TR-1130

JOHN F. KENNEDY SPACE CENTER

SEPTEMBER 12, 1971

STUDY TO DEVELOP IMPROVED METHODS TO DETECT LEAKAGE IN FLUID SYSTEMS

PHASE II

BY: J. C. JANUS & I. CIMERMAN

Reproduced by
NATIONAL TECHNICAL INFORMATION SERVICE
Springfield, Va. 22151

NASA CONTRACT NO. NAS10-7510

DEC 1971
RECEIVED
NASA STI FACILITY
INPUT BRANCH

N72-12210 (NASA-CR-124618) STUDY TO DEVELOP IMPROVED METHODS TO DETECT LEAKAGE IN FLUID SYSTEMS, PHASE 2 J.C. Janus, et al (Dynamatec Corp.) 12 Sep. 1971 36 p CSCL 20D G3/12

Unclas
09262

KSC FORM 16-12 (4/66)

N O T I C E

THIS DOCUMENT HAS BEEN REPRODUCED FROM THE BEST COPY FURNISHED US BY THE SPONSORING AGENCY. ALTHOUGH IT IS RECOGNIZED THAT CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED IN THE INTEREST OF MAKING AVAILABLE AS MUCH INFORMATION AS POSSIBLE.

NASA Contract No. NAS10-7510

STUDY TO DEVELOP IMPROVED METHODS TO DETECT LEAKAGE IN FLUID SYSTEMS

PHASE II

By: J. C. Janus & I. Cimerman
Dynamatec Corporation
Merritt Island, Florida

B. A. Tolson - NASA Project Manager

September 12, 1971

Final Report

Prepared for

NASA, John F. Kennedy Space Center, Florida

This report was prepared as an account of Government-sponsored work. Neither the United States, nor the National Aeronautics and Space Administration (NASA), nor any person acting on behalf of NASA:

A) Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately-owned rights; or

B) Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

As used above, "person acting on behalf of NASA" includes any employee or contractor of NASA, or employee of such contractor, to the extent that such employee or contractor of NASA or employee of such contractor prepares, disseminates, or provides access to any information pursuant to his employment or contract with NASA, or his employment with such contractor.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Study to Develop Improved Methods to Detect Leakage in Fluid Systems Phase II		5. Report Date September 12, 1971
		6. Performing Organization Code
7. Author(s) J. C. Janus & I. Cimerman		8. Performing Organization Report No. DC 71-4
9. Performing Organization Name and Address Dynamatec Corporation 1700 E. Merritt Island Cwsy. Merritt Island, Florida 32952		10. Work Unit No.
		11. Contract or Grant No. NAS10-7510
12. Sponsoring Agency Name and Address B. A. Tolson - Project Manager National Aeronautics & Space Administration Design Engr. - Mechanical Systems Division Kennedy Space Center, Florida 32899		13. Type of Report and Period Covered
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This study was a follow on contract to the Phase I study (TIR - 1088). Its purpose was to develop an ultrasonic contact sensor engineering prototype leak detection system and demonstrate its capabilities under cryogenic operating conditions. Tests were performed at the NASA-KSC cryogenic facility and the highlights were that the transducer performed well on liquid hydrogen plumbing, that flow and valve actuation could be monitored and that the phase change from gaseous to liquid hydrogen could be detected by the externally mounted transducers.

Apollo 15 operations prevented a detailed leak test analysis from being performed at KSC but laboratory tests demonstrated the ability of the system to detect internal leaks past valve seats and to function as a flow meter. These tests were performed by externally mounted transducers and therefore demonstrate that it is not necessary to break into welded systems to locate internal leaks.

17. KeyWords		18. Distribution Statement	
Ultrasonic leak detection Leak detection Space Shuttle leak detection Phase change detection			
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price

KSC FORM OT-320 (7/69) (ONETIME FORM - REPRINT NOT AUTHORIZED)

ACKNOWLEDGEMENTS

This document was prepared by the Dynamatec Corporation. Mr. John C. Janus was the study manager and he was assisted by Mr. I. Cimerman. Mr. J. L. Pearce, G. B. Harman and V. Poston all provided valuable assistance throughout the study.

The Chrysler Corporation, Toledo, Ohio, provided components with weld failures which were used extensively during the development of the contact transducers. In addition to the failed components, the Chrysler Corporation provided an insight to the conditions facing an assembly line leak detection system and emphasized the need for improvements in this field.

Acknowledgement is also made for the valuable technical assistance and guidance provided through the efforts of Mr. Bill A. Tolson, NASA Project Manager for both Phase I and Phase II of this study. The NASA personnel who assisted in the test set up and the testing at the KSC Cryogenic Facility were very helpful. Mr. Carl Jones and Mr. Don Peace both provided valuable assistance and Mr. F. T. Williams coordinated the use of the Cryogenic Facility.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SECTION I

INTRODUCTION

1.1 PURPOSE

The purpose of Contract, NAS10-7510, "Study to Develop Improved Methods to Detect Leakage in Fluid Systems - Phase II," was to design and fabricate an ultrasonic contact sensor leak detector engineering prototype and to demonstrate the detector's potential to NASA by operating it during cryogenic operations at the Kennedy Space Center. Development of this detector was accomplished as a follow on contract to the Dynamatec Corporation's Phase I study which reviewed all presently known leak detection systems and made a recommendation to use an onboard mass spectrometer and an ultrasonic contact sensor leak detection system as the leak detection system for the Space Shuttle.

1.2 SCOPE

The Dynamatec Corporation's contracted statement of work specified that the contractor would:

a) design and fabricate ultrasonic contact sensors
b) design and breadboard supporting electronics and
c) produce and package an ultrasonic contact sensor leak detector engineering prototype for testing at KSC.

In the laboratory, the prototype ultrasonic leak detector would be tested on manufactured leaks. Then, at the Kennedy Space Center, the leak detector would be tested to determine whether background interference would interrupt the detector's leak detection ability under operational conditions. The detector would also be used to analyze and determine internal flow rates as well as valve seat leakage and valve actuations.

SECTION II

REVIEW, EVALUATION AND DESIGN

2.1 GENERAL

The Phase I Study to Develop Improved Methods to Detect Leakage in Fluid Systems established the criteria for a Space Shuttle leak detection system. The results of this study were published in December 1970 as the NASA Kennedy Space Center Technical Report Number TR-1088. These study results provided an understanding as to why the contact sensor ultrasonic leak detection system holds such great promise for future NASA programs. A brief outline of the advantages is as follows:

1. The ultrasonic contact sensor can be used to detect internal leakages without breaking into the system (valve seats, check valves, regulators and seals).
2. The ultrasonic contact sensor can be used during vacuum conditions where it is impossible to draw samples into a mass spectrometer or other gas analyzer.
3. This system can be used to detect flow restrictions or can be calibrated as a flow meter.
4. The system can detect changes in the characteristics of the fluid flowing in the system. Actual tests were conducted to establish that this system could readily detect the change from a gaseous hydrogen flow to a liquid hydrogen flow.
5. The ultrasonic leak detection system can serve double duty by detecting wear conditions in bearing and other moving parts.

2.2 EQUIPMENT DESCRIPTION

The prototype ultrasonic detection system designed during Phase II of the Study to Develop Improved Methods to Detect Leakage in Fluid Systems consists of three main components: a set of contact transducers, a signal conditioner assembly and a control and display unit.

Block diagrams and a brief description of the unit components are provided herein; however, complete circuit schematics and wiring diagrams are being submitted under separate cover. The ultrasonic leak detection system equipment configuration was redesigned from the original concept of a single contact transducer and a bank of filters to a group of transducers each having its own filter tuned to a specific frequency band. The revised concept allowed recording of real time data at the Kennedy Space Center's Cryogenic Facility for subsequent analysis.

2.2.1 Contact Transducers. A number of transducer configurations were investigated. These included commercially available contact microphones and accelerometers. It was found that the contact microphones were incapable of providing sufficient sensitivity for operational usage. In general, accelerometers had a low frequency response except for a subminiature unit which resonated at about 30 KHZ and provided a useful output through the next octave. Experimental transducers which were manufactured were similar in design to a comparable type of piezo electrical accelerometer except that instead of a floating mass, a thick metal disc was placed in firm contact with a thin piezo electric crystal and the assembly compensated to obtain the best compromise between sensitivity and frequency response. A diagram of a typical transducer is as shown in the accompanying figure. The transducer case is of aluminum which is precision machined to obtain a flat contact with the crystal and a precision parallelism between inner and outer faces. The edge of the crystal and the backing disc are isolated from the case walls by a teflon cylinder. This reduces the sensitivity of the transducers to air transmitted vibrations.

Electrical contact to the bottom face of the crystal is provided through the case, while the top face is contacted through the backing disc. A nylon insulator is used between the metal disc and the case cover. The cover is threaded into the case and is used to apply an initial compression to the crystal assembly. In order to provide for sensitive adjustments, a second fine threaded screw is used in the center of the cover as shown in the accompanying sketch.

The prototype unit that was manufactured for NASA delivery has five transducers coupled to five sets of filters. This combination provides for monitoring the following frequency ranges:

1. 1 KHZ to 10 KHZ
2. 10 KHZ to 30 KHZ
3. 30 KHZ to 50 KHZ
4. 50 KHZ to 100 KHZ
5. 1 KHZ to 100 KHZ

CONTACT TRANSDUCER

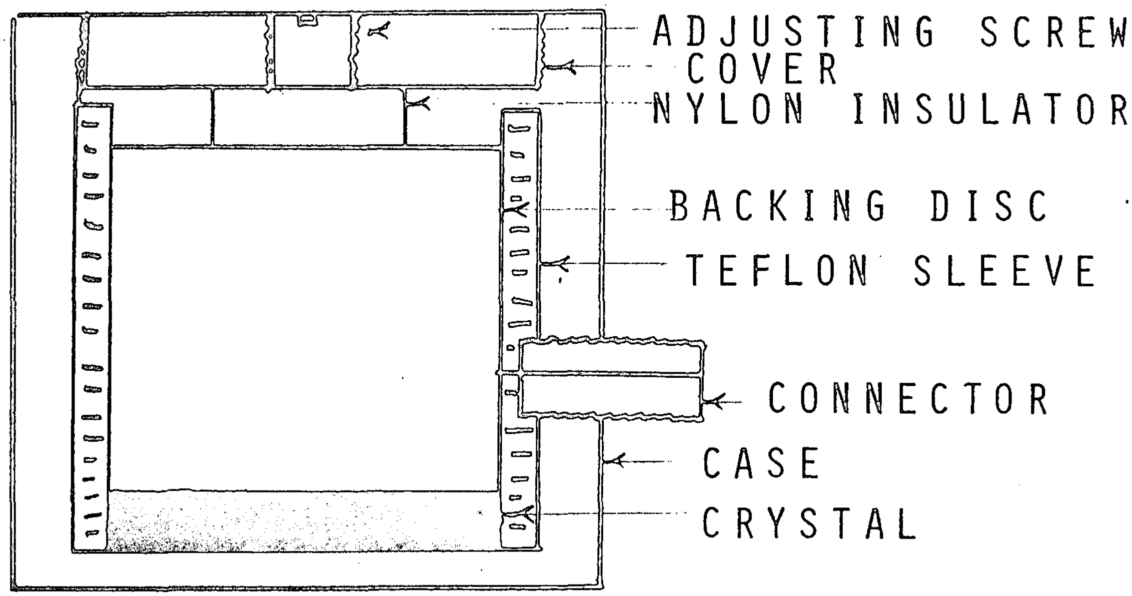


Figure 1

2.2.2 Signal Conditioner Assembly. In compliance with the revised requirements, a five channel signal conditioning unit was assembled in a purged box for operation in hazardous locations. The unit contains five sets of transducer preamplifiers and filters tuned to overlapping frequency bands from 1 KHZ to 100 KHZ. The signal conditioners operate from either 15 VDC or 30 VDC and can be placed up to 100 feet from the control and display unit. The transducers must be located within a 3 foot radius from the signal conditioner.

