtained. Also some mechanical failure of the horizontal tracking mechanism of the "099" occurred and because of these two problems, the phase measurement had to be eliminated.

SECTION IV

ANALYSIS

4.1 STANDARD DEVIATION

The standard deviation is the most accepted measure of variability or error of randomly distributed data. The standard deviation is the square root of the mean-squared deviation of the individual measurements from the mean of the population and is designated sigma (σ).

$$\sigma = \sqrt{\frac{\Sigma (X - X)^2}{n}}$$

It must be emphasized that sigma is a statement of probability based on the assumption that the data are randomly distributed about a mean and constitute a normal distribution. Also the above equation is valid only when n represents the total number of possible observations (the entire population). In practice, the standard deviation is estimated from a sample of the total possible observations and is represented by $S_{(x)}$,

$$S_{(x)} = \sqrt{\frac{\Sigma (X - X)^2}{n-1}}$$

where n is the number of observations taken. The denominator is reduced to n-1 causing $S_{(x)}$ to be conservatively large because it is an estimate of σ based on a sample less than the total number of possible observations.

If the sample represents only a small portion of the total population, $S_{(x)}$ is made even more conservative through the use of the "Student's t". This factor is a direct multiplier of $S_{(x)}$ and insures that the deviation of the sample conservatively represents the deviation of the entire population. The value of the "Student's t" is found from a table and its value is dependent on the confidence level and the number of samples taken. In our case, its value will represent the 95% confidence level.

4.1.1 Amplifier Selection

The charge source is capable of supplying charge to six amplifiers simultaneously during a test. These amplifiers should be selected randomly, but this was not possible because of the positioning of the amplifiers in the field and the need to keep the low-noise cable short that connected the charge source and the amplifiers. There were few positions on the test pad that would allow the simultaneous connection of six amplifiers. However, since the amplifiers were placed in the field in a completely random order, this method was considered acceptable.

4.1.2 Data Recovery

In order to minimize operator reading errors while obtaining the data from the oscillograph rolls, eleven data points were taken per channel per frequency per gain setting. The data was represented on the oscillograph paper as a sine wave and the points were located as shown in Figure 6. The "x" and "y" coordinates of each point were taken and the absolute value of the "y" differences (b_{1y} - b_{2y}, b_{2y} - b_{3y}, b_{3y}- b_{4y}, etc.) were averaged to obtain "delta L" which was used to calculate the voltage. The "x" differences between the reference channel and amplifier channel data points (a_{1x} - b_{1x}, a_{2x} - b_{2x}, a_{3x} - b_{3x}, etc.) would have been used to calculate the phase. But, because of the problems that were described above, the phase shift determination was abandoned.

4.1.3 Formulations Used

4.1.3.1 The method employed in this accuracy study was to record an accurately known input voltage using the Pyro instrumentation system. From the data obtained, the input voltage was then calculated and compared to the true known value. This comparison provides a direct measure of accuracy of the Pyro instrumentation. The calculated voltage (E(CALC)) was calculated from the following:

$$E(CALC) = \frac{(E_{CAL})\ (\Delta L)\ (10^3)}{(L_{CAL})\ (GAIN)\ (CAP)}$$

Where:

E_{CAL} (volts) is the reference voltage placed on the FM tape just prior to each test (see para 3. 3. 6).

L_{CAL} (inches) is the measured amplitude of E_{CAL} on the oscillograph paper. This obviously gives a calibration in volts per inch.

ΔL (Delta L in inches) is the averaged amplitude of the output trace as recorded on the oscillograph paper of a particular amplifier at a particular gain setting and frequency.

GAIN (in mv per picocoulomb-pcb) is the actual recorded gain of the particular amplifier in question.

10^3 is a conversion of 1, 000 mv per volt.

CAP (picofarads) is the measured capacitance of the capacitor that is supplying the charge to the amplifier.

4. 1. 3. 2 Attenuation in decibels (db) could be obtained with little extra effort and was, therefore, calculated from

$$\text{ATTN} = 20 \log_{10} \frac{E_{CAL}}{E_{TRUE}}$$

Where E_{TRUE} is the accurately measured input voltage.

4. 1. 3. 3 The deviation is the difference between the calculated voltage and input voltage.

$$\text{DEV (VOLTS)} = E_{CALC} - E_{TRUE}$$

4. 2 OUTPUT FORMATS

All calculations and data reduction were handled by the Computer Center at the AFRPL. Two basic output formats were used and will be explained.

4.2.1 Collected Data Format

A separate test was conducted for each gain setting and data was collected for each frequency during each test (see para 3.3.5). As the data was reduced for gains 2 and 5, it became obvious that data should be collected at 8000 Hz and 12000 Hz and this was subsequently done. Figure 7 is a sample of this data as found in Section VII, part 2. The following information was printed out for each test because it was subject to change:

Channel refers to the oscillograph channel. Channel 1 was the reference channel that would have been used for determining phase shift.

Item number refers to the location of the amplifiers as determined by Project Pyro.

Amp S/N and VCO S/N refer to the serial number of the corresponding amplifier and voltage controlled oscillator.

Gain (mv/pcb) is the calibrated gain of the corresponding amplifier.

Gain Date is the date that the amplifier gain was recorded. The first two numbers refer to month, the next two are the day, and the last is the year in the 1960 decade.

Cal Volts is the value of the calibration voltage put on the FM tape.

L Cal is the corresponding deflection that the calibration voltage created.

CAP is the value of the capacitor placed in series with the amplifier input.

As was previously mentioned, two oscillograph runs were made for each test, the first with channels 1, 2, 3, and 4 recorded and the second with channels 1, 5, 6, and 7 recorded. This allowed adequate separation of the channels and amplitude. Thus the two oscillograph cut numbers

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	OCTOBER 18, 1967	5.000	2.000

CHANNEL	2	3	4	5	6	7
ITEM NUMBER	125	225	126	226	127	227
AMP S/N	1048	1596	1041	1050	1595	1386
VCO S/N	112026	9E0227	911663	9E0346	9E0294	9E0292
GAIN(HV/PCB)	4.700	5.000	4.960	5.010	4.930	5.000
GAIN DATE	01317	05207	01127	01107	01137	02017
CAL VOLTS	1.035	1.036	1.015	1.026	1.022	0.964
LCAL(IN.)	1.890	1.877	1.821	1.887	1.856	1.711
CAP(PF)	128.250	127.950	127.600	127.600	127.150	126.700
FREQUENCY = 10 HZ			OSC CUT NO. 7677			
CALC VOLTS				2.563	2.606	2.637
DEV(VOLTS)				+0.563	+0.606	+0.637
ATTN(DB)				+2.155	+2.300	+2.403
DELTA L(IN.)				3.013	2.967	2.966
FREQUENCY = 25 HZ			OSC CUT NO. 7660, 7678			
CALC VOLTS	2.109	2.136	2.115	2.104	2.155	2.160
DEV(VOLTS)	+0.109	+0.136	+0.115	+0.104	+0.155	+0.160
ATTN(DB)	+0.463	+0.573	+0.487	+0.440	+0.650	+0.668
DELTA L(IN.)	2.322	2.476	2.401	2.473	2.454	2.429
FREQUENCY = 50 HZ			OSC CUT NO. 7661			
CALC VOLTS	2.022	2.065	2.033			
DEV(VOLTS)	+0.022	+0.065	+0.033			
ATTN(DB)	+0.097	+0.278	+0.143			
DELTA L(IN.)	2.226	2.393	2.308			

Figure 7. Collected Data Format

listed for most frequencies refers to the two groups of channels respectively. At times, due to technical difficulties, a group of data would be unusable and therefore only one cut number appears.

When the deviation is shown positive, the calculated voltage was greater than the input voltage, and correspondingly, the attenuation is shown positive. The reverse is true when the negative sign appears.

4.2.2 Calculated Data Format

The results of all the tests are tabulated in the format shown in Figure 8. These results are found in Section VII, part 1. These results are grouped on a frequency basis by gain setting. The data found under each gain setting is the averaged result from the six channels as described in para 4.2.1. The final results are shown as a ratio of the calculated voltage to the true input voltage plus or minus a value that reflects the 95% confidence level. This value is determined by multiplying $S_{(x)}$ by the proper "Student's t" value (see para 4.1).

A ratio was chosen to represent the results so that all the gains could be combined rather than presenting separate results for each. However, above 3000 Hz, there is a marked difference between gain 50 and the other gains, therefore, the results were tabulated to show this difference in order that it could be taken into account when reducing the Pyro data.

TEST AREA 1-90 ACCURACY STUDY (PYRO)

GAIN SET	2	5	10	20	50
INPUT VOLTS(TRUE)	5.000	2.000	1.000	0.500	0.200

FREQUENCY = 3000 HZ

INPUT VOLTS(CALC)	4.731	1.950	0.985	0.494	0.194
DEV(VOLTS)	-0.269	-0.050	-0.015	-0.006	-0.006
E(CALC)/E(TRUE)	0.946	0.975	0.985	0.989	0.968
ATTN(DB)	-0.480	-0.222	-0.132	-0.099	-0.282

E(CALC)/E(TRUE)(ALL GAINS)	0.972 + 0.0[illegible]	ATTN -0.243 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.973 + 0.040	ATTN -0.233 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.968 + 0.059	ATTN -0.282 DB

FREQUENCY = 6000 HZ

INPUT VOLTS(CALC)	4.621	1.900	0.966	0.477	0.183
DEV(VOLTS)	-0.379	-0.100	-0.034	-0.023	-0.017
E(CALC)/E(TRUE)	0.924	0.950	0.966	0.953	0.914
ATTN(DB)	-0.684	-0.444	-0.301	-0.417	-0.781

E(CALC)/E(TRUE)(ALL GAINS)	0.943 + 0.062	ATTN -0.525 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.951 + 0.035	ATTN -0.461 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.914 + 0.120	ATTN -0.781 DB

FREQUENCY = 8000 HZ

INPUT VOLTS(CALC)			0.939	0.463	0.175
DEV(VOLTS)			-0.061	-0.037	-0.025
E(CALC)/E(TRUE)			0.939	0.926	0.873
ATTN(DB)			-0.550	-0.671	-1.178

E(CALC)/E(TRUE)(ALL GAINS)	0.911 + 0.111	ATTN -0.800 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.932 + 0.042	ATTN -0.611 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.873 + 0.189	ATTN -1.178 DB

Figure 8. Calculated Data Format

SECTION V

RESULTS

5.1 GRAPHS

The results of this accuracy study cannot be simply stated as a certain percentage plus or minus an error band because it can be easily seen that the results are highly frequency dependent and to some extent gain dependent. The results are thus presented as explained above in tabular form and as graphs in Section VII.