The nominal frequency coverage of the conditioners is as follows:

Channel 1 - 1 to 10 KHZ
Channel 2 - 10 to 30 KHZ
Channel 3 - 30 to 60 KHZ
Channel 4 - 50 to 100 KHZ
Channel 5 - 1 to 100 KHZ

Measured frequency response curves are shown in Figures 3-7.

Channel 1 is intended to detect energy in the audio range such as that produced by mechanical valve actuation, pipe vibrations and similar occurrences for comparison with the ultrasonic energy produced by fluid flow through the same equipment. Similarly, Channel 5 covers the full spectrum and provides an indication of all the frequencies being generated. However, due to its wide band width, the signal to noise ratio is somewhat poorer than that of the other channels. A block diagram of the assembly appears in Figure 2. A low noise voltage amplifier raises the transducer output to a level suitable for driving the filter. A gain control is used to equalize level on all channels.

The output amplifier is similar in design to the first amplifier. It compensates for the attenuation in the filter and provides a low impedance output to drive up to 100 feet of shielded cable and the control unit.

2.2.3 Control and Display Unit. The control and display unit provides regulated DC power for the signal conditioners and incorporates additional circuitry to measure and display the signals detected by the transducers. The block diagram of Figure 8 shows the internal configuration of the unit. The five inputs correspond to the five channels of the signal conditioner assembly. Any one channel can be switch selected for processing. The input signal can be displayed on the built in oscilloscope and can be translated to the audio range for aural recognition. Translation is accomplished by mixing with a signal from one of the built in local oscillators of which three are provided with fixed