The first graph, Figure 9, shows the accuracy dependency on frequency and gain. The data points are tabulated in Table I.

The second graph, Figure 10, shows the overall accuracy and error band when all gains are taken together.

The third graph, Figure 11, shows the accuracy for all gains together up to but not including gain 50. It can be easily observed how the accuracy and uncertainty (error band) improve when this gain is eliminated.

The fourth graph, Figure 12, shows the attenuation in decibels of all the gains minus gain 50.

5.2 STATEMENTS OF ACCURACY

A statement could be made on the overall system accuracy if certain frequency and gain restrictions are imposed.

If the frequencies of interest are limited to those between 50 Hz and 3000 Hz, then the overall Pyro system bias is -2.6% ±4.6%, taking into account all gains.

If the frequencies of interest are limited to those between 50 Hz and 6000 Hz then the bias (not including gain 50) is -5.6% ±6.7%.

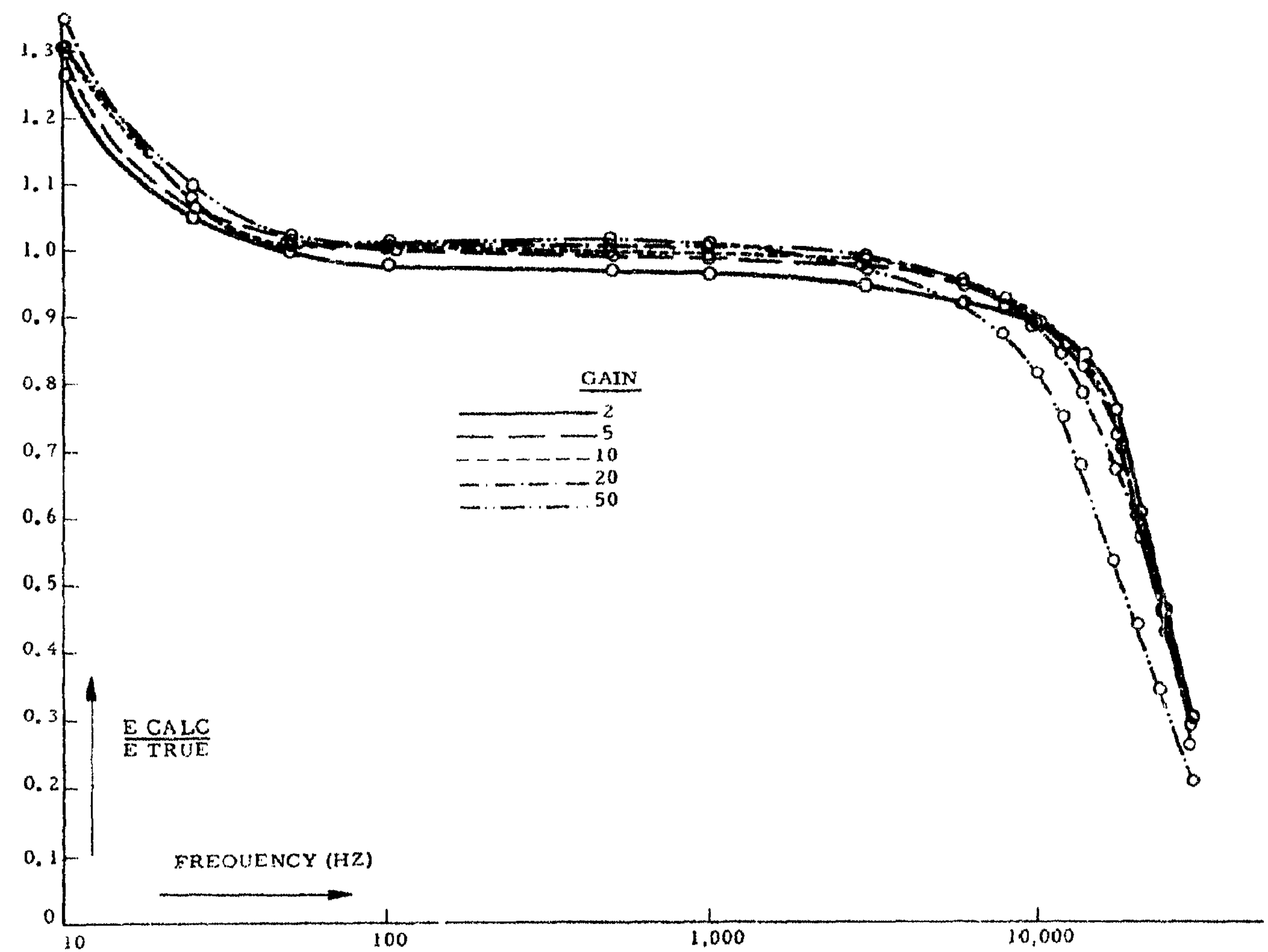


Figure 9. Response Curves (for each Gain)

TABLE I. PYRO ACCURACY RESULTS, DATA POINTS

DATA POINTS $\left(\frac{E\ CALC}{E\ TRUE}\right)$

Input Voltage	5.000	[illegible].000	1.000	0.500	0.200
Gain	2	5	10	20	50
Freq (Hz)					
10	1.264	1.300	1.307	1.353	1.319
25	1.050	1.064	1.079	1.074	1.095
50	0.999	1.02[illegible]	1.014	1.018	1.030
100	0.979	1.003	1.006	1.007	1.011
500	0.976	0.997	1.006	1.011	1.020
1000	0.965	0.995	0.995	1.005	1.007
3000	0.946	0.974	0.985	0.989	0.977
6000	0.924	0.950	0.966	0.953	0.923
8000	-	-	0.939	0.926	0.882
10000	0.893	0.893	0.902	0.887	0.815
12000	-	-	0.858	0.850	0.755
14000	0.845	0.831	0.833	0.797	0.687
18000	0.763	0.724	0.708	0.673	0.546
21000	0.610	0.610	0.606	0.571	0.448
25000	0.472	0.469	0.467	0.429	0.355
30000	0.308	0.305	0.293	0.262	0.208

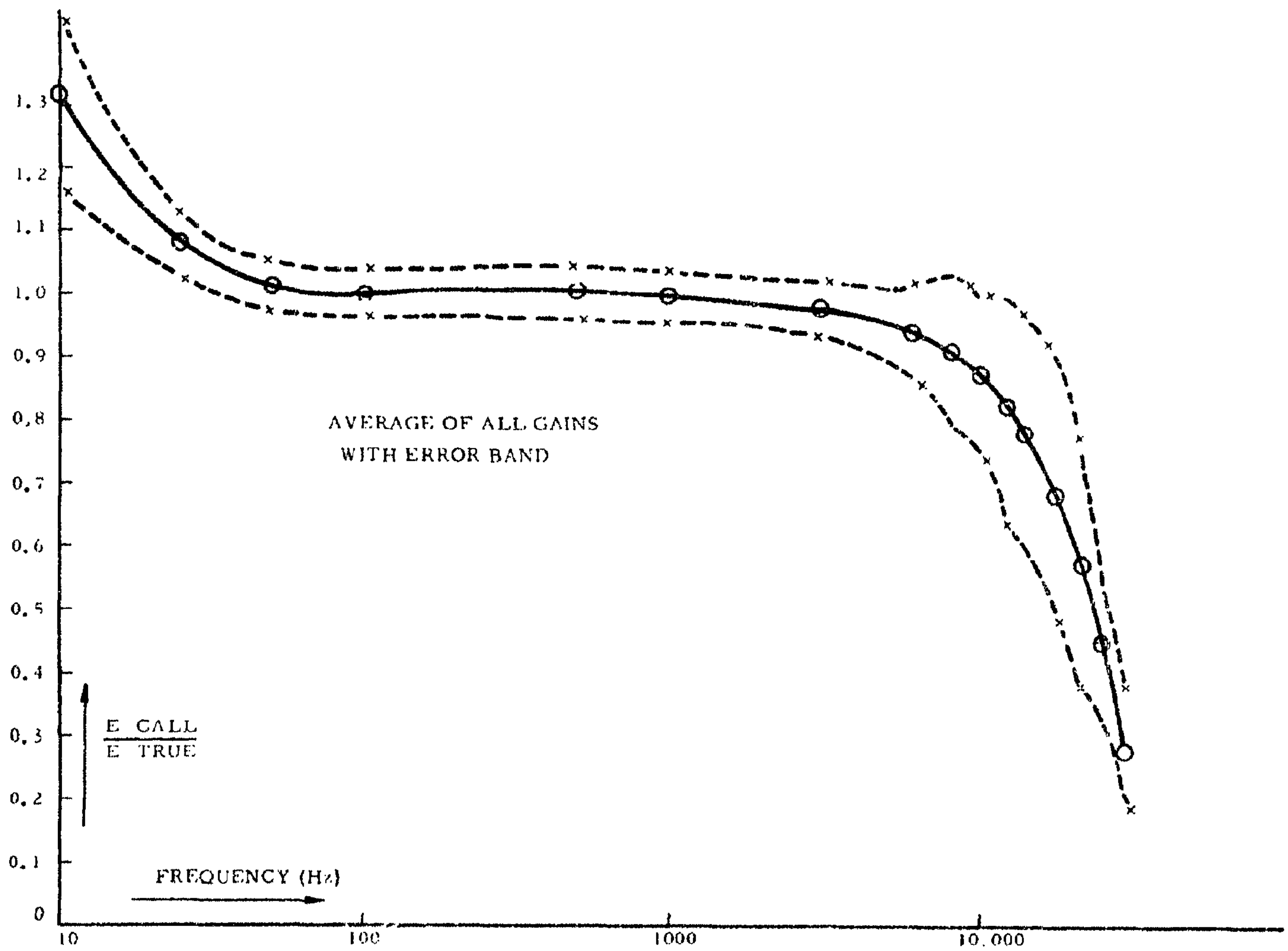


Figure 10. Response Curve (Average)