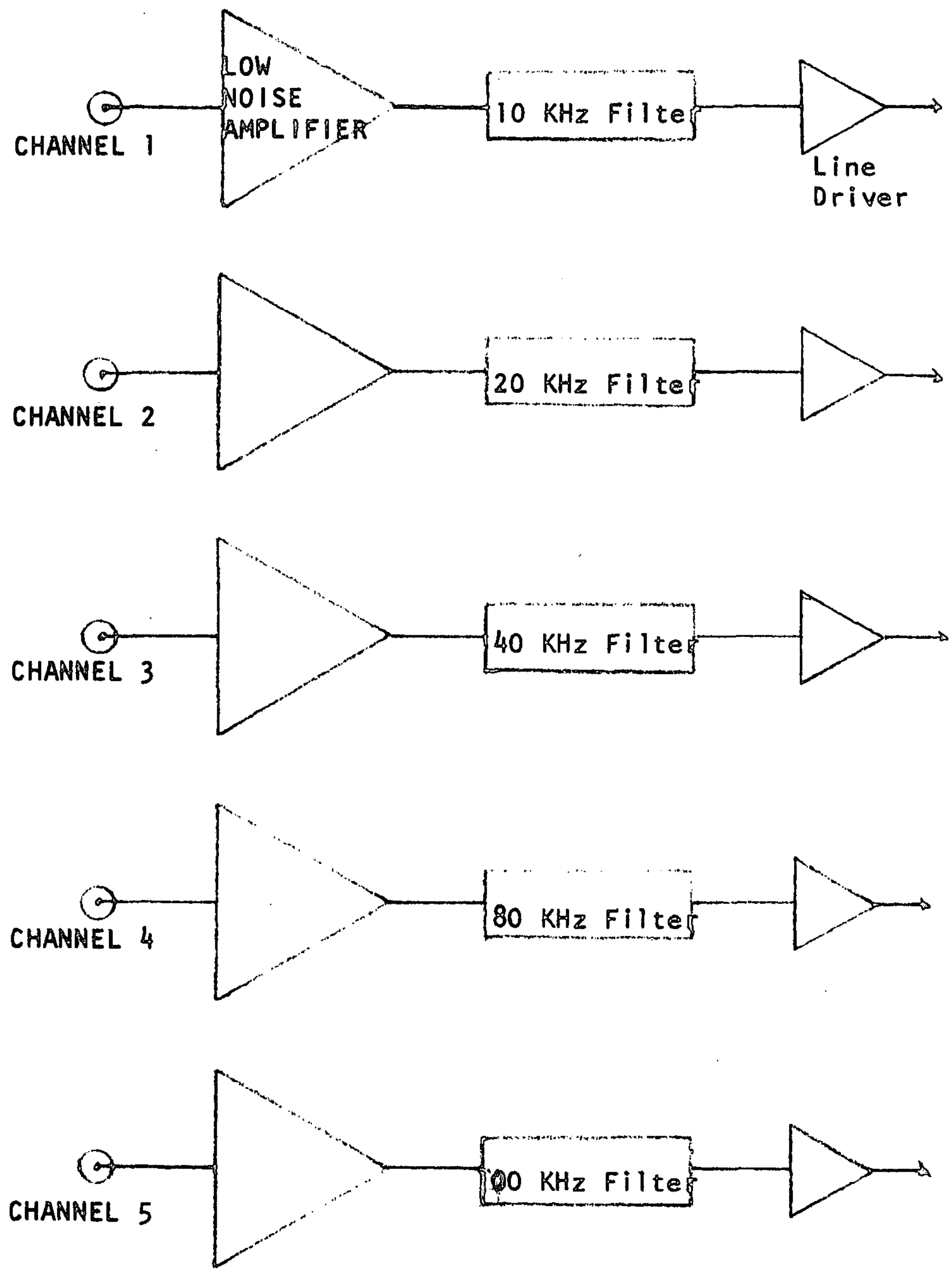


Figure 2

ULTRASONIC LEAK DETECTOR
SIGNAL CONDITIONER

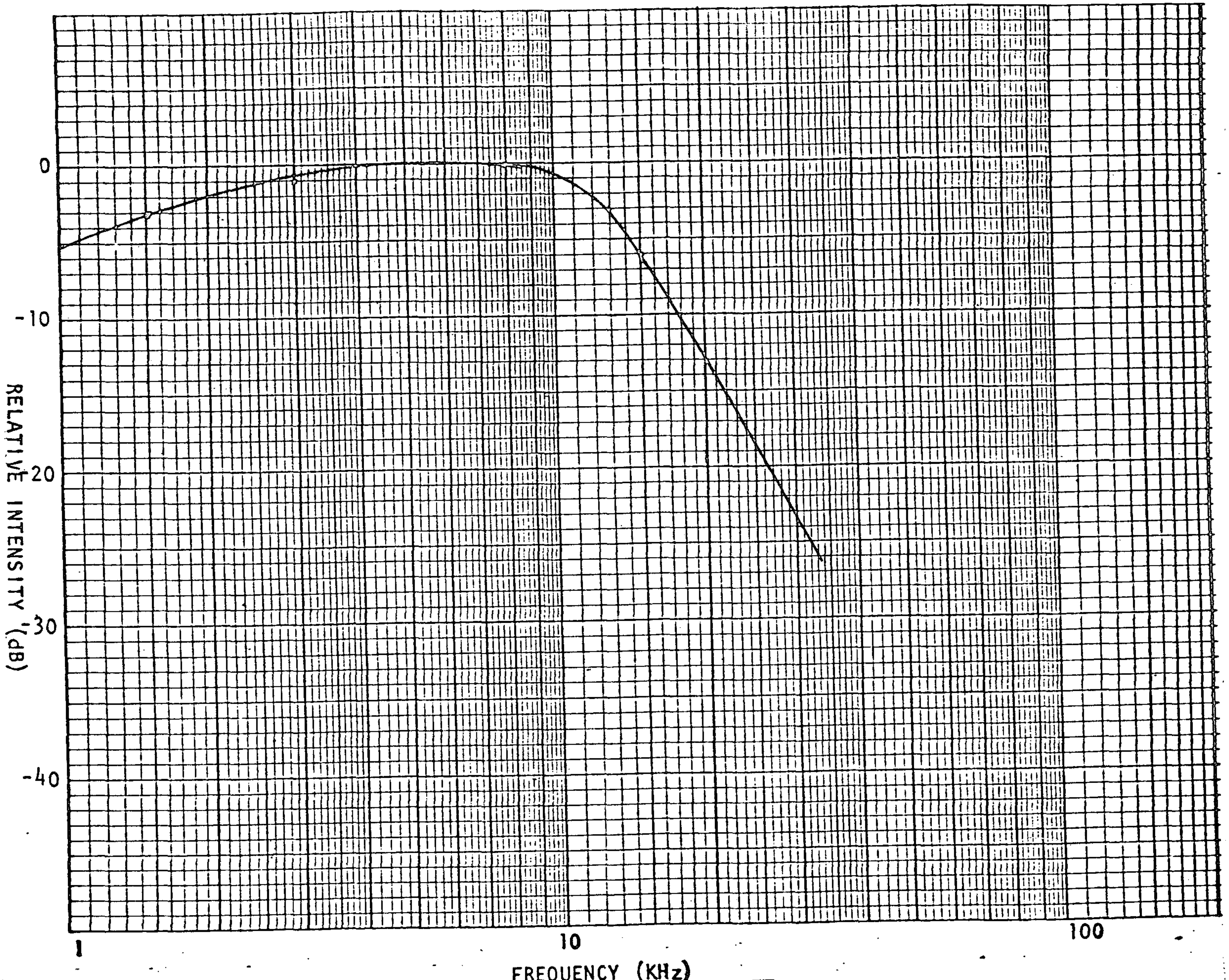


Figure 3

Frequency Response
Channel 1

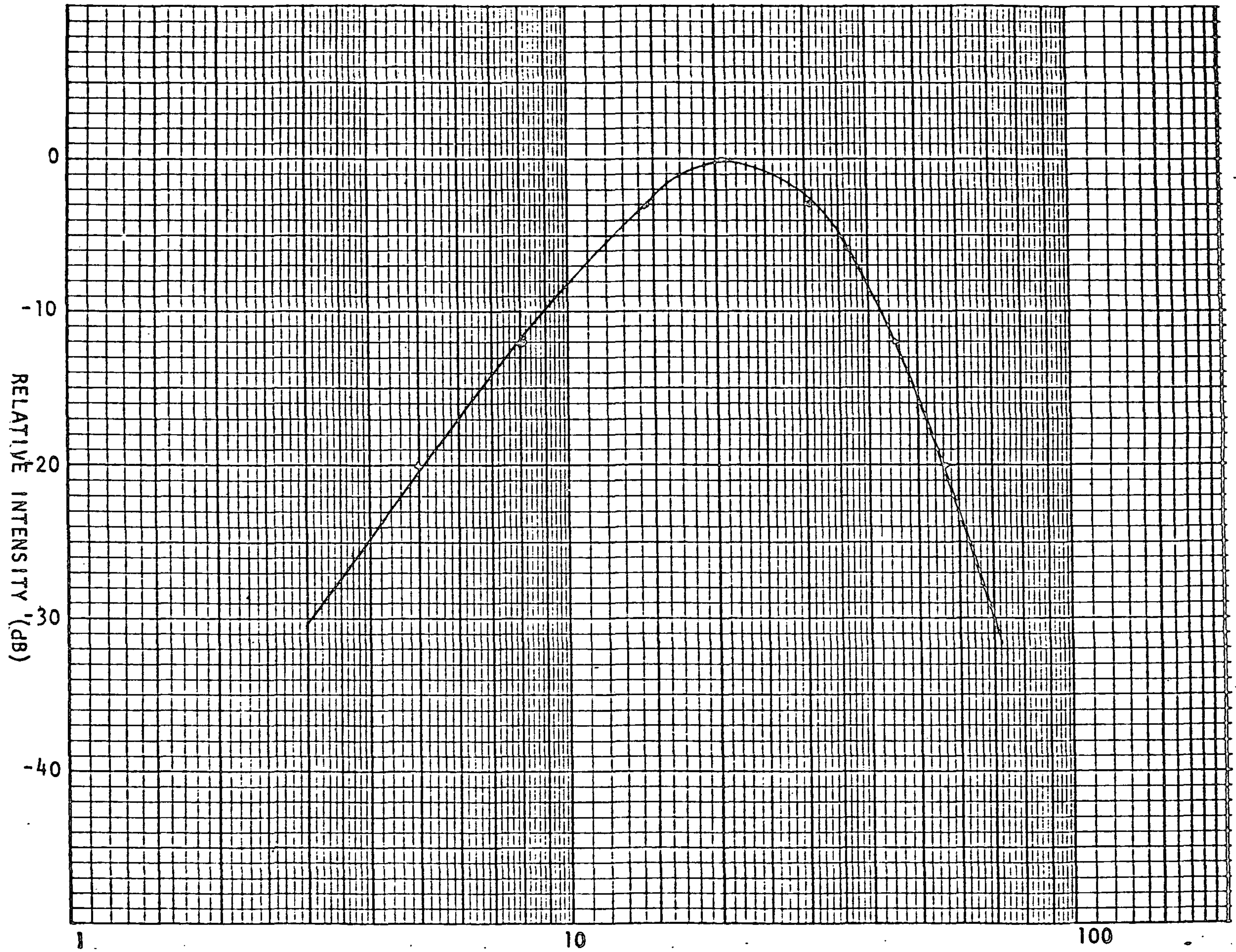


Figure 4

Frequency Response
Channel 2

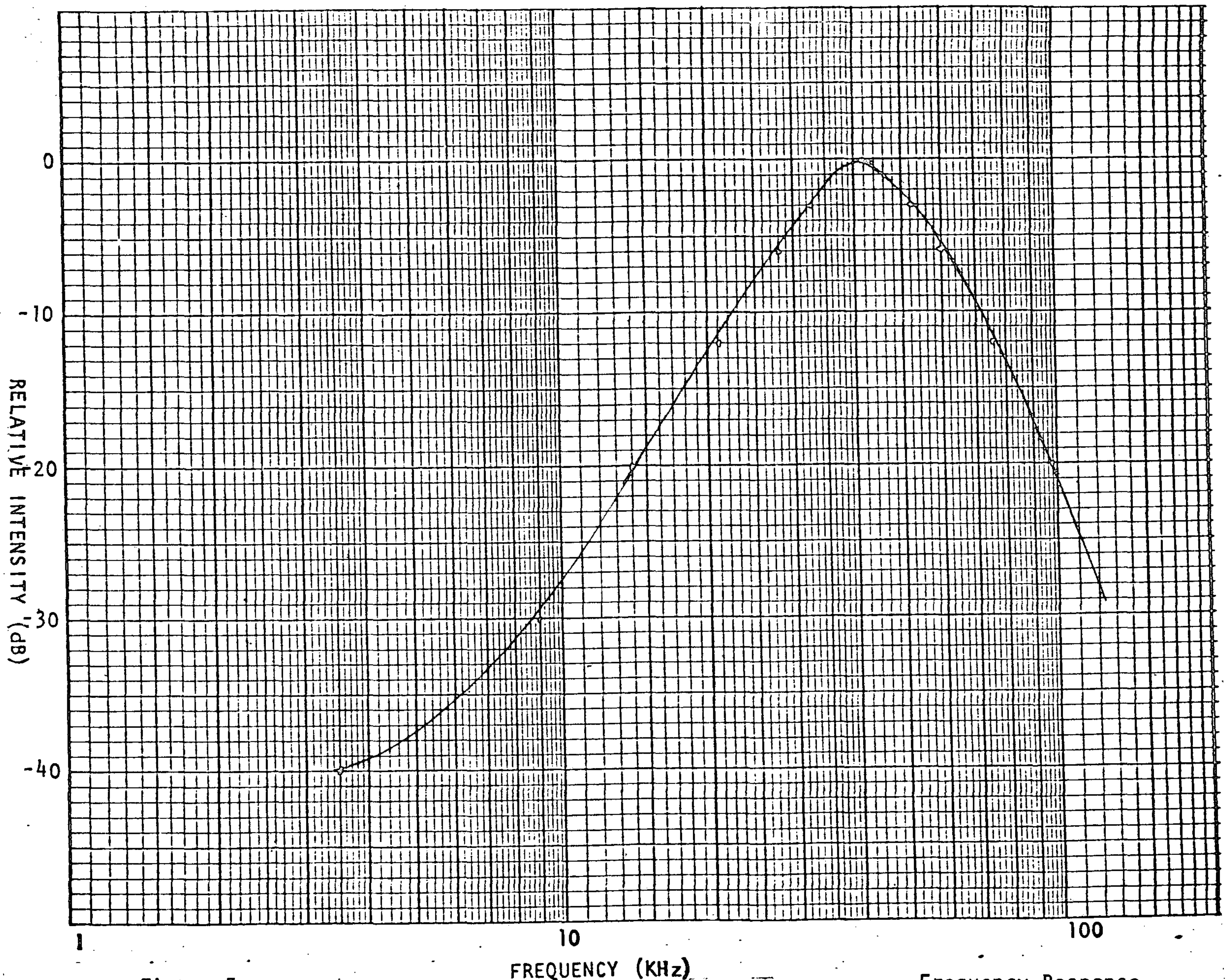


Figure 5

Frequency Response
Channel 3

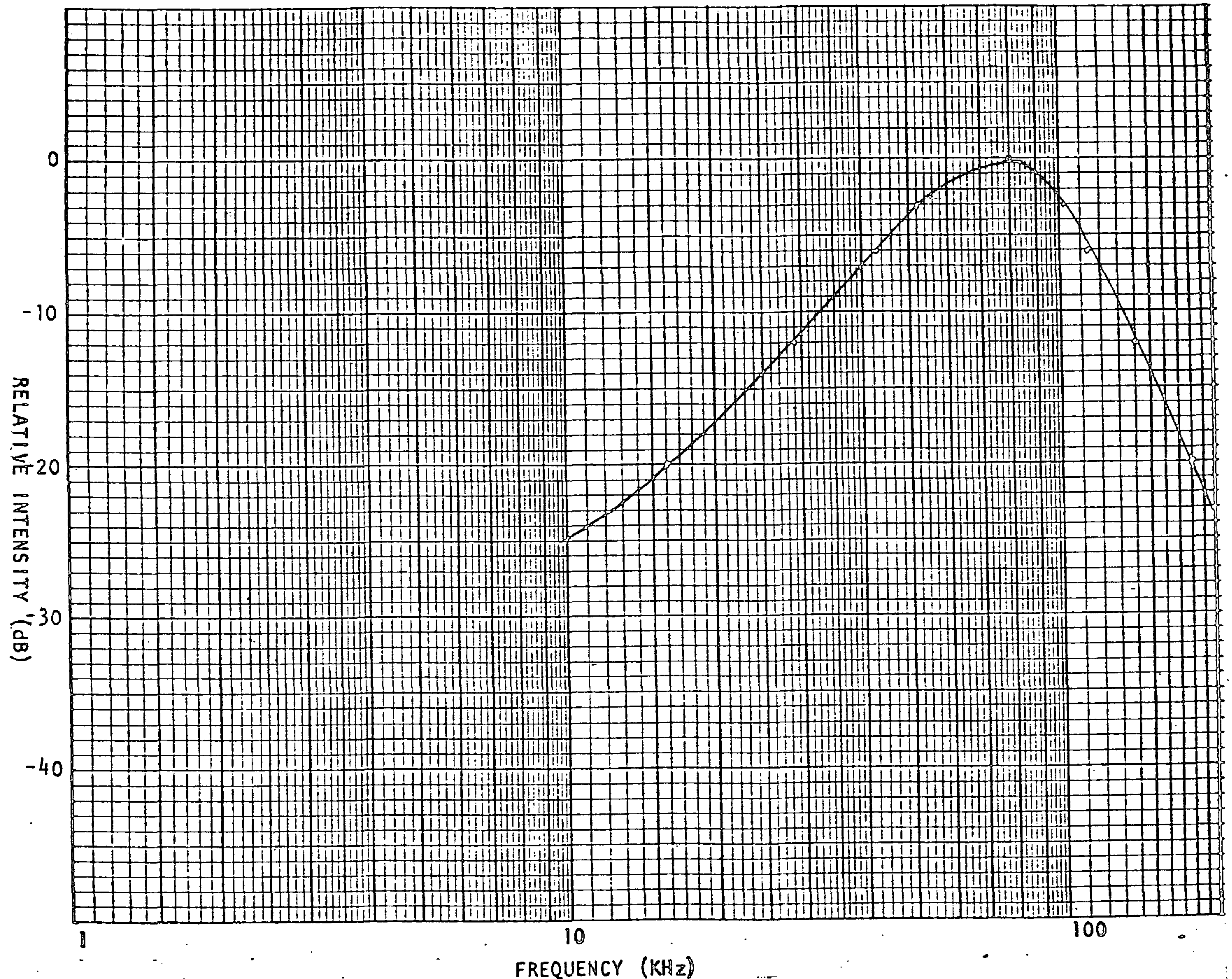


Figure 6

Frequency Response
Channel 4

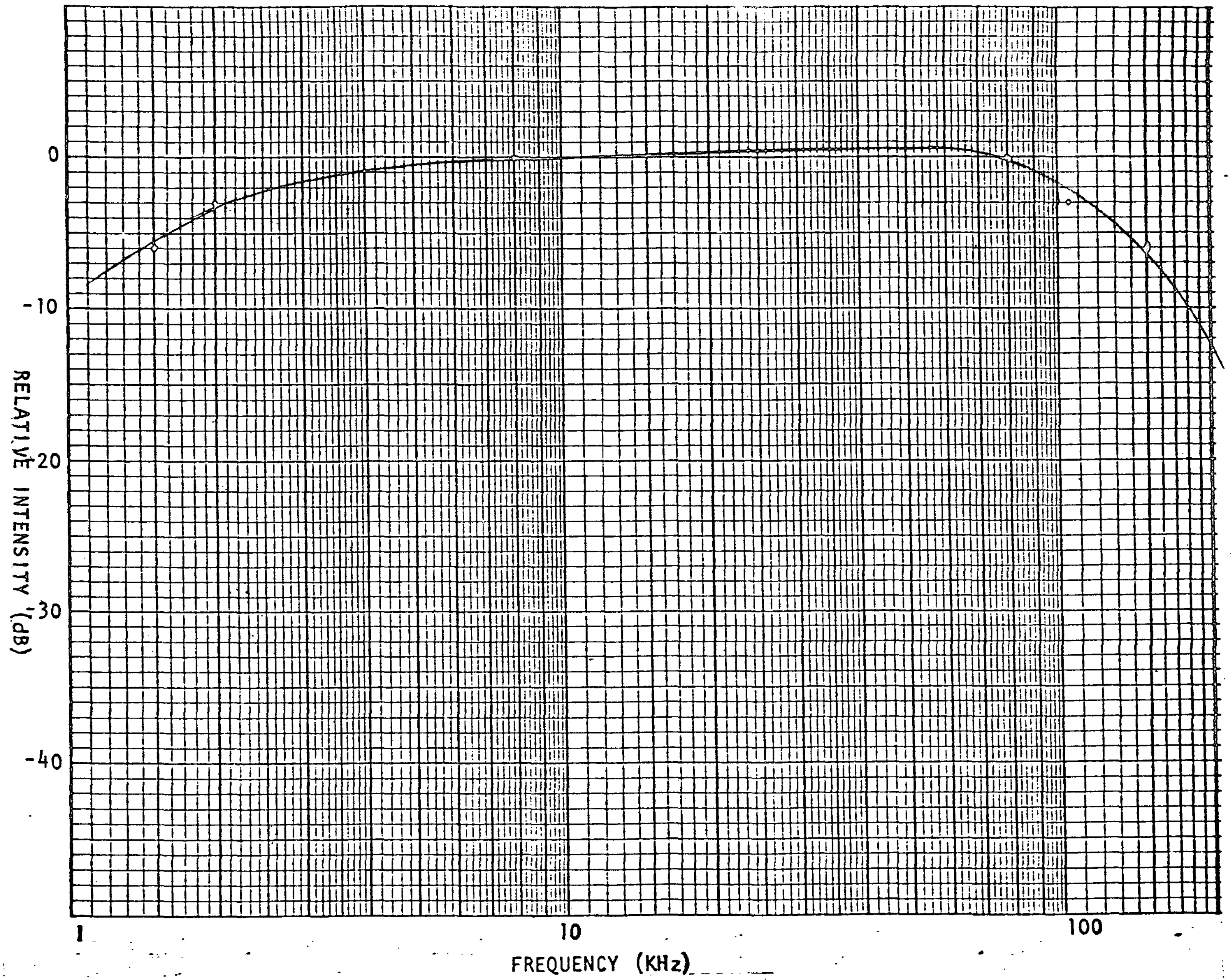


Figure 7 Frequency Response Channel 5

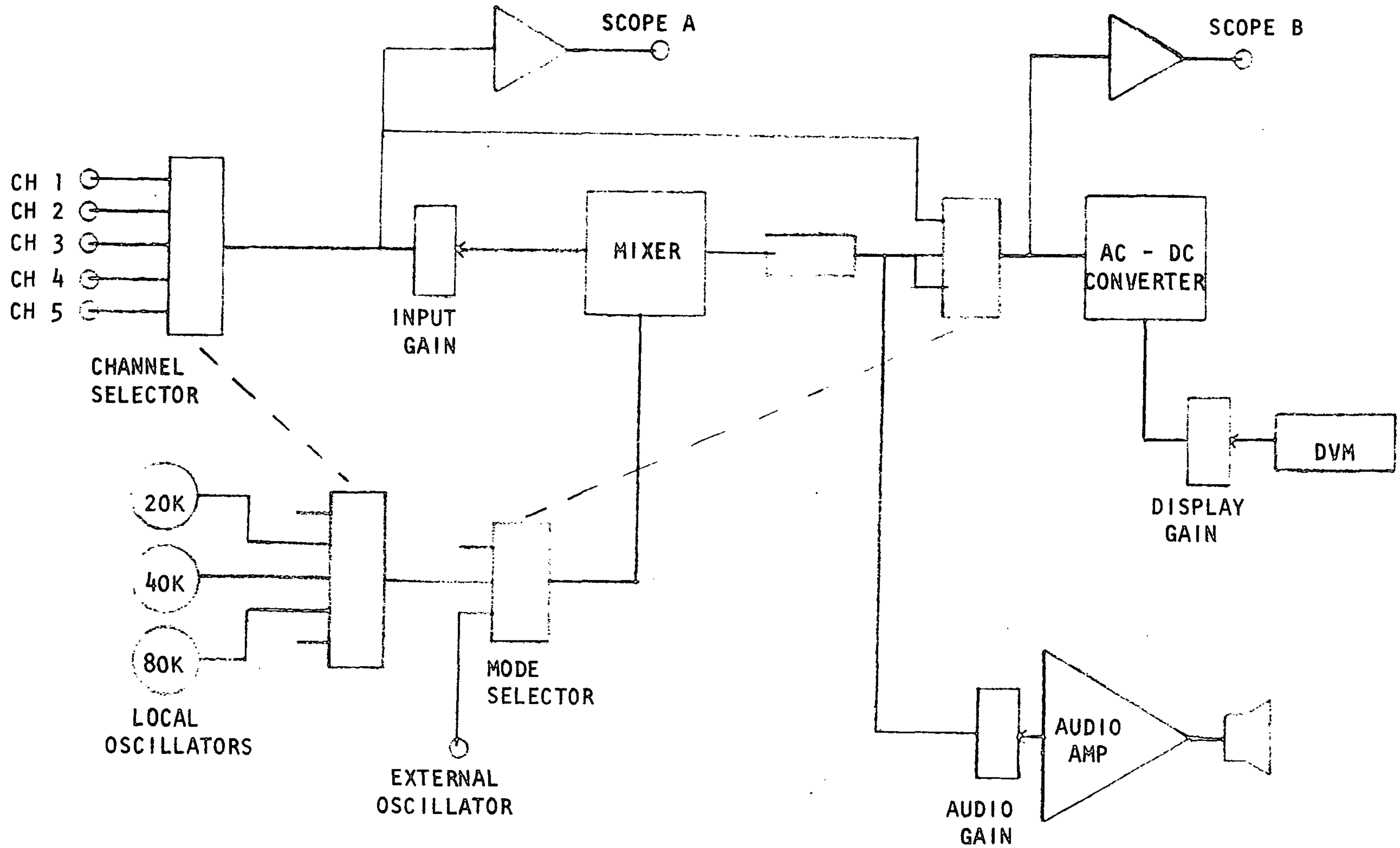


Figure 8

ULTRASONIC LEAK DETECTOR
CONTROL UNIT

frequencies of 20, 40 and 80 KHZ. Additionally, a switch position and front panel connector are provided to allow mixing with an external variable frequency oscillator. The output of the mixer is passed through a low pass filter with cut off frequency of 2 KHZ. By means of the variable frequency oscillator any 4 KHZ portion of the input signal can be selected for measurement. The mixer output is used to drive an audio amplifier and speaker and is brought out to a front panel connector for display in the CRT or on an external recorder.

Either the input signal or the translated signal can be selected and converted to DC and displayed on a built in digital meter. Additionally, the digital meter provides BCD outputs, available through an internal wiring strip, which may be used to drive an external printer, if desired.

2.3 LAB TESTS

The laboratory tests performed were mainly of a qualitative nature since their purpose was to improve the performance capabilities of transducer and its supporting electronics.

A series of failed components were used in the laboratory. These were tested at up to 250 pounds helium pressure using a water bath to locate and establish the size of the leaks prior to mounting the units on the test bench. These units ranged from zero detectable leakage to 30 bubbles a second leakage.

Nitrogen was used as the basic pressurant since it produced slower leak rates and allowed for longer pressure decay tests to be performed. One interesting factor that was discovered was that the same leak produced more ultrasonic noise with nitrogen although the leak rate was greater using helium. This was accounted for by the heavier nitrogen molecules producing a greater impact which in turn was transmitted along the steel container to the transducer.

This is somewhat contrary to other published reports which state that the lighter molecules should generate greater noise when escaping from an orfis. However, in these cases, the ultrasonic sound was measured from sound generated through the surrounding air and not through the metal container.

In the Phase I report, it was stated that a 60 PSI Delta P was required to assure good leak detection. The laboratory tests disproved this; and, as the transducers were perfected, leaks were detected below the 10 PSI Delta P range. It is felt that with a transducer designed for utmost sensitivity, even lower Delta P ranges will not preclude leak detection. This would be a major goal for a spacecraft skin leak detector. It was established during the Phase I study that with the exception of the low pressure side of the life support system, all operational systems were of the 60 PSI and above range.

From the laboratory tests performed, it was established that small leaks (one or two bubbles a second) are extremely hard to detect unless the transducer is mounted very near the leak. However, if the surface is wetted, the detection capability is greatly extended. The transducer is detecting the breaking of the bubble in this case and not the impact of the molecules on the surface. Other tests demonstrated the ability to calibrate the system for use as a flow meter and to detect valve actuation (pressurized or unpressurized).

Since a detailed set of detection tests were scheduled for KSC, the laboratory tests were not intended as a qualitative analysis of the equipment's capability but as a prototype development tool.

2.4 KSC TESTS

2.4.1 KSC Test Setup. The original plan for the engineering prototype hardware was to install the leak detection unit on cryogenic hardware at Launch Complex 39 and then to monitor the cryogenic loading of the Apollo 15 vehicle and booster. The unit was designed to have a purged transducer amplifier box mounted in the vicinity of the cryogenic plumbing, a power supply and supporting electronics located in the purged area and the readout panel in the Launch Control Center.