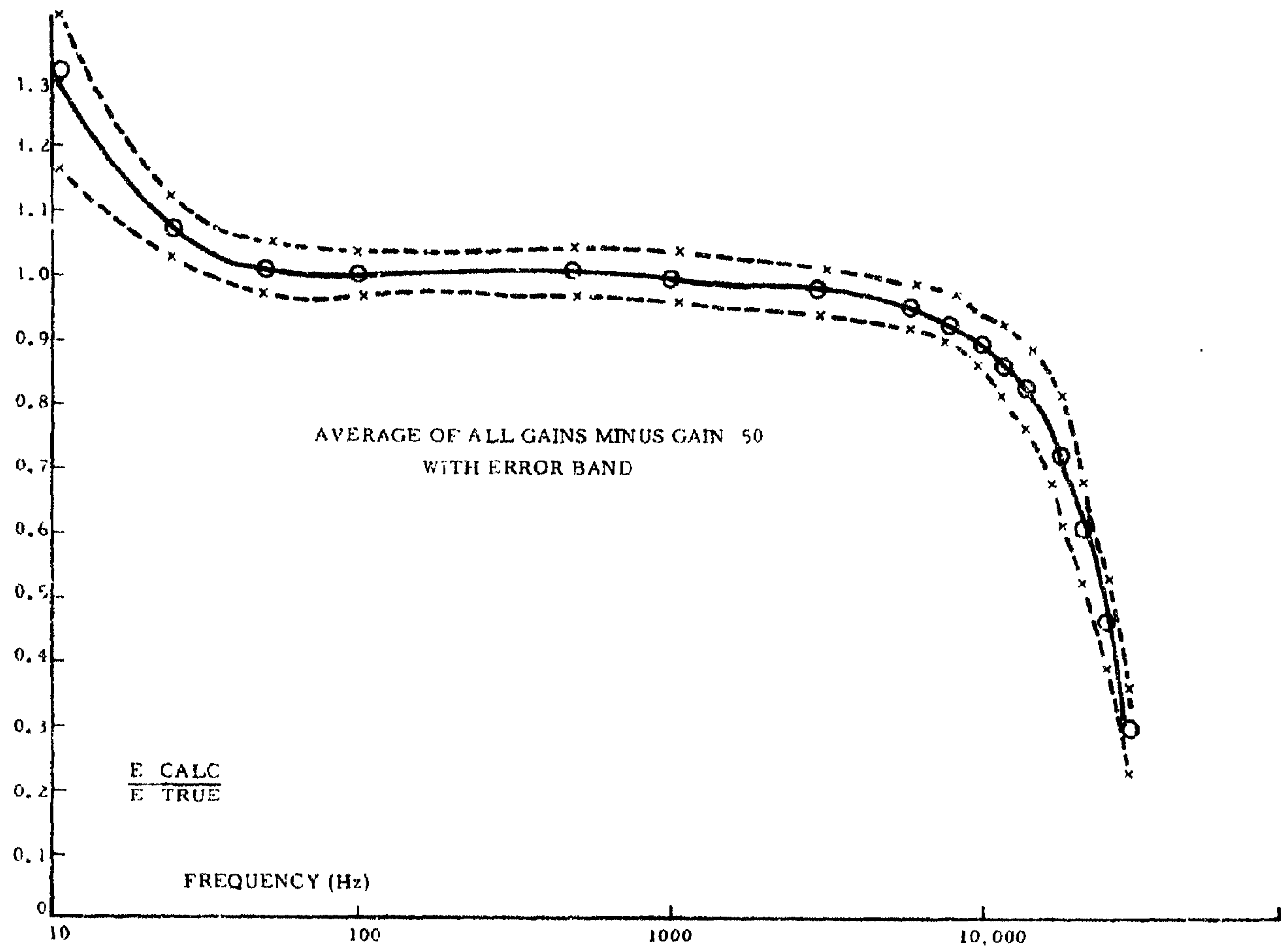


Figure 11. Response Curve (Average Minus Gain 50)

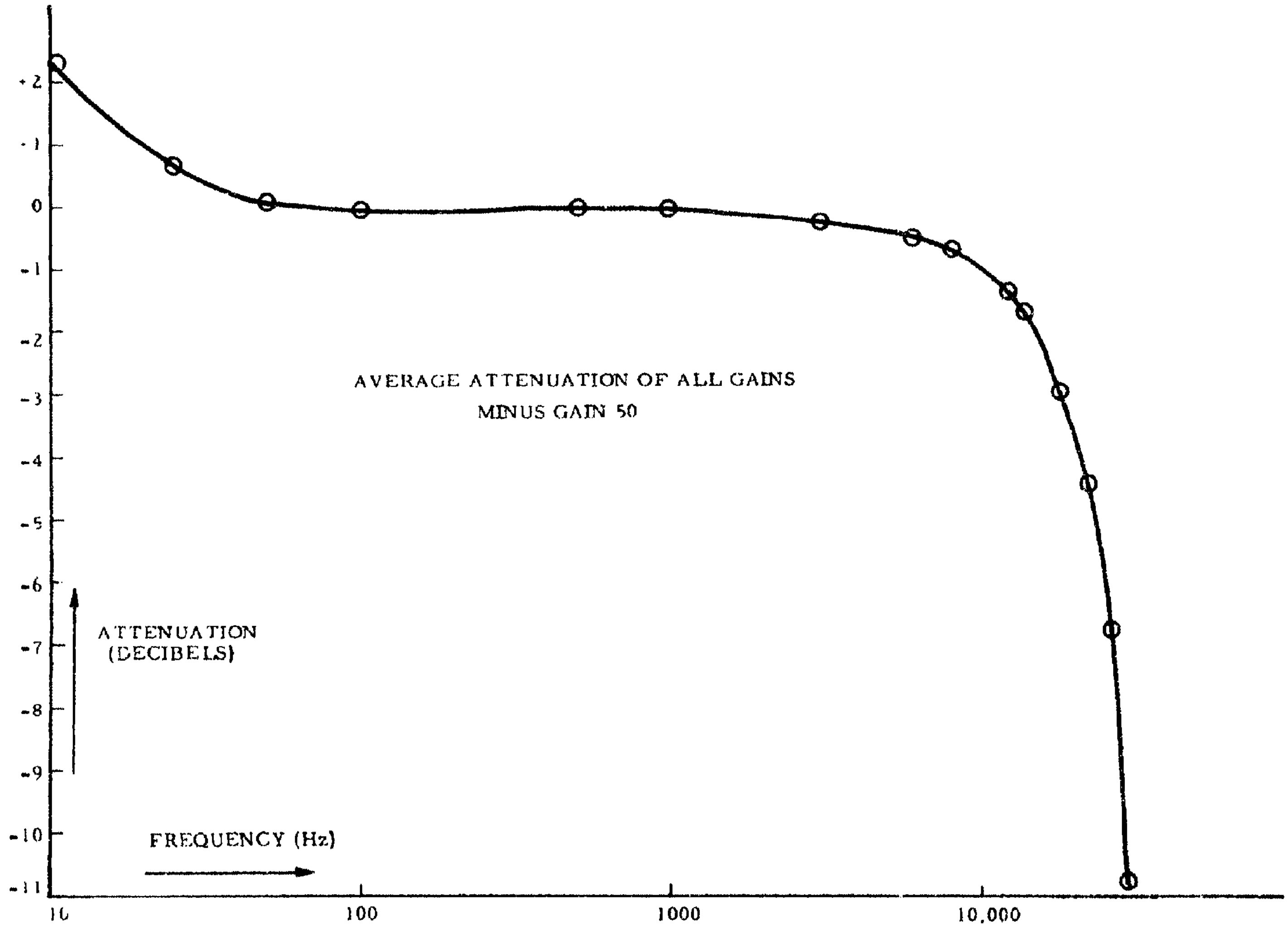


Figure 12. Attenuation Curve (Average Minus Gain 50)

Eliminating gain 50, we find at the following frequencies:

FREQUENCY	BIAS	UNCERTAINTY	ATTENUATION
10000 Hz	10.7%	±4.2%	-0.97 db
14000 Hz	17.4%	±7.6%	-1.65 db
21000 Hz	40.1%	±8.1%	-4.45 db

5.3 CONFIDENCE LEVEL

All accuracy figures in this report are for the 95% confidence level.

SECTION VI

CONCLUSIONS

6.1 ACCURACY

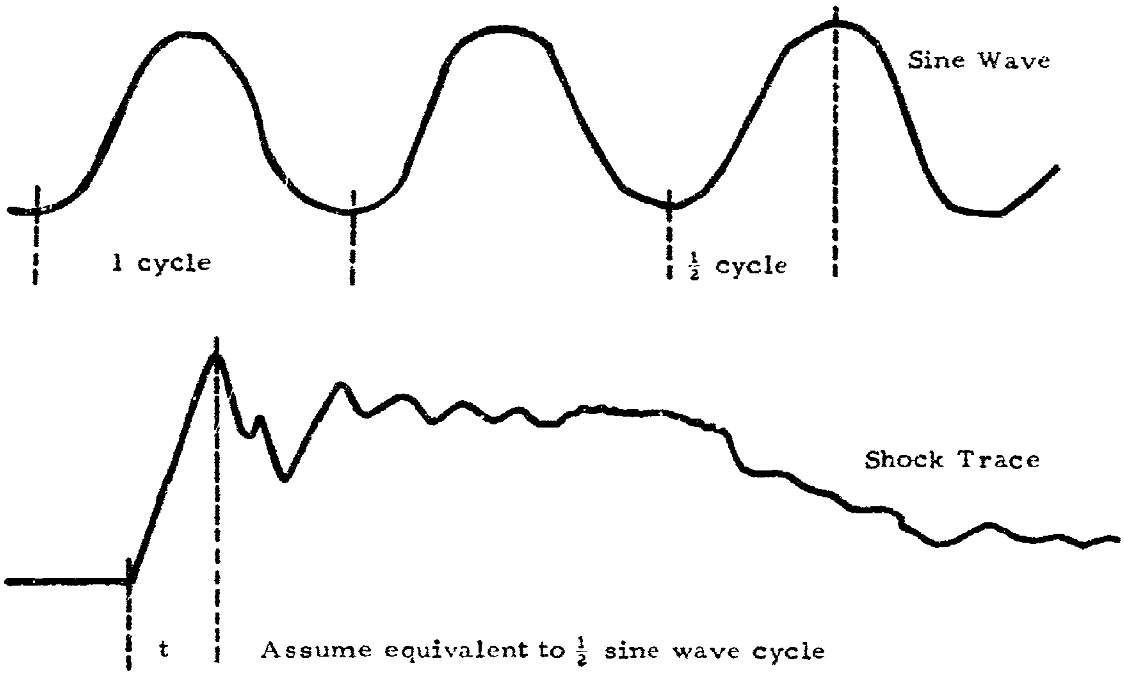
It can be stated that the Pyro pressure system for dynamic pressures between 50 Hz and 9000 Hz can be considered 90% accurate when gains from 2 to 20 are considered. For higher frequencies, the accuracy deteriorates rapidly.

6.2 SHOCK FRONT

The intensity of the initial shock front is of considerable interest and importance because of the destruction it can cause to structures. Determining the amplitude of this initial pressure rise accurately is of prime importance to Project Pyro. For any given test the equivalent frequency of the pressure spike can be approximated by considering the rise time of the shock wave to be approximately equivalent to one-half of a sine wave cycle (see Figure 13). Once the equivalent frequency has been determined, the error of the measured amplitude can be determined from the calculated and collected data (Section VII) and since this error is a bias, the measured value can be corrected to the true value.

6.3 TRANSDUCER ACCURACY

Since there is no suitable dynamic pressure calibrator currently available, the accuracy of the Pyro pressure system could not be determined in a true end-to-end fashion. The pressure transducers had to be taken out of the system. However, these transducers (see para 2.2.1) are statically calibrated to ±3% and in general have a natural resonant frequency in excess of 100000 Hz. (This has been verified by the AFRPL Shock Tube Facility). They would then conservatively have a usable frequency range in excess of 20000 Hz.



if t = 20 sec, then the time per cycle = 2t = 40 sec

let f = frequency in Hz

then $\frac{1}{f} = \frac{40 \text{ sec}}{\text{cycle}} = \frac{40\,(10^{-6}) \text{ sec}}{\text{cycle}}$

$f = \frac{10^{6} \text{ cycles}}{40 \text{ sec}} = 25{,}000 \text{ cycles/sec} = 25{,}000 \text{ Hz}$

Figure 13. Sine Wave Approximation of Shock Front

SECTION VII

DATA

7.1 CALCULATED DATA (RESULTS)

TEST AREA 1-90 ACCURACY STUDY (PYRO)

GAIN SET	2	5	10	20	50
INPUT VOLTS(TRUE)	5.000	2.000	1.000	0.500	0.200

FREQUENCY = 10 HZ

INPUT VOLTS(CALC)	6.319	2.602	1.307	0.677	0.262
DEV(VOLTS)	+1.319	+0.602	+0.307	+0.177	+0.062
E(CALC)/E(TRUE)	1.264	1.301	1.307	1.353	1.309
ATTN(DB)	+2.034	+2.287	+2.327	+2.628	+2.340

E(CALC)/E(TRUE)(ALL GAINS) 1.308 + 0.156 ATTN +2.323 DB

FREQUENCY = 25 HZ

INPUT VOLTS(CALC)	5.252	2.130	1.079	0.537	0.217
DEV(VOLTS)	+0.252	+0.130	+0.079	+0.037	+0.017
E(CALC)/E(TRUE)	1.050	1.065	1.079	1.074	1.085
ATTN(DB)	+0.427	+0.547	+0.657	+0.622	+0.710

E(CALC)/E(TRUE)(ALL GAINS) 1.070 + 0.037 ATTN +0.593 DB

FREQUENCY = 50 HZ

INPUT VOLTS(CALC)	4.995	2.040	1.014	0.509	0.204
DEV(VOLTS)	-0.005	+0.040	+0.014	+0.009	+0.004
E(CALC)/E(TRUE)	0.999	1.020	1.014	1.018	1.021
ATTN(DB)	-0.009	+0.173	+0.122	+0.153	+0.176

E(CALC)/E(TRUE)(ALL GAINS) 1.014 + 0.031 ATTN +0.123 DB

TEST AREA 1-90 ACCURACY STUDY (PYRO)

GAIN SET	2	5	10	20	50
INPUT VOLTS(TRUE)	5.000	2.000	1.000	0.500	0.200

FREQUENCY = 100 HZ

INPUT VOLTS(CALC)	4.897	2.008	1.006	0.504	0.200
DEV(VOLTS)	-0.103	+0.008	+0.006	+0.004	+0.000
E(CALC)/E(TRUE)	0.979	1.004	1.006	1.007	1.002
ATTN(DB)	-0.181	+0.033	+0.056	+0.063	+0.014

E(CALC)/E(TRUE)(ALL GAINS) 0.999 + 0.033 ATTN -0.003 DB

FREQUENCY = 500 HZ

INPUT VOLTS(CALC)	4.879	1.995	1.006	0.505	0.202
DEV(VOLTS)	-0.121	-0.005	+0.006	+0.005	+0.002
E(CALC)/E(TRUE)	0.976	0.997	1.006	1.011	1.011
ATTN(DB)	-0.213	-0.024	+0.048	+0.092	+0.099

E(CALC)/E(TRUE)(ALL GAINS) 1.000 + 0.035 ATTN +0.000 DB

FREQUENCY = 1000 HZ

INPUT VOLTS(CALC)	4.826	1.991	0.995	0.502	0.200
DEV(VOLTS)	-0.174	-0.009	-0.005	+0.002	-0.000
E(CALC)/E(TRUE)	0.965	0.996	0.995	1.005	0.998
ATTN(DB)	-0.308	-0.038	-0.041	+0.039	-0.019

E(CALC)/E(TRUE)(ALL GAINS) 0.992 + 0.037 ATTN -0.073 DB

TEST AREA 1-90 ACCURACY STUDY (PYRO)

GAIN SET	2	5	10	20	50
INPUT VOLTS(TRUE)	5.000	2.000	1.000	0.500	0.200

FREQUENCY = 3000 HZ

INPUT VOLTS(CALC)	4.731	1.950	0.985	0.494	0.194
DEV(VOLTS)	-0.269	-0.050	-0.015	-0.006	-0.006
E(CALC)/E(TRUE)	0.946	0.975	0.985	0.989	0.968
ATTN(DB)	-0.480	-0.222	-0.132	-0.099	-0.282

E(CALC)/E(TRUE)(ALL GAINS)	0.972 + 0.040	ATTN	-0.243 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.973 + 0.040	ATTN	-0.233 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.968 + 0.059	ATTN	-0.282 DB

FREQUENCY = 6000 HZ

INPUT VOLTS(CALC)	4.621	1.900	0.966	0.477	0.183
DEV(VOLTS)	-0.379	-0.100	-0.034	-0.023	-0.017
E(CALC)/E(TRUE)	0.924	0.950	0.966	0.953	0.914
ATTN(DB)	-0.684	-0.444	-0.301	-0.417	-0.781

E(CALC)/E(TRUE)(ALL GAINS)	0.943 + 0.062	ATTN	-0.525 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.951 + 0.035	ATTN	-0.461 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.914 + 0.120	ATTN	-0.781 DB

FREQUENCY = 8000 HZ

INPUT VOLTS(CALC)			0.939	0.463	0.175
DEV(VOLTS)			-0.061	-0.037	-0.025
E(CALC)/E(TRUE)			0.939	0.926	0.873
ATTN(DB)			-0.550	-0.671	-1.178

E(CALC)/E(TRUE)(ALL GAINS)	0.911 + 0.111	ATTN	-0.800 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.932 + 0.042	ATTN	-0.611 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.873 + 0.189	ATTN	-1.178 DB

TEST AREA 1-90 ACCURACY STUDY (PYRO)

GAIN SET	2	5	10	20	50
INPUT VOLTS(TRUE)	5.000	2.000	1.000	0.500	0.200

FREQUENCY = 10000 HZ

INPUT VOLTS(CALC)	4.464	1.788	0.902	0.443	0.161
DEV(VOLTS)	-0.536	-0.212	-0.098	-0.057	-0.039
E(CALC)/E(TRUE)	0.893	0.894	0.902	0.887	0.807
ATTN(DB)	-0.985	-0.974	-0.896	-1.046	-1.861

E(CALC)/E(TRUE)(ALL GAINS)	0.876 + 0.116	ATTN -1.152 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.893 + 0.042	ATTN -0.975 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.807 + 0.247	ATTN -1.861 DB

FREQUENCY = 12000 HZ

INPUT VOLTS(CALC)			0.858	0.425	0.149
DEV(VOLTS)			-0.142	-0.075	-0.051
E(CALC)/E(TRUE)			0.858	0.850	0.747
ATTN(DB)			-1.330	-1.412	-2.529

E(CALC)/E(TRUE)(ALL GAINS)	0.816 + 0.180	ATTN -1.757 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.854 + 0.068	ATTN -1.371 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.747 + 0.285	ATTN -2.529 DB

FREQUENCY = 14000 HZ

INPUT VOLTS(CALC)	4.225	1.664	0.833	0.399	0.136
DEV(VOLTS)	-0.775	-0.336	-0.167	-0.101	-0.064
E(CALC)/E(TRUE)	0.845	0.832	0.833	0.797	0.679
ATTN(DB)	-1.463	-1.598	-1.584	-1.967	-3.360

E(CALC)/E(TRUE)(ALL GAINS)	0.796 + 0.180	ATTN -1.995 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.827 + 0.076	ATTN -1.653 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.679 + 0.331	ATTN -3.360 DB

TEST AREA 1-90 ACCURACY STUDY (PYRO)

GAIN SET	2	5	10	20	50
INPUT VOLTS(TRUE)	5.000	2.000	1.000	0.500	0.200

FREQUENCY = 18000 HZ

INPUT VOLTS(CALC)	3.814	1.450	0.708	0.336	0.108
DEV(VOLTS)	-1.186	-0.550	-0.292	-0.164	-0.092
E(CALC)/E(TRUE)	0.763	0.725	0.708	0.673	0.539
ATTN(DB)	-2.351	-2.794	-2.997	-3.440	-5.363