This concept was changed during the fourth month of the contract at which time the NASA directed the contractor to plan to conduct the testing at the KSC Cryogenic Facility during Apollo 15's hydrogen dewar loading. This added a new dimension by allowing the leak detector's electronics to be packaged so that the entire unit could be installed as a semi-portable ultrasonic leak detector. Following the decision to use the KSC Cryogenic Facility as the test area, a series of interface meetings were held with NASA. The results were that a pressurized transducer amplifier box was located near the hydrogen dewar and five transducers were mounted on the dewar piping and coupled to the amplifier box by contractor furnished cables. Government furnished cables were used to interface the amplifier box with the recorder and power supply in the "safe" area of facility. This configuration was used to monitor the hydrogen dewar loading operations for Apollo 15. Additional detailed leak detection tests were scheduled; however, these were eliminated by NASA due to modifications to the Cryogenic Facility.

2.4.2 KSC Operational Application. The operational application of the ultrasonic detection equipment took place during the loading of hydrogen dewars for Apollo 15 at the Cryogenic #2 Facility.

Five transducers were attached to pipes clustered near the base of the dewar:

Channel 1 on 1/8" line to 125 line.
Channel 2 on a purge line, flex section.
Channel 3 on the facility vent line.
Channel 4 on the same purge line as Channel 2, but on the rigid section of the line.
Channel 5 on a 5/8" vent line.

The tests were performed on a non-interference basis with other operational activities and the location of the transducers was dictated solely by the requirement that the transducers and cables be out of the way of the operational crew when they needed access to valves and controls in the vicinity of the dewar.

Approximately thirty minutes of data were recorded on magnetic tape for subsequent analysis. Voice comments were incorporated on the tape to aid in location of the various sequences. During the recording period, it was not possible to record a timing track; therefore, the specific beginning and end of each sequence can only be surmised from the data.

Several major event occurrences are recognizable by reference to the voice annotation, specifically: the beginning of line purging, fill valve opening, disconnection of the sampling equipment and the beginning of liquid flow through the vent lines which signified that the dewar was full.

Due to Apollo 15 data reduction commitments, it was not possible to have the recordings analyzed at the Central Instrumentation Facility. Originally, the intention was to run a full spectrum analysis on the data using a set of 1/3 octave filters available at the CIF. Instead the tape was reproduced at the Quick Look Data Station where an artificial timing track was added to allow stripping of the data on a Brush recorder. Playback on a Panoramic telemetry analyser was used to display the frequency spectrum and Polaroid photographs were made of some sequences. These are reproduced below along with a copy of the voice annotation and time amplitude oscillograph recordings of some of the events or examples of the data obtained.

Frequency amplitude signatures of the phase change were developed from the spectrum analyzer photographs by applying suitable correction factors due to filter response.

2.4.3 Phase Change Detection. One very significant result of the test was the equipment's ability to detect phase changes, i.e., beginning of liquid flow through the vent lines signifying the completion of the fill cycle. As the liquid hydrogen reached the vent line walls and was subjected to the temperature change, there was bubbling and the flow, for about 20 seconds, consisted of a mixture of liquid and gas. The resultant turbulence produced high amplitude vibrations most noticeable in the high sonic range as shown in the accompanying illustrations. Ultrasonic energy was still present although its level dropped considerably when the flow became all liquid.

The problem is to develop a simple fill completion detector consisting of a wide band contact transducer attached to the vent line to monitor the fill state of the vessel. The output of the transducer would be separated into two selected frequency bands, one in the ultrasonic range and another in the mid audio range. Sensing of a predetermined power level in both bands would detect the phase change and could be used to activate an alarm or a suitable fill completion indicator. Sensing of two separate frequencies would avoid a false alarm caused by external disturbances such as line vibration and shock noises which are low frequency.