E(CALC)/E(TRUE)(ALL GAINS)	0.681 + 0.215	ATTN -3.389 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.718 + 0.112	ATTN -2.896 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.539 + 0.348	ATTN -5.363 DB

FREQUENCY = 21000 HZ

INPUT VOLTS(CALC)	3.051	1.221	0.606	0.285	0.088
DEV(VOLTS)	-1.949	-0.779	-0.394	-0.215	-0.112
E(CALC)/E(TRUE)	0.610	0.610	0.606	0.571	0.442
ATTN(DB)	-4.292	-4.288	-4.350	-4.867	-7.090

E(CALC)/E(TRUE)(ALL GAINS)	0.567 + 0.185	ATTN -4.977 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.599 + 0.081	ATTN -4.449 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.442 + 0.319	ATTN -7.090 DB

FREQUENCY = 25000 HZ

INPUT VOLTS(CALC)	2.362	0.938	0.467	0.214	0.069
DEV(VOLTS)	-2.638	-1.062	-0.533	-0.286	-0.131
E(CALC)/E(TRUE)	0.472	0.469	0.467	0.429	0.347
ATTN(DB)	-6.513	-6.575	-6.613	-7.355	-9.189

E(CALC)/E(TRUE)(ALL GAINS)	0.446 + 0.117	ATTN -7.249 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.459 + 0.068	ATTN -6.764 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.347 + 0.280	ATTN -9.189 DB

TEST AREA 1-90 ACCURACY STUDY (PYRO)

GAIN SET	2	5	10	20	50
INPUT VOLTS(TRUE)	5.000	2.000	1.000	0.500	0.200

FREQUENCY = 30000 HZ

INPUT VOLTS(CALC)	1.540	0.611	0.293	0.131	0.041
DEV(VOLTS)	-3.460	-1.389	-0.707	-0.369	-0.159
E(CALC)/E(TRUE)	0.308	0.305	0.293	0.262	0.203
ATTN(DB)	-10.229	-10.301	-10.676	-11.649	-13.829

E(CALC)/E(TRUE)(ALL GAINS)	0.282 + 0.090	ATTN -11.337 DB
E(CALC)/E(TRUE)(MINUS GAIN 50)	0.292 + 0.058	ATTN -10.714 DB
E(CALC)/E(TRUE)(GAIN 50 ONLY)	0.203 + 0.178	ATTN -13.829 DB

7.2 COLLECTED DATA

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	OCTOBER 18, 1967	2.000	5.000

CHANNEL	2	3	4	5	6	7
ITEM NUMBER	125	225	126	226	127	227
AMP S/N	1048	1596	1041	1050	1595	1386
VCO S/N	1Z2026	9E0277	9Z1663	9E0346	9E0294	9E0292
GAIN(MV/PCB)	1.890	2.000	2.000	1.990	1.980	1.990
GAIN DATE	01317	05207	01127	01107	01137	02017
CAL VOLTS	1.009	1.006	1.004	1.003	1.004	0.993
LCAL(IN.)	1.870	1.858	1.835	1.864	1.877	1.839
CAP(PF)	128.250	127.950	127.600	127.600	127.150	126.700

FREQUENCY = 10 HZ OSC CUT NO. 7615, 7631

CALC VOLTS	6.341	6.336	6.287	6.368	6.304	6.278
DEV(VOLTS)	+1.341	+1.336	+1.287	+1.368	+1.304	+1.278
ATTN(DB)	+2.064	+2.057	+1.990	+2.100	+2.013	+1.978
DELTA L(IN.)	2.848	2.994	2.933	3.005	2.967	2.931

FREQUENCY = 25 HZ OSC CUT NO. 7616, 7632

CALC VOLTS	5.194	5.319	5.282	5.235	5.245	5.238
DEV(VOLTS)	+0.194	+0.319	+0.282	+0.235	+0.245	+0.238
ATTN(DB)	+0.330	+0.537	+0.477	+0.399	+0.415	+0.405
DELTA L(IN.)	2.333	2.514	2.464	2.470	2.468	2.446

FREQUENCY = 50 HZ OSC CUT NO. 7617, 7633

CALC VOLTS	4.962	5.033	4.977	5.017	4.996	4.984
DEV(VOLTS)	-0.038	+0.033	-0.023	+0.017	-0.004	-0.016
ATTN(DB)	-0.066	+0.057	-0.041	+0.030	-0.007	-0.027
DELTA L(IN.)	2.229	2.379	2.322	2.368	2.352	2.327

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	OCTOBER 18, 1967	2.000	5.000

CHANNEL	2	3	4	5	6	7
FREQUENCY = 100 HZ		OSC CUT NO. 7618, 7634				
CALC VOLTS	4.915	4.952	4.859	4.908	4.887	4.862
DEV(VOLTS)	-0.085	-0.048	-0.141	-0.092	-0.113	-0.138
ATTN(DB)	-0.148	-0.084	-0.249	-0.162	-0.199	-0.244
DELTA L(IN.)	2.208	2.340	2.267	2.316	2.300	2.270
FREQUENCY = 500 HZ		OSC CUT NO. 7619, 7635				
CALC VOLTS	4.856	4.935	4.829	4.919	4.894	4.840
DEV(VOLTS)	-0.144	-0.065	-0.171	-0.081	-0.106	-0.160
ATTN(DB)	-0.253	-0.113	-0.302	-0.141	-0.187	-0.282
DELTA L(IN.)	2.181	2.332	2.253	2.321	2.303	2.260
FREQUENCY = 1000 HZ		OSC CUT NO. 7620, 7636				
CALC VOLTS	4.827	4.867	4.758	4.826	4.880	4.796
DEV(VOLTS)	-0.173	-0.133	-0.242	-0.174	-0.120	-0.204
ATTN(DB)	-0.306	-0.233	-0.430	-0.307	-0.211	-0.362
DELTA L(IN.)	2.168	2.300	2.220	2.278	2.297	2.239
FREQUENCY = 3000 HZ		OSC CUT NO. 7621, 7637				
CALC VOLTS	4.752	4.809	4.743	4.733	4.703	4.648
DEV(VOLTS)	-0.248	-0.191	-0.257	-0.267	-0.297	-0.352
ATTN(DB)	-0.441	-0.339	-0.459	-0.476	-0.532	-0.634
DELTA L(IN.)	2.134	2.272	2.213	2.234	2.214	2.170

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	OCTOBER 18, 1967	2.000	5.000

CHANNEL	2	3	4	5	6	7
FREQUENCY = 6000 HZ			OSC CUT NO. 7647			
CALC VOLTS				4.650	4.629	4.584
DEV(VOLTS)				-0.350	-0.371	-0.416
ATTN(DB)				-0.629	-0.669	-0.754
DELTA L(IN.)				2.195	2.179	2.140
FREQUENCY = 10000 HZ			OSC CUT NO. 7622, 7648			
CALC VOLTS	4.594	4.587	4.513	4.435	4.309	4.346
DEV(VOLTS)	-0.406	-0.413	-0.487	-0.565	-0.691	-0.654
ATTN(DB)	-0.736	-0.748	-0.891	-1.042	-1.292	-1.217
DELTA L(IN.)	2.063	2.168	2.105	2.093	2.028	2.029
FREQUENCY = 14000 HZ			OSC CUT NO. 7623, 7649			
CALC VOLTS	4.428	4.354	4.333	4.203	3.982	4.052
DEV(VOLTS)	-0.572	-0.646	-0.667	-0.797	-1.018	-0.948
ATTN(DB)	-1.056	-1.202	-1.243	-1.509	-1.978	-1.826
DELTA L(IN.)	1.989	2.058	2.022	1.983	1.874	1.892
FREQUENCY = 18000 HZ			OSC CUT NO. 7624, 7650			
CALC VOLTS	4.130	3.978	4.033	3.668	3.446	3.630
DEV(VOLTS)	-0.870	-1.022	-0.967	-1.332	-1.554	-1.370
ATTN(DB)	-1.661	-1.986	-1.867	-2.690	-3.234	-2.781
DELTA L(IN.)	1.855	1.880	1.882	1.731	1.622	1.695

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	OCTOBER 18, 1967	2.000	5.000

CHANNEL	2	3	4	5	6	7

FREQUENCY = 21000 HZ   OSC CUT NO. 7626, 7651

CALC VOLTS	3.183	3.043	2.993	3.160	2.915	3.008
DEV(VOLTS)	-1.817	-1.957	-2.007	-1.840	-2.085	-1.992
ATTN(DB)	-3.921	-4.312	-4.456	-3.986	-4.686	-4.414
DELTA L(IN.)	1.430	1.438	1.397	1.491	1.372	1.404

FREQUENCY = 25000 HZ   OSC CUT NO. 7627, 7655

CALC VOLTS	2.437	2.366	2.278	2.452	2.348	2.292
DEV(VOLTS)	-2.563	-2.634	-2.722	-2.548	-2.652	-2.708
ATTN(DB)	-6.241	-6.501	-6.830	-6.190	-6.564	-6.775
DELTA L(IN.)	1.095	1.118	1.063	1.157	1.105	1.070

FREQUENCY = 30000 HZ   OSC CUT NO. 7628, 7656

CALC VOLTS	1.558	1.601	1.460	1.585	1.555	1.480
DEV(VOLTS)	-3.442	-3.399	-3.540	-3.415	-3.445	-3.520
ATTN(DB)	-10.128	-9.892	-10.690	-9.979	-10.144	-10.574
DELTA L(IN.)	0.700	0.757	0.681	0.748	0.732	0.691

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	OCTOBER 18, 1967	5.000	2.000

CHANNEL	2	3	4	5	6	7
ITEM NUMBER	125	225	126	226	127	227
AMP S/N	1048	1596	1041	1050	1595	1386
VCO S/N	1Z2026	9E0227	9Z1663	9E0346	9E0294	9E0292
GAIN(MV/PCB)	4.700	5.000	4.960	5.010	4.930	5.000
GAIN DATE	01317	05207	01127	01107	01137	02017
CAL VOLTS	1.035	1.036	1.015	1.026	1.022	0.964
LCAL(IN.)	1.890	1.877	1.821	1.887	1.856	1.711
CAP(PF)	128.250	127.950	127.600	127.600	127.150	126.700