CRYO #2 TEST TAPE

TIME	VOICE ANNOTATION
1848	Fill line is open 5 min. purge
1849:35	End first sequence End fill line purge sequence
1850	Start chill down flow time is 0858Z
1901	End first tape
1906:53	Start second tape Deward is 3/4 full
1909	Channel 1 momentarily disconnected connected now
1912:50	Dewar is full
1913:54	Stop first duplicate tape
1921:40	Start second duplicate tape
1923:37	Start liquid flow through vent lines
1932:12	Sampling equipment being disconnected
1933:58	Sampling disconnect complete
1936:22	Static conditions at end of test

Figure 9

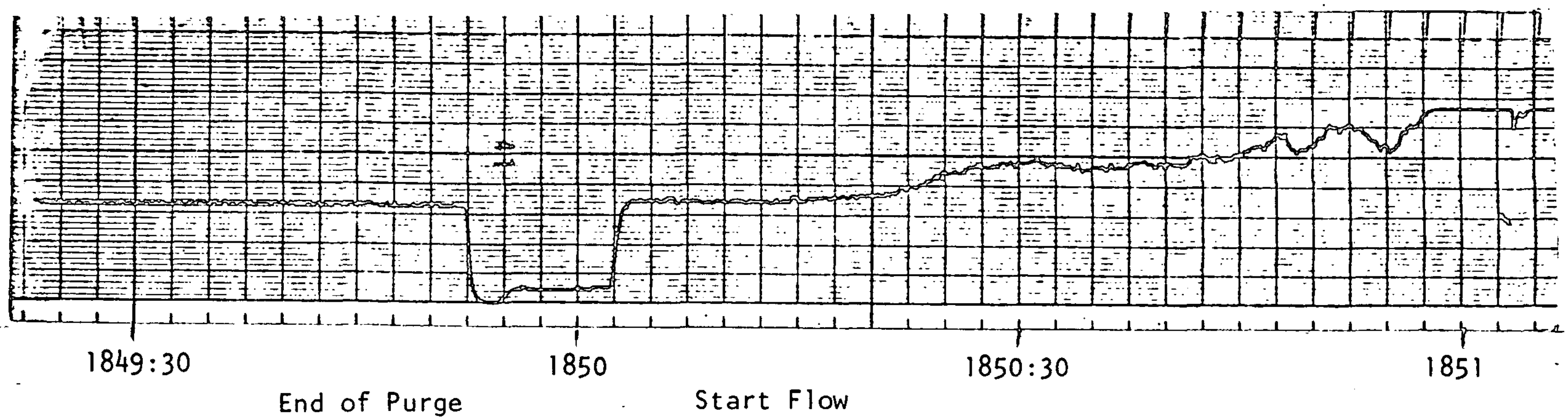
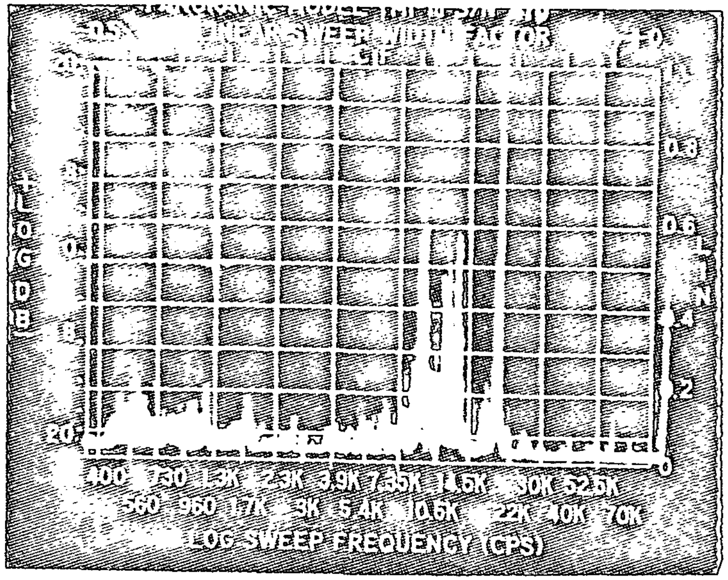
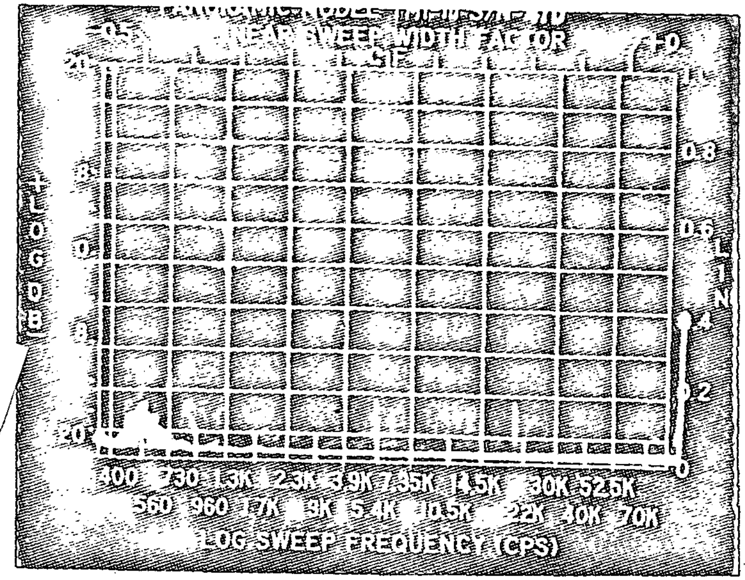