FREQUENCY = 10 HZ OSC CUT NO. 7677

CALC VOLTS				2.563	2.606	2.637
DEV(VOLTS)				+0.563	+0.606	+0.637
ATTN(DB)				+2.155	+2.300	+2.403
DELTA L(IN.)				3.013	2.967	2.966

FREQUENCY = 25 HZ OSC CUT NO. 7660, 7678

CALC VOLTS	2.109	2.136	2.115	2.104	2.155	2.160
DEV(VOLTS)	+0.109	+0.136	+0.115	+0.104	+0.155	+0.160
ATTN(DB)	+0.463	+0.573	+0.487	+0.440	+0.650	+0.668
DELTA L(IN.)	2.322	2.476	2.401	2.473	2.454	2.429

FREQUENCY = 50 HZ OSC CUT NO. 7661

CALC VOLTS	2.022	2.065	2.033
DEV(VOLTS)	+0.022	+0.065	+0.033
ATTN(DB)	+0.097	+0.278	+0.143
DELTA L(IN.)	2.226	2.393	2.308

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	OCTOBER 18, 1967	5.000	2.000

CHANNEL	2	3	4	5	6	7
FREQUENCY = 100 HZ		OSC CUT NO. 7664, 7679				
CALC VOLTS	1.988	2.022	2.001	1.984	2.026	2.024
DEV(VOLTS)	-0.012	+0.022	+0.001	-0.016	+0.026	+0.024
ATTN(DB)	-0.054	+0.094	+0.004	-0.070	+0.114	+0.106
DELTA L(IN.)	2.188	2.343	2.271	2.333	2.307	2.277
FREQUENCY = 500 HZ		OSC CUT NO. 7665, 7680				
CALC VOLTS	1.969	2.017	1.994	1.964	2.010	2.013
DEV(VOLTS)	-0.031	+0.017	-0.006	-0.036	+0.010	+0.013
ATTN(DB)	-0.137	+0.075	-0.028	-0.156	+0.044	+0.057
DELTA L(IN.)	2.167	2.338	2.263	2.309	2.288	2.264
FREQUENCY = 1000 HZ		OSC CUT NO. 7666, 7681				
CALC VOLTS	1.976	2.007	1.990	1.958	1.997	2.019
DEV(VOLTS)	-0.024	+0.007	-0.010	-0.042	-0.003	+0.019
ATTN(DB)	-0.105	+0.030	-0.042	-0.185	-0.011	+0.084
DELTA L(IN.)	2.175	2.326	2.259	2.302	2.274	2.271
FREQUENCY = 3000 HZ		OSC CUT NO. 7667, 7682				
CALC VOLTS	1.935	1.962	1.931	1.927	1.969	1.974
DEV(VOLTS)	-0.065	-0.038	-0.069	-0.073	-0.031	-0.026
ATTN(DB)	-0.289	-0.167	-0.304	-0.322	-0.134	-0.115
DELTA L(IN.)	2.130	2.274	2.192	2.266	2.242	2.219

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	OCTOBER 18, 1967	5.000	2.000

CHANNEL	2	3	4	5	6	7
FREQUENCY = 6000 HZ			OSC CUT NO. 7668, 7683			
CALC VOLTS	1.920	1.930	1.909	1.860	1.876	1.907
DEV(VOLTS)	-0.080	-0.070	-0.091	-0.140	-0.124	-0.093
ATTN(DB)	-0.353	-0.309	-0.402	-0.632	-0.556	-0.414
DELTA L(IN.)	2.114	2.237	2.168	2.186	2.136	2.144
FREQUENCY = 10000 HZ			OSC CUT NO. 7669, 7684			
CALC VOLTS	1.792	1.765	1.771	1.791	1.782	1.827
DEV(VOLTS)	-0.208	-0.235	-0.229	-0.209	-0.218	-0.173
ATTN(DB)	-0.955	-1.087	-1.058	-0.960	-1.003	-0.787
DELTA L(IN.)	1.972	2.045	2.010	2.105	2.029	2.054
FREQUENCY = 14000 HZ			OSC CUT NO. 7670, 7685			
CALC VOLTS	1.702	1.651	1.663	1.672	1.635	1.661
DEV(VOLTS)	-0.298	-0.349	-0.337	-0.328	-0.365	-0.339
ATTN(DB)	-1.403	-1.665	-1.601	-1.557	-1.751	-1.615
DELTA L(IN.)	1.873	1.914	1.888	1.966	1.861	1.868
FREQUENCY = 18000 HZ			OSC CUT NO. 7671, 7686			
CALC VOLTS	1.482	1.414	1.459	1.464	1.403	1.476
DEV(VOLTS)	-0.518	-0.586	-0.541	-0.536	-0.597	-0.524
ATTN(DB)	-2.604	-3.009	-2.742	-2.707	-3.078	-2.638
DELTA L(IN.)	1.631	1.639	1.656	1.722	1.597	1.660

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	OCTOBER 18, 1967	5.000	2.000

CHANNEL	2	3	4	5	6	7
FREQUENCY = 21000 HZ			OSC CUT NO. 7672, 7687			
CALC VOLTS	1.267	1.211	1.209	1.260	1.189	1.188
DEV(VOLTS)	-0.733	-0.789	-0.791	-0.740	-0.811	-0.812
ATTN(DB)	-3.962	-4.355	-4.370	-4.015	-4.518	-4.527
DELTA L(IN.)	1.395	1.404	1.373	1.481	1.353	1.335
FREQUENCY = 25000 HZ			OSC CUT NO. 7673, 7688			
CALC VOLTS	0.966	0.953	0.919	0.963	0.936	0.891
DEV(VOLTS)	-1.034	-1.047	-1.081	-1.037	-1.064	-1.109
ATTN(DB)	-6.320	-6.436	-6.753	-6.347	-6.591	-7.027
DELTA L(IN.)	1.064	1.105	1.043	1.132	1.066	1.002
FREQUENCY = 30000 HZ			OSC CUT NO. 7674, 7689			
CALC VOLTS	0.618	0.619	0.613	0.621	0.621	0.574
DEV(VOLTS)	-1.382	-1.381	-1.387	-1.379	-1.379	-1.426
ATTN(DB)	-10.194	-10.186	-10.274	-10.165	-10.164	-10.846
DELTA L(IN.)	0.681	0.717	0.696	0.730	0.707	0.645

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	10.000	1.000

CHANNEL	2	3	4	5	6	7
ITEM NUMBER	125	225	126	226	127	227
AMP S/N	1048	1596	1041	1391	1595	1386
VCO S/N	1Z2026	9E0277	9Z1663	9E0346	9E0294	9E0292
GAIN(MV/PCB)	9.300	9.990	9.920	9.990	10.100	9.970
GAIN DATE	01317	07207	01127	04267	01137	07207
CAL VOLTS	0.991	1.024	0.975	1.007	1.022	1.018
LCAL(IN.)	1.725	1.809	1.775	1.763	1.816	1.659
CAP(PF)	128.250	127.950	127.600	127.600	127.150	126.700

FREQUENCY = 10 HZ OSC CUT NO. 8316, 8333

CALC VOLTS	1.141	1.364	1.208	1.321	1.339	1.371
DEV(VOLTS)	+0.141	+0.364	+0.208	+0.321	+0.339	+0.371
ATTN(DB)	+1.146	+2.698	+1.640	+2.417	+2.538	+2.741
DELTA L(IN.)	2.369	3.081	2.784	2.947	3.057	2.822

FREQUENCY = 25 HZ OSC CUT NO. 8317, 8334

CALC VOLTS	1.071	1.096	0.958	1.068	1.072	1.087
DEV(VOLTS)	+0.071	+0.096	-0.042	+0.068	+0.072	+0.087
ATTN(DB)	+0.596	+0.794	-0.377	+0.568	+0.601	+0.722
DELTA L(IN.)	2.223	2.474	2.207	2.382	2.445	2.237

FREQUENCY = 50 HZ OSC CUT NO. 8318, 8335

CALC VOLTS	1.015	1.029	0.904	1.003	1.007	1.017
DEV(VOLTS)	+0.015	+0.029	-0.096	+0.003	+0.007	+0.017
ATTN(DB)	+0.131	+0.245	-0.878	+0.023	+0.058	+0.149
DELTA L(IN.)	2.108	2.323	2.083	2.237	2.297	2.094

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	10.000	1.000

FREQUENCY = 100 HZ OSC CUT NO. 8319, 8336

CHANNEL	2	3	4	5	6	7
CALC VOLTS	1.004	1.021	0.900	0.998	0.998	1.011
DEV(VOLTS)	+0.004	+0.021	-0.100	-0.002	-0.002	+0.011
ATTN(DB)	+0.038	+0.183	-0.917	-0.014	-0.020	+0.092
DELTA L(IN.)	2.085	2.306	2.074	2.228	2.277	2.080

FREQUENCY = 500 HZ OSC CUT NO. 8320, 8337

CHANNEL	2	3	4	5	6	7
CALC VOLTS	1.004	1.013	0.887	1.000	1.001	1.010
DEV(VOLTS)	+0.004	+0.013	-0.113	+0.000	+0.001	+0.010
ATTN(DB)	+0.031	+0.114	-1.038	+0.004	+0.006	+0.084
DELTA L(IN.)	2.083	2.288	2.045	2.232	2.284	2.079

FREQUENCY = 1000 HZ OSC CUT NO. 8321, 8338

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.996	1.006	0.884	0.984	0.988	1.002
DEV(VOLTS)	-0.004	+0.006	-0.116	-0.016	-0.012	+0.002
ATTN(DB)	-0.034	+0.050	-1.068	-0.137	-0.102	+0.018
DELTA L(IN.)	2.068	2.271	2.038	2.196	2.255	2.063

FREQUENCY = 3000 HZ OSC CUT NO. 8322, 8339

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.983	0.995	0.874	0.982	0.975	0.989
DEV(VOLTS)	-0.017	-0.005	-0.126	-0.018	-0.025	-0.011
ATTN(DB)	-0.152	-0.042	-1.173	-0.157	-0.220	-0.092
DELTA L(IN.)	2.040	2.247	2.014	2.191	2.225	2.037