Figure 10

Start of Chill Down Flow
Channel 1

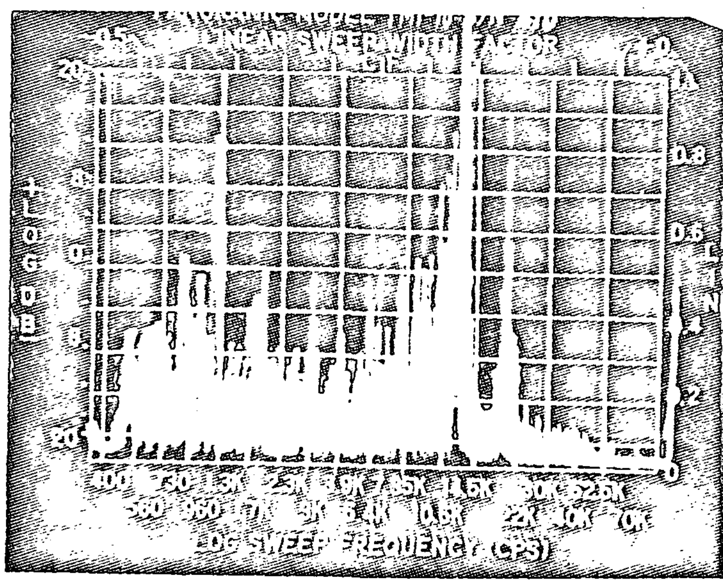


T=1848:55 During Purge

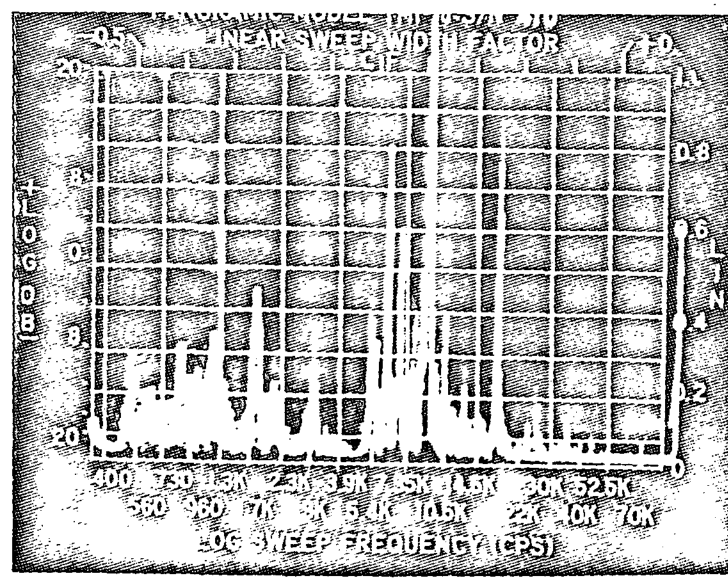


T=1850:00 After Purge, Before Start of Fill

NOT REPRODUCIBLE



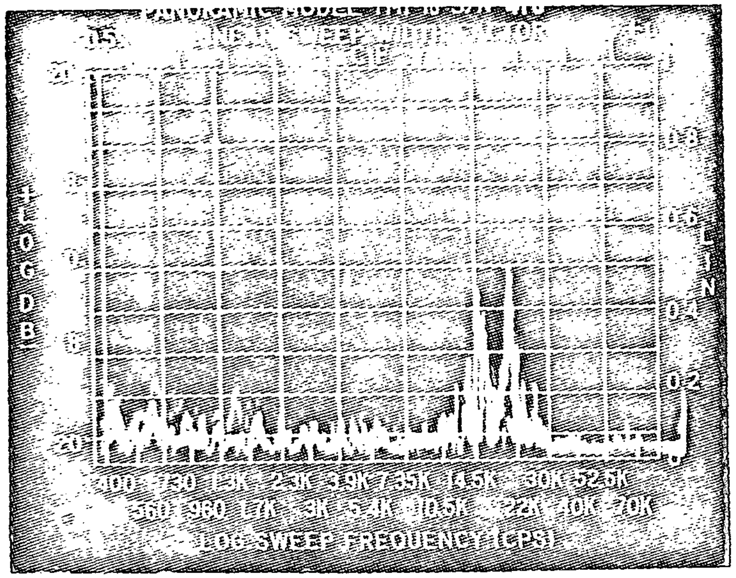
T=1850:50 Start of Fill Line Flow



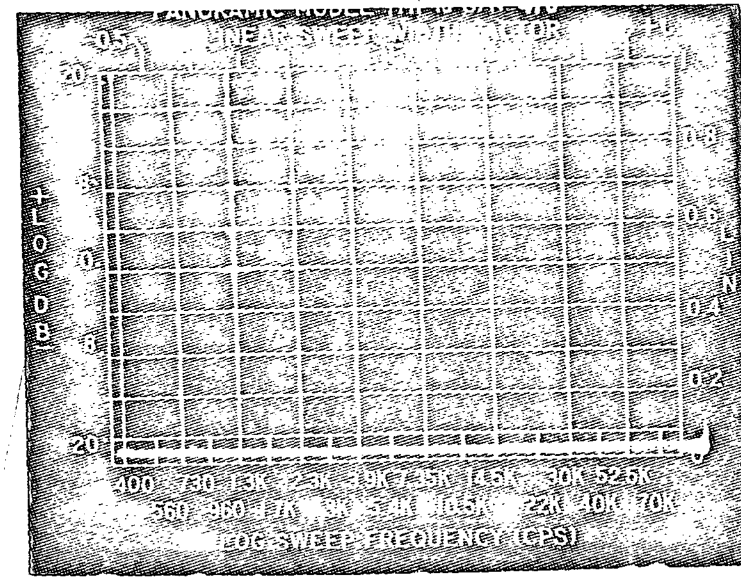
T=1858:20 During Fill Line Flow

Figure 11

Purge and Flow
Channel 1

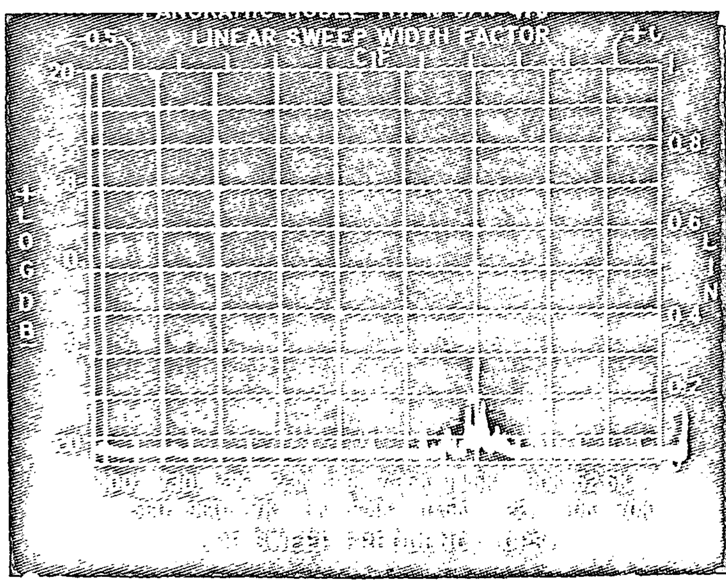


T=1848:50 During Purge

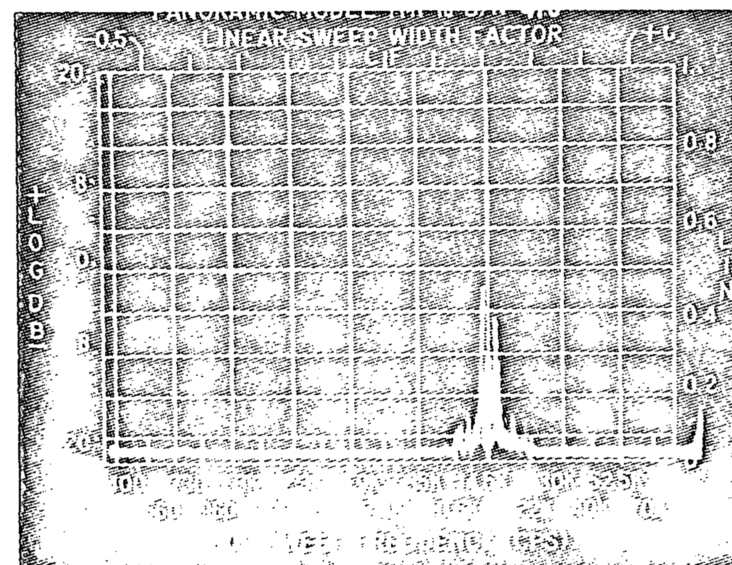


T=1850:05 After Purge, Before Start of Fill

NOT REPRODUCIBLE



T=1851:00 Start of Fill Line Flow



T=1851:25 During Fill Line Flow

Figure 12

Purge and Flow
Flex Purge Line
Channel 2

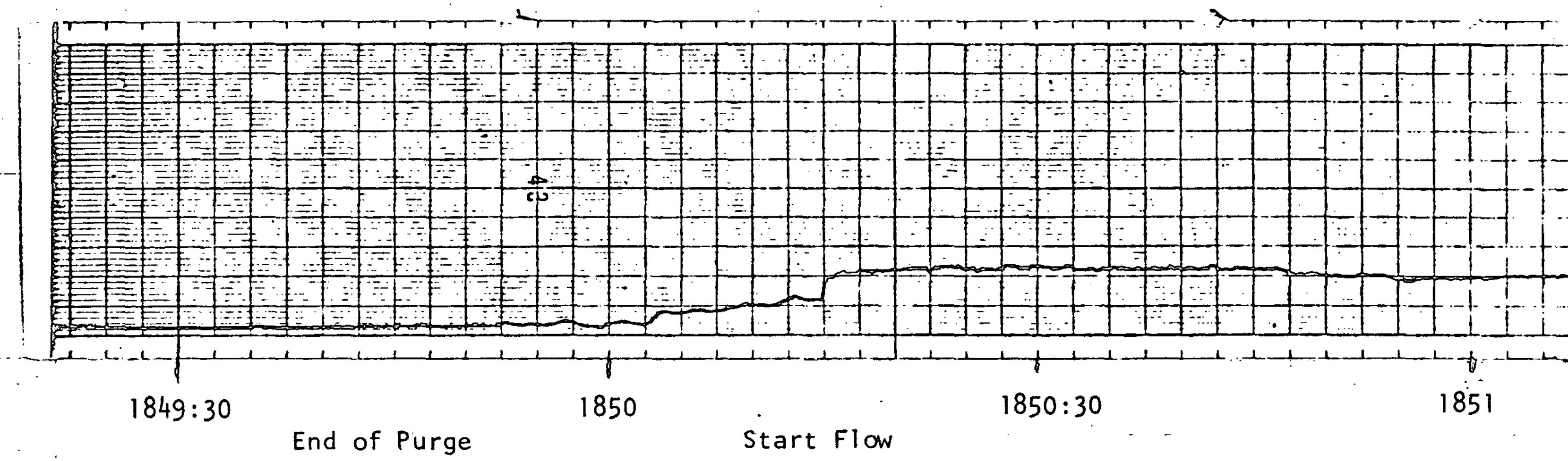


Figure 13

Start of Chill Down Flow
Channel 3

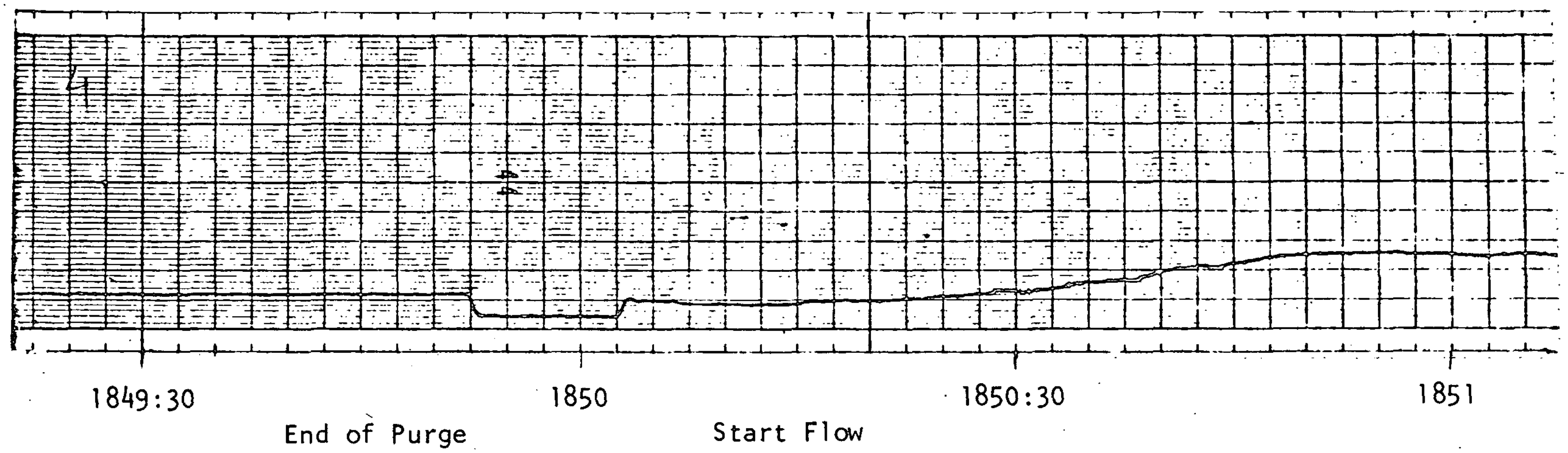


Figure 14

Start of Chill Down Flow
Channel 4

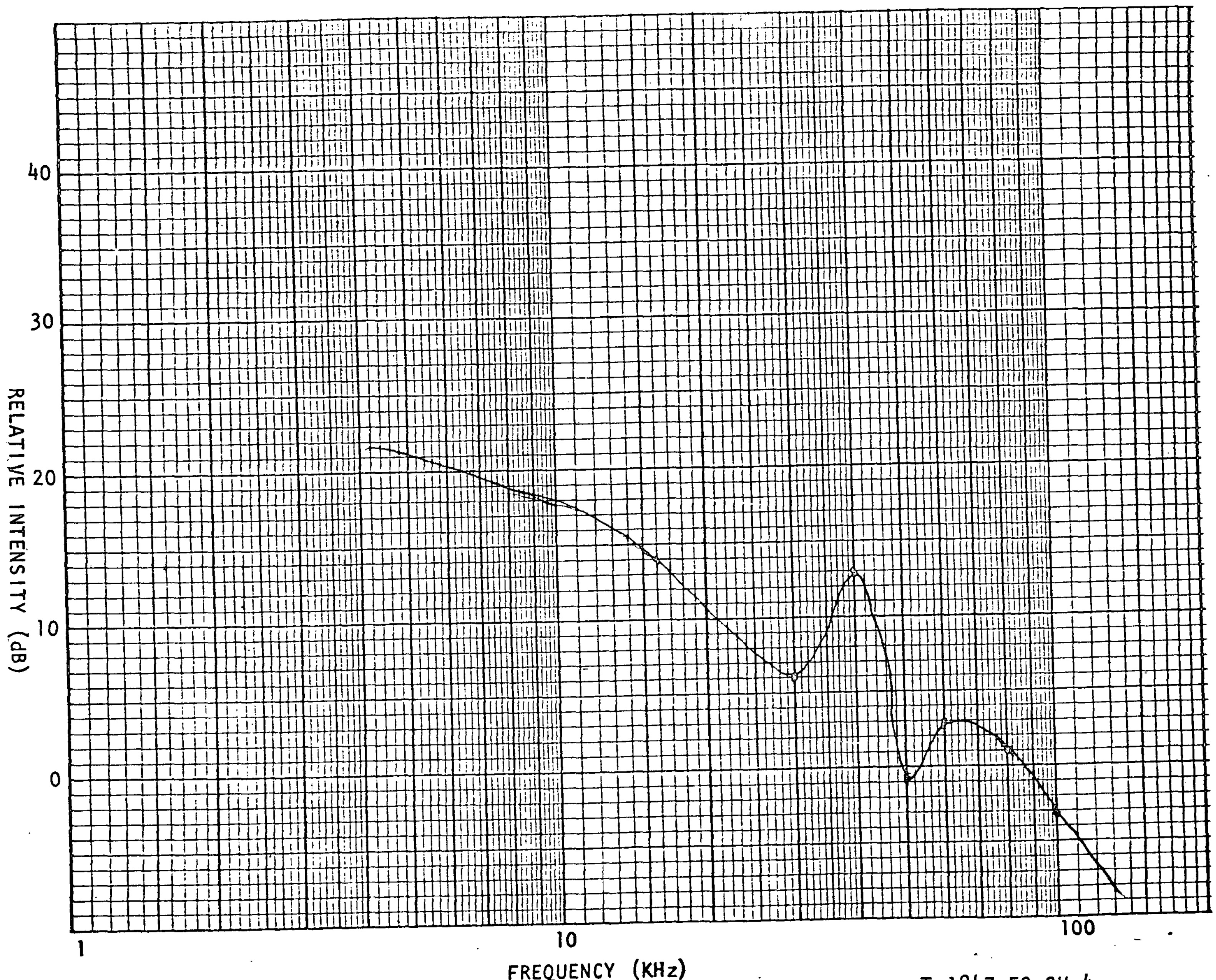


Figure 15

T=1847:50 CH 4
During Fill Line Purge

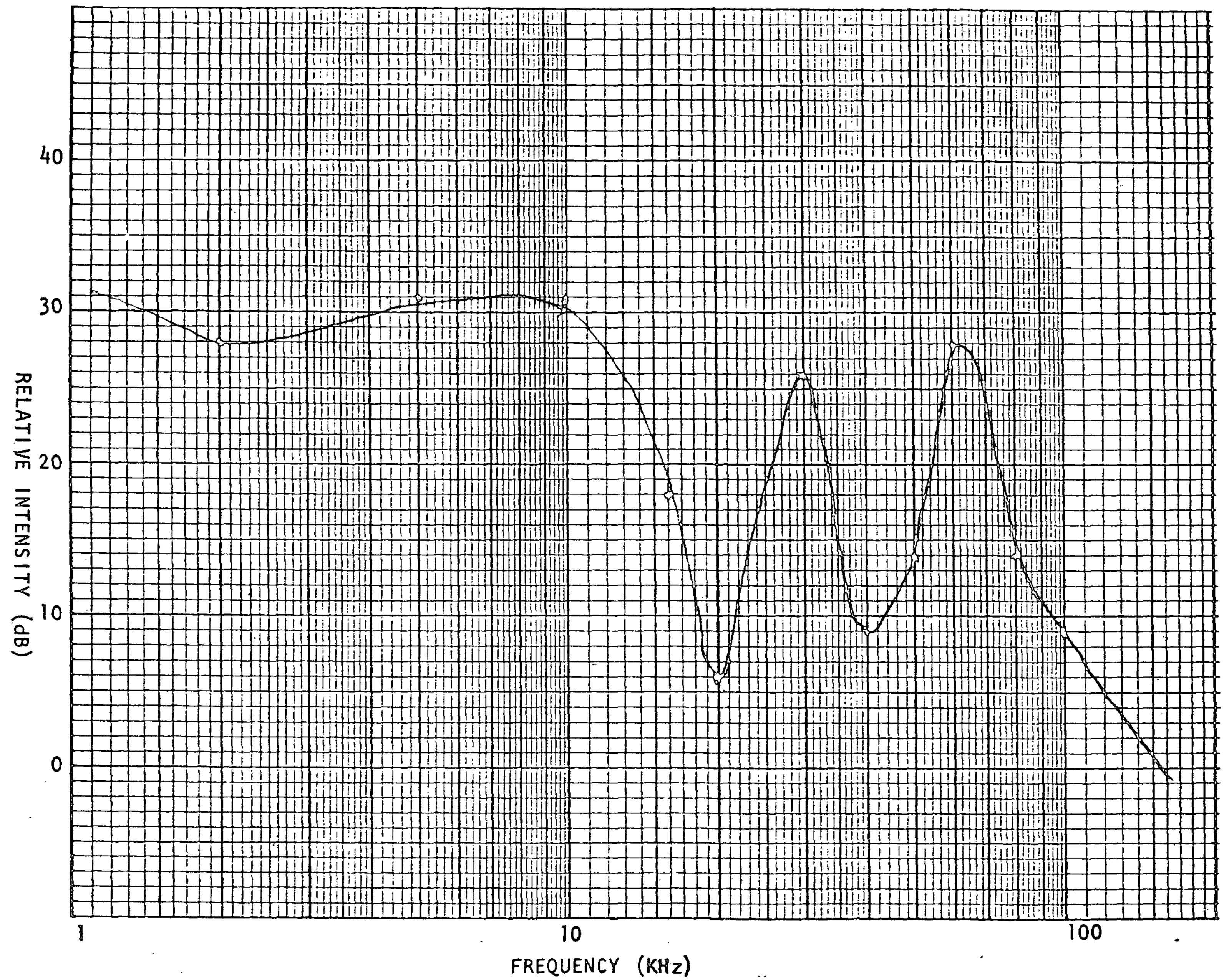


Figure 16

T=1851:00 CH 4
Fill Line Flow
(One Minute After Start)

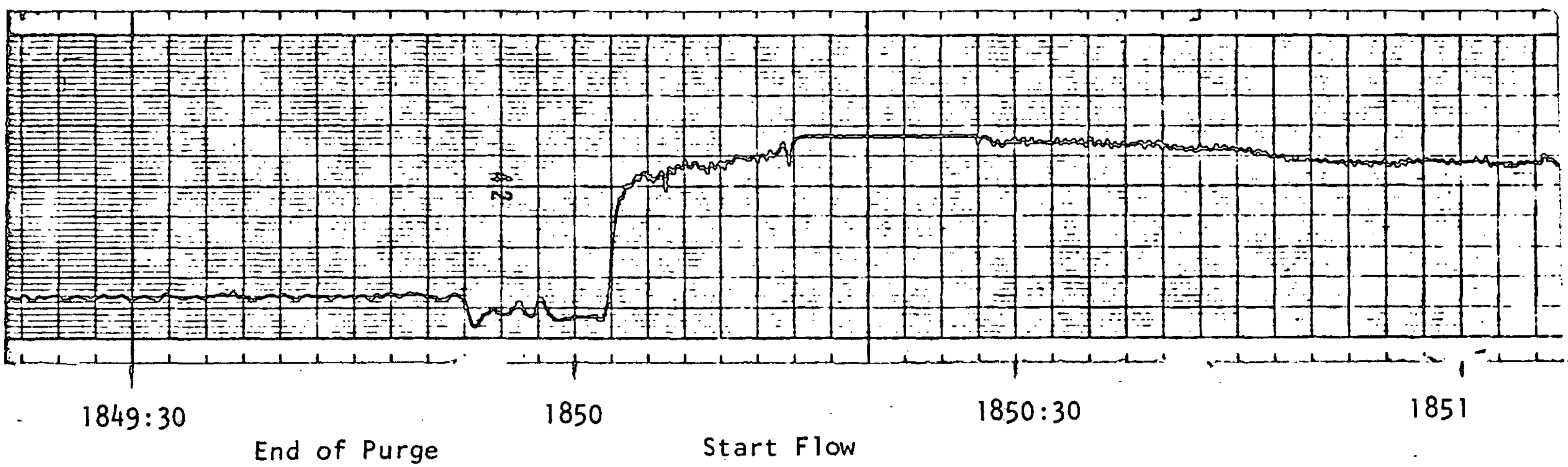


Figure 17

Start of Chill Down Flow
Channel 5

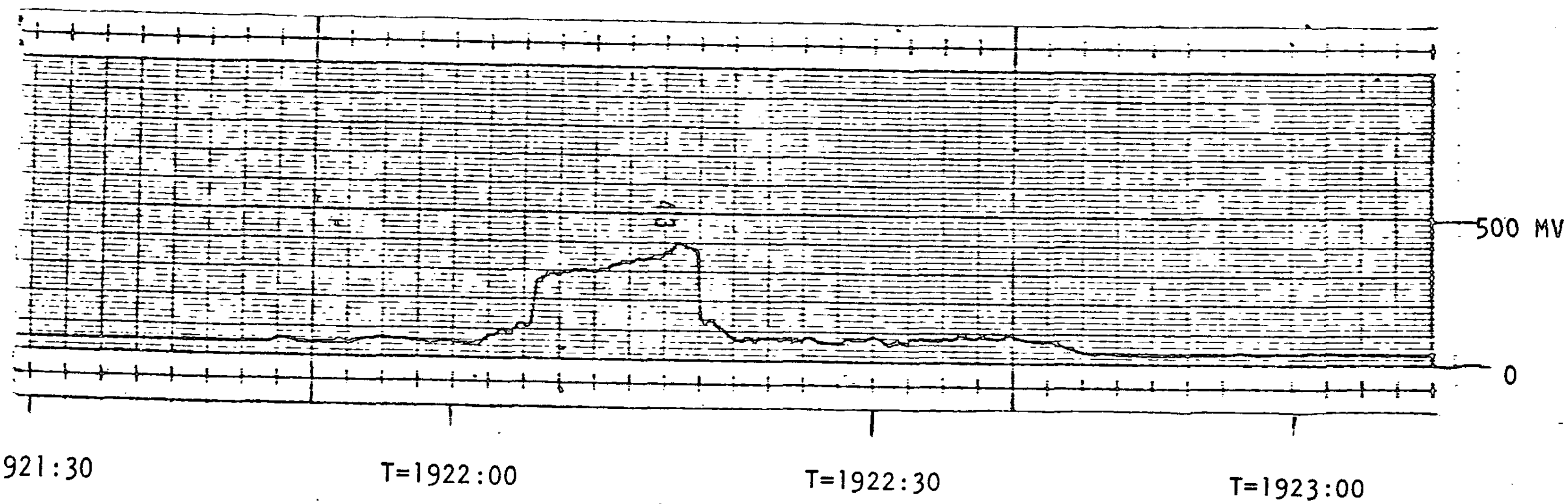
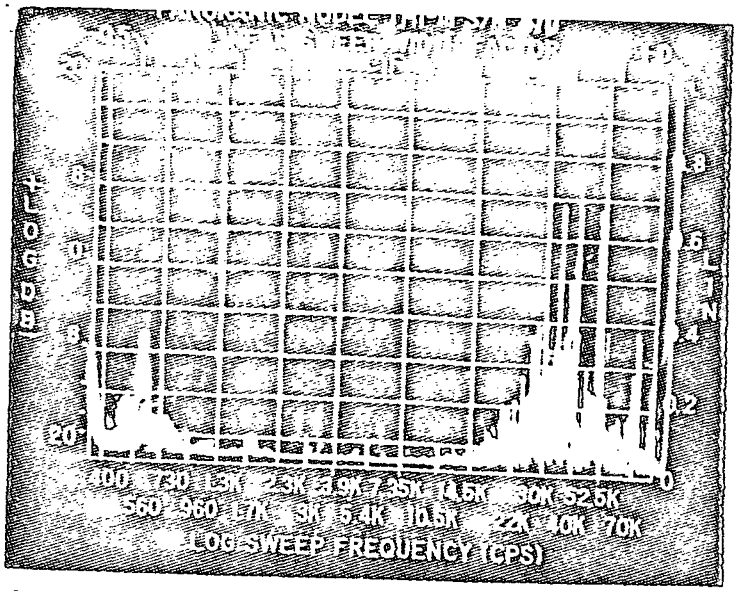
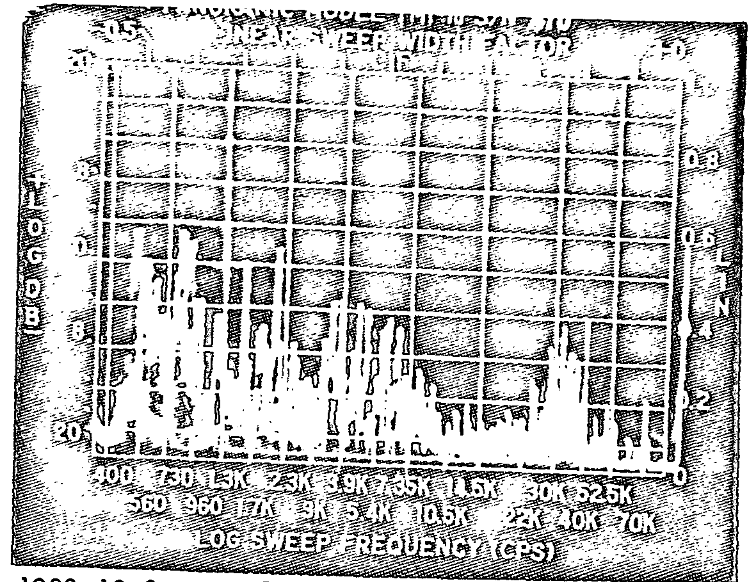