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	10.000	1.000

FREQUENCY = 6000 HZ OSC CUT NO. 8323, 8340

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.971	0.967	0.857	0.970	0.955	0.966
DEV(VOLTS)	-0.029	-0.033	-0.143	-0.030	-0.045	-0.034
ATTN(DB)	-0.257	-0.292	-1.345	-0.263	-0.396	-0.300
DELTA L(IN.)	2.016	2.183	1.974	2.165	2.180	1.989

FREQUENCY = 8000 HZ OSC CUT NO. 8324, 8341

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.948	0.927	0.827	0.949	0.922	0.946
DEV(VOLTS)	-0.052	-0.073	-0.173	-0.051	-0.078	-0.054
ATTN(DB)	-0.463	-0.657	-1.650	-0.453	-0.702	-0.480
DELTA L(IN.)	1.968	2.094	1.906	2.118	2.105	1.948

FREQUENCY = 10000 HZ OSC CUT NO. 8325, 8342

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.920	0.902	0.809	0.908	0.877	0.902
DEV(VOLTS)	-0.080	-0.098	-0.191	-0.092	-0.123	-0.098
ATTN(DB)	-0.721	-0.892	-1.837	-0.839	-1.138	-0.894
DELTA L(IN.)	1.911	2.038	1.866	2.026	2.002	1.857

FREQUENCY = 12000 HZ OSC CUT NO. 8326, 8343

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.882	0.841	0.764	0.876	0.828	0.863
DEV(VOLTS)	-0.118	-0.159	-0.236	-0.124	-0.172	-0.137
ATTN(DB)	-1.087	-1.507	-2.336	-1.151	-1.637	-1.281
DELTA L(IN.)	1.832	1.898	1.761	1.954	1.890	1.776

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	10.000	1.000

CHANNEL	2	3	4	5	6	7
FREQUENCY = 14000 HZ			OSC CUT NO. 8327, 8344			
CALC VOLTS	0.863	0.817	0.740	0.855	0.799	0.832
DEV(VOLTS)	-0.137	-0.183	-0.260	-0.145	-0.201	-0.168
ATTN(DB)	-1.284	-1.752	-2.613	-1.357	-1.952	-1.595
DELTA L(IN.)	1.791	1.846	1.706	1.909	1.823	1.713
FREQUENCY = 18000 HZ			OSC CUT NO. 8328, 8345			
CALC VOLTS	0.761	0.700	0.607	0.735	0.677	0.668
DEV(VOLTS)	-0.239	-0.300	-0.393	-0.265	-0.323	-0.332
ATTN(DB)	-2.370	-3.102	-4.337	-2.671	-3.392	-3.501
DELTA L(IN.)	1.580	1.580	1.399	1.641	1.544	1.376
FREQUENCY = 21000 HZ			OSC CUT NO. 8329, 8346			
CALC VOLTS	0.657	0.586	0.534	0.630	0.571	0.586
DEV(VOLTS)	-0.343	-0.414	-0.466	-0.370	-0.429	-0.414
ATTN(DB)	-3.648	-4.640	-5.457	-4.014	-4.871	-4.636
DELTA L(IN.)	1.364	1.324	1.230	1.406	1.303	1.207
FREQUENCY = 25000 HZ			OSC CUT NO. 8330, 8347			
CALC VOLTS	0.498	0.450	0.405	0.488	0.451	0.448
DEV(VOLTS)	-0.502	-0.550	-0.595	-0.512	-0.549	-0.552
ATTN(DB)	-6.048	-6.938	-7.860	-6.228	-6.924	-6.972
DELTA L(IN.)	1.035	1.016	0.933	1.089	1.028	0.922

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	10.000	1.000

FREQUENCY = 30000 HZ OSC CUT NO. 8331, 8348

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.317	0.291	0.256	0.305	0.279	0.270
DEV(VOLTS)	-0.683	-0.709	-0.744	-0.695	-0.721	-0.730
ATTN(DB)	-9.969	-10.708	-11.851	-10.317	-11.089	-11.373
DELTA L(IN.)	0.659	0.658	0.589	0.680	0.637	0.556

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	20.000	0.500

CHANNEL	2	3	4	5	6	7
ITEM NUMBER	125	225	126	226	127	227
AMP S/N	1048	1596	1041	1391	1595	1386
VCO S/N	1Z2026	9E0277	9Z1663	9E0346	9E0294	9E0292
GAIN(MV/PCB)	18.900	20.400	20.100	20.200	20.000	20.000
GAIN DATE	01317	0[illegible]207	01127	04267	01137	07207
CAL VOLTS	1.106	0.991	1.051	0.978	1.003	1.013
LCAL(IN.)	1.956	1.739	1.718	1.715	1.792	1.667
CAP(PF)	128.250	127.950	127.600	127.600	127.150	126.700

FREQUENCY = 10 HZ OSC CUT NO. 8350, 8371

CALC VOLTS	0.634	0.694	0.688	0.673	0.679	0.693
DEV(VOLTS)	+0.134	+0.194	+0.188	+0.173	+0.179	+0.193
ATTN(DB)	+2.063	+2.848	+2.767	+2.577	+2.655	+2.830
DELTA L(IN.)	2.717	3.179	2.883	3.040	3.084	2.887

FREQUENCY = 25 HZ OSC CUT NO. 8351, 8372

CALC VOLTS	0.537	0.546	0.536	0.535	0.530	0.539
DEV(VOLTS)	+0.037	+0.046	+0.036	+0.035	+0.030	+0.039
ATTN(DB)	+0.624	+0.762	+0.604	+0.591	+0.50[illegible]	+0.644
DELTA L(IN.)	2.303	2.501	2.247	2.418	2.408	2.245

FREQUENCY = 50 HZ OSC CUT NO. 8352, 8373

CALC VOLTS	0.514	0.521	0.505	0.505	0.501	0.507
DEV(VOLTS)	+0.014	+0.021	+0.005	+0.005	+0.001	+0.007
ATTN(DB)	+0.237	+0.351	+0.094	+0.092	+0.023	+0.117
DELTA L(IN.)	2.202	2.385	2.119	2.283	2.278	2.113

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	20.000	0.500

CHANNEL	2	3	4	5	6	7

FREQUENCY = 100 HZ OSC CUT NO. 8353, 8374

CALC VOLTS	0.507	0.512	0.495	0.503	0.501	0.504
DEV(VOLTS)	+0.007	+0.012	-0.005	+0.003	+0.001	+0.004
ATTN(DB)	+0.122	+0.205	-0.088	+0.056	+0.013	+0.067
DELTA L(IN.)	2.173	2.345	2.075	2.274	2.275	2.101

FREQUENCY = 500 HZ OSC CUT NO. 8354, 8375

CALC VOLTS	0.503	0.515	0.503	0.503	0.502	0.506
DEV(VOLTS)	+0.003	+0.015	+0.003	+0.003	+0.002	+0.006
ATTN(DB)	+0.053	+0.251	+0.053	+0.052	+0.041	+0.097
DELTA L(IN.)	2.156	2.358	2.109	2.273	2.282	2.108

FREQUENCY = 1000 HZ OSC CUT NO. 8355, 8376

CALC VOLTS	0.502	0.511	0.501	0.501	0.498	0.500
DEV(VOLTS)	+0.002	+0.011	+0.001	+0.001	-0.002	+0.000
ATTN(DB)	+0.040	+0.197	+0.018	+0.011	-0.037	+0.006
DELTA L(IN.)	2.153	2.343	2.101	2.262	2.262	2.086

FREQUENCY = 3000 HZ OSC CUT NO. 8356, 8377

CALC VOLTS	0.497	0.498	0.492	0.495	0.489	0.495
DEV(VOLTS)	-0.003	-0.002	-0.008	-0.005	-0.011	-0.005
ATTN(DB)	-0.054	-0.039	-0.144	-0.083	-0.190	-0.082
DELTA L(IN.)	2.130	2.280	2.062	2.238	2.222	2.065

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	20.000	0.500

CHANNEL	2	3	4	5	6	7

FREQUENCY = 6000 HZ OSC CUT NO. 8357, 8378

CALC VOLTS	0.483	0.476	0.476	0.483	0.466	0.475
DEV(VOLTS)	-0.017	-0.024	-0.024	-0.017	-0.034	-0.025
ATTN(DB)	-0.300	-0.425	-0.420	-0.296	-0.620	-0.445
DELTA L(IN.)	2.070	2.181	1.998	2.184	2.115	1.980

FREQUENCY = 8000 HZ OSC CUT NO. 3358, 8379

CALC VOLTS	0.476	0.458	0.467	0.473	0.446	0.458
DEV(VOLTS)	-0.024	-0.042	-0.033	-0.027	-0.054	-0.042
ATTN(DB)	-0.426	-0.766	-0.597	-0.489	-0.993	-0.769
DELTA L(IN.)	2.040	2.097	1.957	2.136	2.026	1.908

FREQUENCY = 10000 HZ OSC CUT NO. 8359, 8380

CALC VOLTS	0.458	0.435	0.447	0.457	0.422	0.441
DEV(VOLTS)	-0.042	-0.065	-0.053	-0.043	-0.078	-0.059
ATTN(DB)	-0.767	-1.207	-0.977	-0.787	-1.472	-1.086
DELTA L(IN.)	1.962	1.993	1.873	2.064	1.918	1.840

FREQUENCY = 12000 HZ OSC CUT NO. 8360, 8381

CALC VOLTS	0.445	0.412	0.435	0.443	0.398	0.418
DEV(VOLTS)	-0.055	-0.088	-0.065	-0.057	-0.102	-0.082
ATTN(DB)	-1.016	-1.685	-1.211	-1.058	-1.985	-1.561
DELTA L(IN.)	1.906	1.887	1.824	2.000	1.807	1.742

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	20.000	0.500

FREQUENCY = 14000 HZ   OSC CUT NO. 8361, 8382

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.430	0.382	0.415	0.417	0.366	0.383
DEV(VOLTS)	-0.070	-0.118	-0.085	-0.083	-0.134	-0.117
ATTN(DB)	-1.319	-2.339	-1.628	-1.575	-2.702	-2.325
DELTA L(IN.)	1.841	1.750	1.738	1.885	1.664	1.595

FREQUENCY = 18000 HZ   OSC CUT NO. 8362, 8383

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.375	0.320	0.344	0.365	0.303	0.313
DEV(VOLTS)	-0.125	-0.180	-0.156	-0.135	-0.197	-0.187
ATTN(DB)	-2.493	-3.887	-3.259	-2.740	-4.353	-4.075
DELTA L(IN.)	1.608	1.464	1.441	1.648	1.376	1.304

FREQUENCY = 21000 HZ   OSC CUT NO. 8363, 8384

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.326	0.267	0.301	0.308	0.249	0.262
DEV(VOLTS)	-0.174	-0.233	-0.199	-0.192	-0.251	-0.238
ATTN(DB)	-3.728	-5.444	-4.397	-4.204	-6.050	-5.625
DELTA L(IN.)	1.395	1.224	1.264	1.393	1.132	1.091

FREQUENCY = 25000 HZ   OSC CUT NO. 8364, 8385

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.247	0.200	0.226	0.234	0.190	0.189
DEV(VOLTS)	-0.253	-0.300	-0.274	-0.266	-0.310	-0.311
ATTN(DB)	-6.128	-7.948	-6.907	-6.587	-8.414	-8.431
DELTA L(IN.)	1.058	0.917	0.947	1.058	0.862	0.790

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	20.000	0.500

FREQUENCY = 30000 HZ OSC CUT NO. 8365, 8386

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.155	0.123	0.137	0.146	0.115	0.108
DEV(VOLTS)	-0.345	-0.377	-0.363	-0.354	-0.385	-0.392
ATTN(DB)	-10.155	-12.208	-11.219	-10.701	-12.763	-13.277
DELTA L(IN.)	0.666	0.562	0.576	0.659	0.523	0.452

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	50.000	0.200

CHANNEL	2	3	4	5	6	7
ITEM NUMBER	125	225	126	226	127	227
AMP S/N	1048	1596	1041	1391	1595	1386
VCO S/N	1Z2026	9E0277	9Z1663	9E0346	9E0294	9E0292
GAIN(MV/PCB)	46.900	50.500	50.500	51.300	51.500	50.100
GAIN DATE	01317	07207	01127	04267	01137	07207
CAL VOLTS	0.925	0.952	0.947	1.011	1.067	1.082
LCAL(IN.)	1.656	1.692	1.591	1.764	1.871	1.740
CAP(PF)	128.250	127.950	127.600	127.600	127.150	126.700

FREQUENCY = 10 HZ OSC CUT NO. 8388, 8406

CALC VOLTS	0.214	0.273	0.266	0.275	0.263	0.279
DEV(VOLTS)	+0.014	+0.073	+0.066	+0.075	+0.063	+0.079
ATTN(DB)	+0.602	+2.718	+2.484	+2.761	+2.392	+2.885
DELTA L(IN.)	2.308	3.141	2.882	3.140	3.025	2.845

FREQUENCY = 25 HZ OSC CUT NO. 8389, 8407

CALC VOLTS	0.215	0.219	0.213	0.221	0.212	0.223
DEV(VOLTS)	+0.015	+0.019	+0.013	+0.021	+0.012	+0.023
ATTN(DB)	+0.629	+0.770	+0.546	+0.872	+0.491	+0.944
DELTA L(IN.)	2.315	2.510	2.306	2.526	2.430	2.276

FREQUENCY = 50 HZ OSC CUT NO. 8390, 8408

CALC VOLTS	0.203	0.204	0.199	0.208	0.200	0.209
DEV(VOLTS)	+0.003	+0.004	-0.001	+0.008	+0.000	+0.009
ATTN(DB)	+0.147	+0.188	-0.039	+0.350	+0.002	+0.402
DELTA L(IN.)	2.190	2.347	2.155	2.379	2.297	2.138

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	50.000	0.200

FREQUENCY = 100 HZ   OSC CUT NO. 8391, 8409

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.199	0.201	0.196	0.204	0.196	0.207
DEV(VOLTS)	-0.001	+0.001	-0.004	+0.004	-0.004	+0.007
ATTN(DB)	-0.053	+0.042	-0.174	+0.157	-0.187	+0.287
DELTA L(IN.)	2.140	2.308	2.122	2.327	2.248	2.110

FREQUENCY = 500 HZ   OSC CUT NO. 8392, 8413

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.200	0.204	0.198	0.206	0.199	0.206
DEV(VOLTS)	+0.000	+0.004	-0.002	+0.006	-0.001	+0.006
ATTN(DB)	+0.014	+0.179	-0.086	+0.242	-0.034	+0.270
DELTA L(IN.)	2.157	2.345	2.144	2.349	2.288	2.105

FREQUENCY = 1000 HZ   OSC CUT NO. 8393, 8414

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.198	0.201	0.196	0.203	0.195	0.204
DEV(VOLTS)	-0.002	+0.001	-0.004	+0.003	-0.005	+0.004
ATTN(DB)	-0.078	+0.055	-0.184	+0.113	-0.210	+0.182
DELTA L(IN.)	2.134	2.312	2.120	2.315	2.242	2.084

FREQUENCY = 3000 HZ   OSC CUT NO. 8394, 8415

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.195	0.193	0.191	0.199	0.186	0.197
DEV(VOLTS)	-0.005	-0.007	-0.009	-0.001	-0.014	-0.003
ATTN(DB)	-0.199	-0.327	-0.402	-0.051	-0.611	-0.117
DELTA L(IN.)	2.104	2.212	2.067	2.272	2.141	2.014

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	50.000	0.200

CHANNEL	2	3	4	5	6	7

FREQUENCY = 6000 HZ OSC CUT NO. 8395, 8416

CALC VOLTS	0.191	0.174	0.187	0.193	0.170	0.182
DEV(VOLTS)	-0.009	-0.026	-0.013	-0.007	-0.030	-0.018
ATTN(DB)	-0.409	-1.197	-0.601	-0.301	-1.436	-0.797
DELTA L(IN.)	2.054	2.002	2.020	2.207	1.947	1.862

FREQUENCY = 8000 HZ OSC CUT NO. 8396, 8417

CALC VOLTS	0.191	0.163	0.183	0.188	0.155	0.169
DEV(VOLTS)	-0.009	-0.037	-0.017	-0.012	-0.045	-0.031
ATTN(DB)	-0.404	-1.787	-0.765	-0.559	-2.232	-1.477
DELTA L(IN.)	2.055	1.870	1.983	2.143	1.776	1.722

FREQUENCY = 10000 HZ OSC CUT NO. 8397, 8418

CALC VOLTS	0.182	0.144	0.174	0.178	0.137	0.153
DEV(VOLTS)	-0.018	-0.056	-0.026	-0.022	-0.063	-0.047
ATTN(DB)	-0.807	-2.842	-1.207	-0.995	-3.271	-2.355
DELTA L(IN.)	1.962	1.656	1.884	2.037	1.576	1.556

FREQUENCY = 12000 HZ OSC CUT NO. 8398, 8419

CALC VOLTS	0.173	0.128	0.164	0.170	0.122	0.139
DEV(VOLTS)	-0.027	-0.072	-0.036	-0.030	-0.078	-0.061
ATTN(DB)	-1.269	-3.856	-1.733	-1.400	-4.259	-3.149
DELTA L(IN.)	1.860	1.474	1.773	1.945	1.407	1.420

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	50.000	0.200

FREQUENCY = 14000 HZ   OSC CUT NO. 8399, 8420

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.167	0.114	0.155	0.154	0.106	0.119
DEV(VOLTS)	-0.033	-0.086	-0.045	-0.046	-0.094	-0.081
ATTN(DB)	-1.585	-4.870	-2.212	-2.259	-5.539	-4.490
DELTA L(IN.)	1.794	1.311	1.678	1.762	1.214	1.217

FREQUENCY = 18000 HZ   OSC CUT NO. 8400, 8421

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.142	0.085	0.124	0.130	0.079	0.087
DEV(VOLTS)	-0.058	-0.115	-0.076	-0.070	-0.121	-0.113
ATTN(DB)	-2.957	-7.427	-4.178	-3.769	-8.047	-7.187
DELTA L(IN.)	1.532	0.977	1.338	1.480	0.909	0.892

FREQUENCY = 21000 HZ   OSC CUT NO. 8401, 8422

CHANNEL	2	3	4	5	6	7
CALC VOLTS	0.120	0.066	0.103	0.108	0.063	0.070
DEV(VOLTS)	-0.080	-0.134	-0.097	-0.092	-0.137	-0.130
ATTN(DB)	-4.424	-9.668	-5.775	-5.333	-9.977	-9.105
DELTA L(IN.)	1.294	0.755	1.114	1.236	0.728	0.716

FREQUENCY = 25000 HZ   OSC CUT NO. 8402

CHANNEL	2	3	4
CALC VOLTS	0.090	0.046	0.072
DEV(VOLTS)	-0.110	-0.154	-0.128
ATTN(DB)	-6.973	-12.697	-8.834
DELTA L(IN.)	0.965	0.533	0.783

TEST AREA 1-90 ACCURACY STUDY (PYRO)

DATE	TEST DATE	GAIN SET	INPUT VOLTS(TRUE)
MARCH 14, 1969	NOVEMBER 2, 1967	50.000	0.200

CHANNEL	2	3	4	5	6	7

FREQUENCY = 30000 HZ   OSC CUT NO. 8403

CALC VOLTS	0.055	0.027	0.041
DEV(VOLTS)	-0.145	-0.173	-0.159
ATTN(DB)	-11.292	-17.444	-13.818
DELTA L(IN.)	0.587	0.308	0.441

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13. ABSTRACT

An accuracy study was performed on the pressure measurement instrumentation of Project Pyro (Blast Hazards Testing) located at Test Area 1-90 at the Air Force Rocket Propulsion Laboratory (AFRPL), Edwards AFB, California. This report presents the methods, techniques, problems, results, and conclusions of this accuracy study. A pseudo end-to-end technique was employed to obtain the data with the results being presented to a 95% confidence level (approximately ±2σ). For frequencies between 50 Hz and 6000 Hz and amplifier gain positions 2 through 20, the bias was found to be -5.6% with an uncertainty of ±6.7%.

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