Figure 18

Phase Change
Channel 3

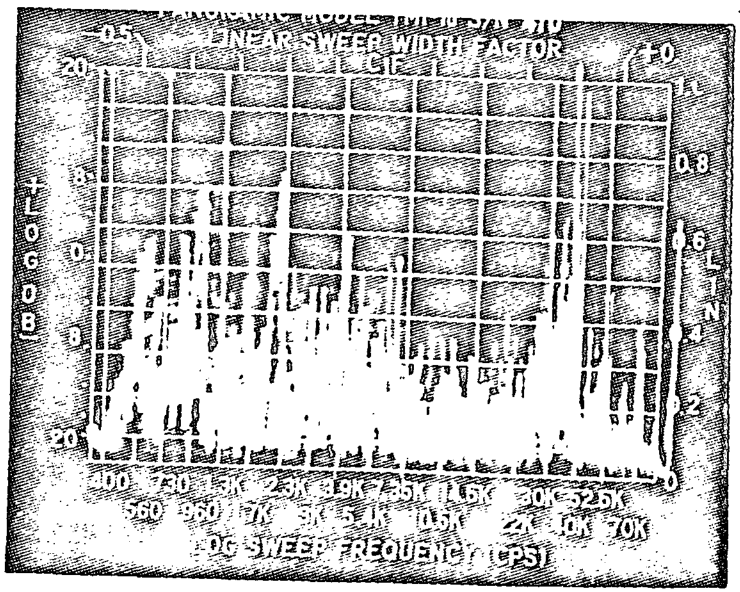


T=1922 Gas Flow

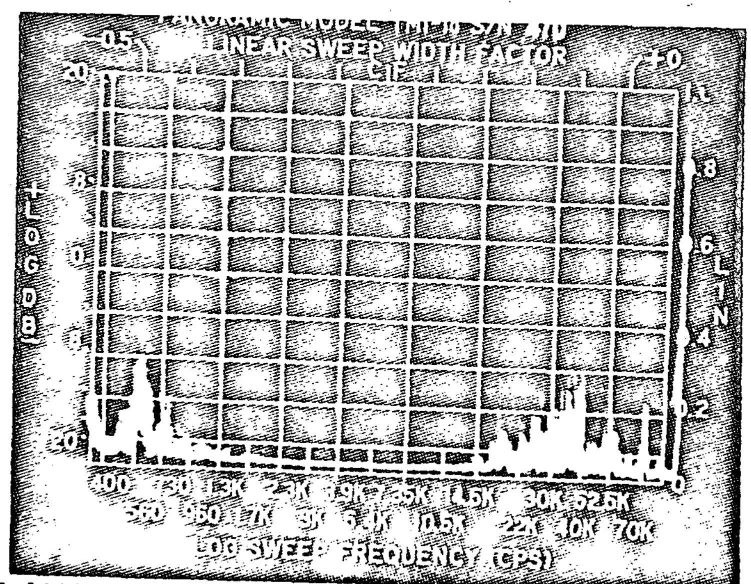


T=1922:10 Start of Liquid Flow

NOT REPRODUCIBLE



T=1922:35 Boiling



T=1922:59 Liquid Flow

Figure 19

Vent Line, Phase Change
Channel 3

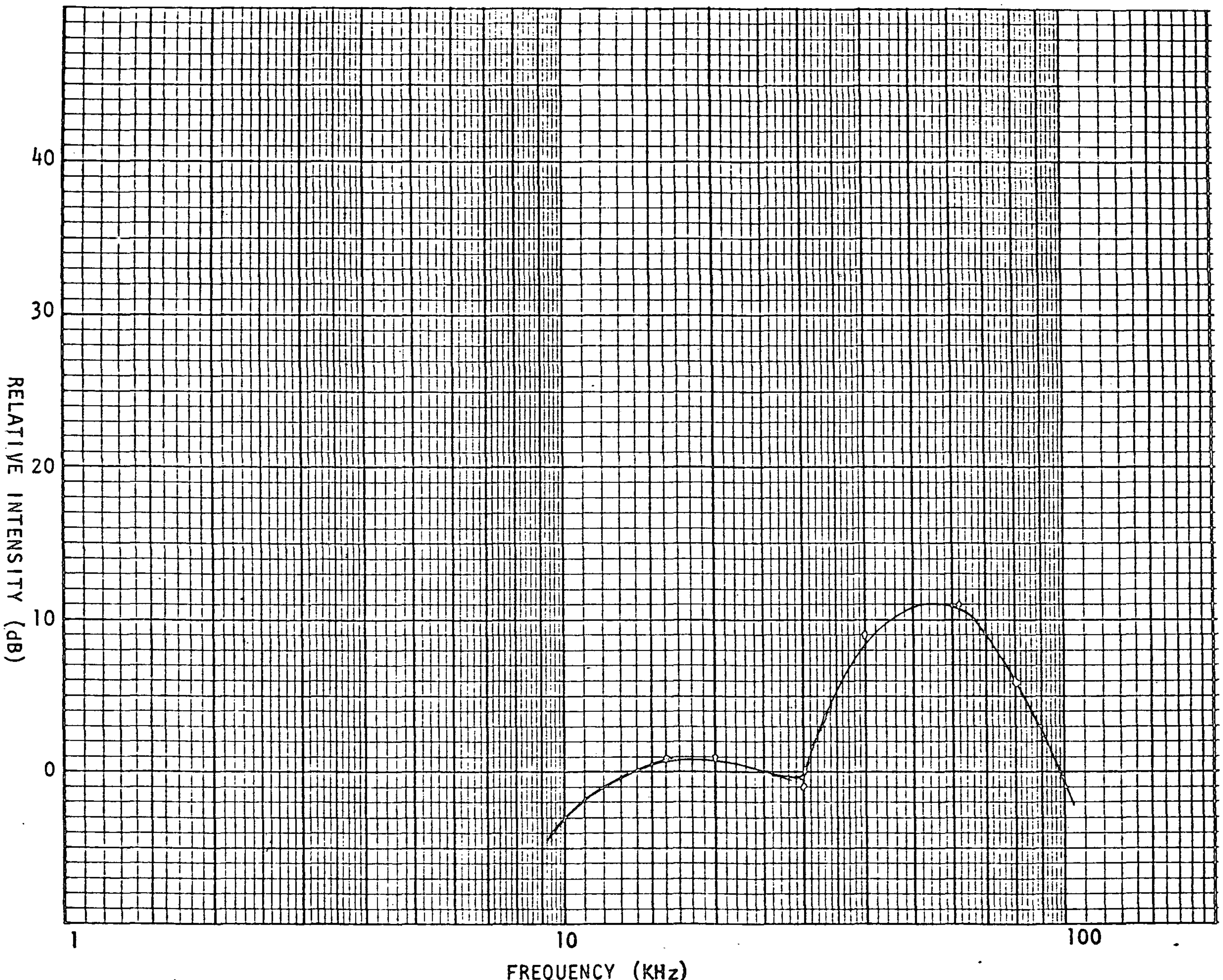


Figure 20

T=1922:00 CH 3_
Gas Flow Thru Vent Line

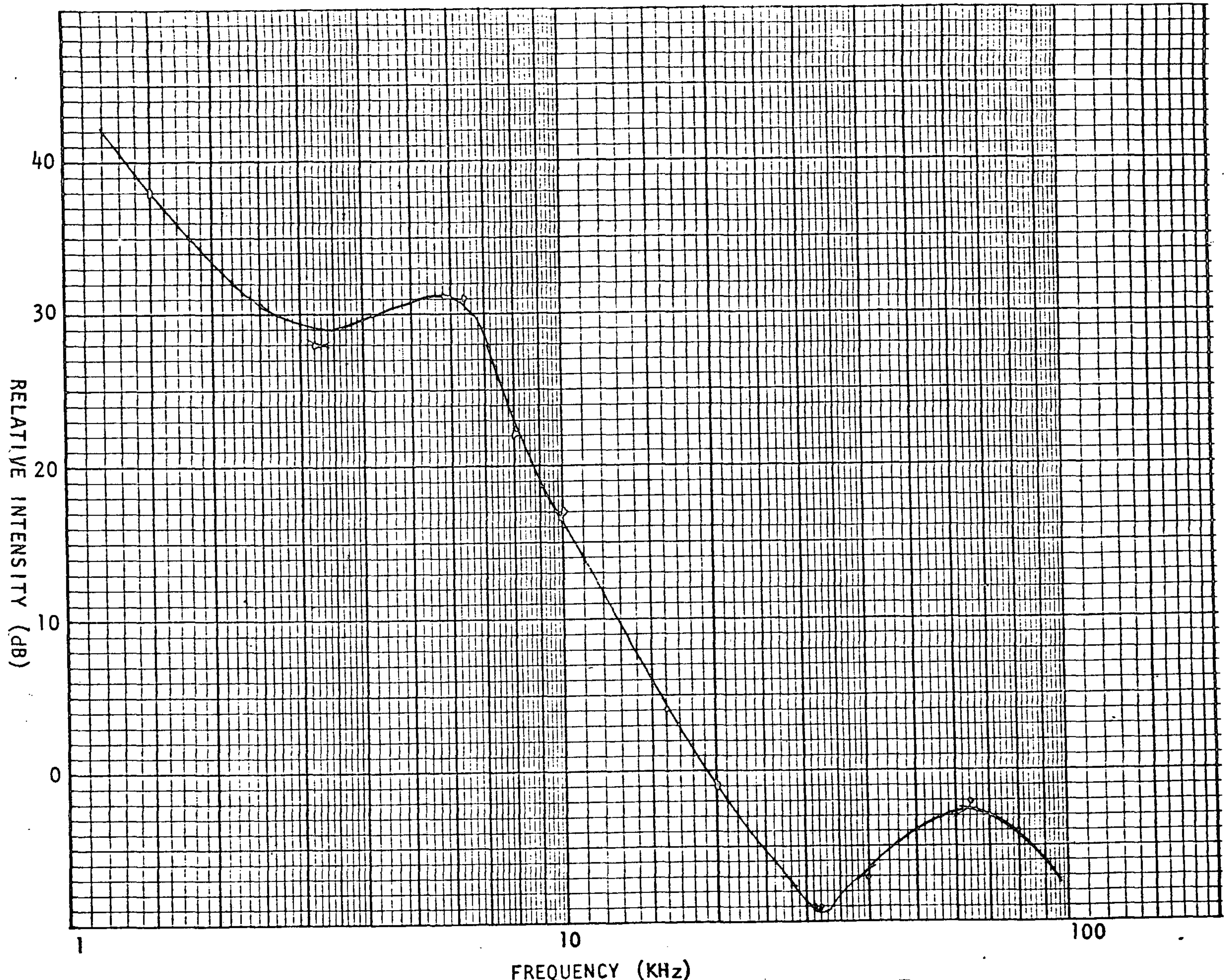


Figure 21

T=1922:10 CH 3
Start of Phase Change

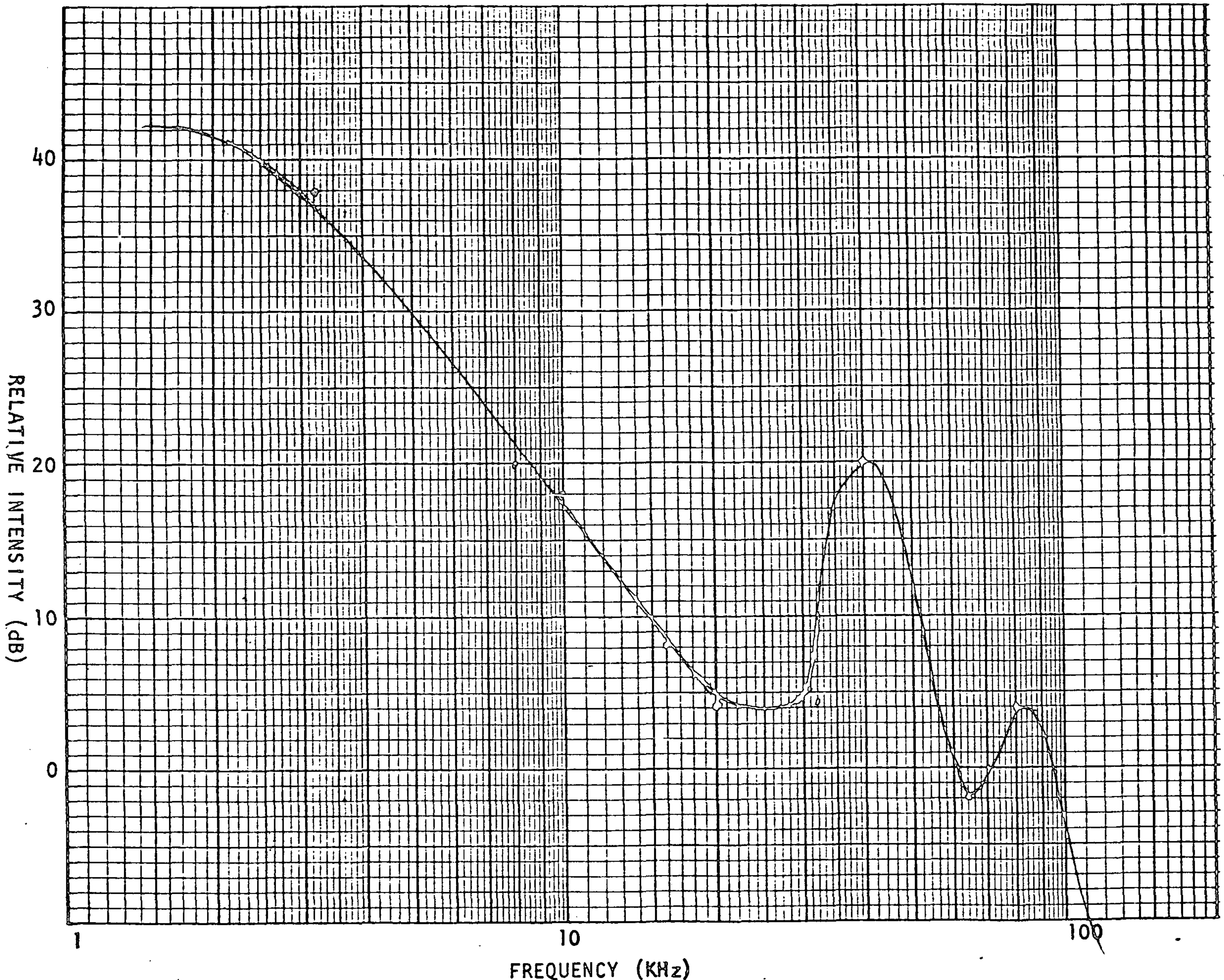


Figure 22

T=1922:35 CH 3
Peak Turbulence During Phase Change

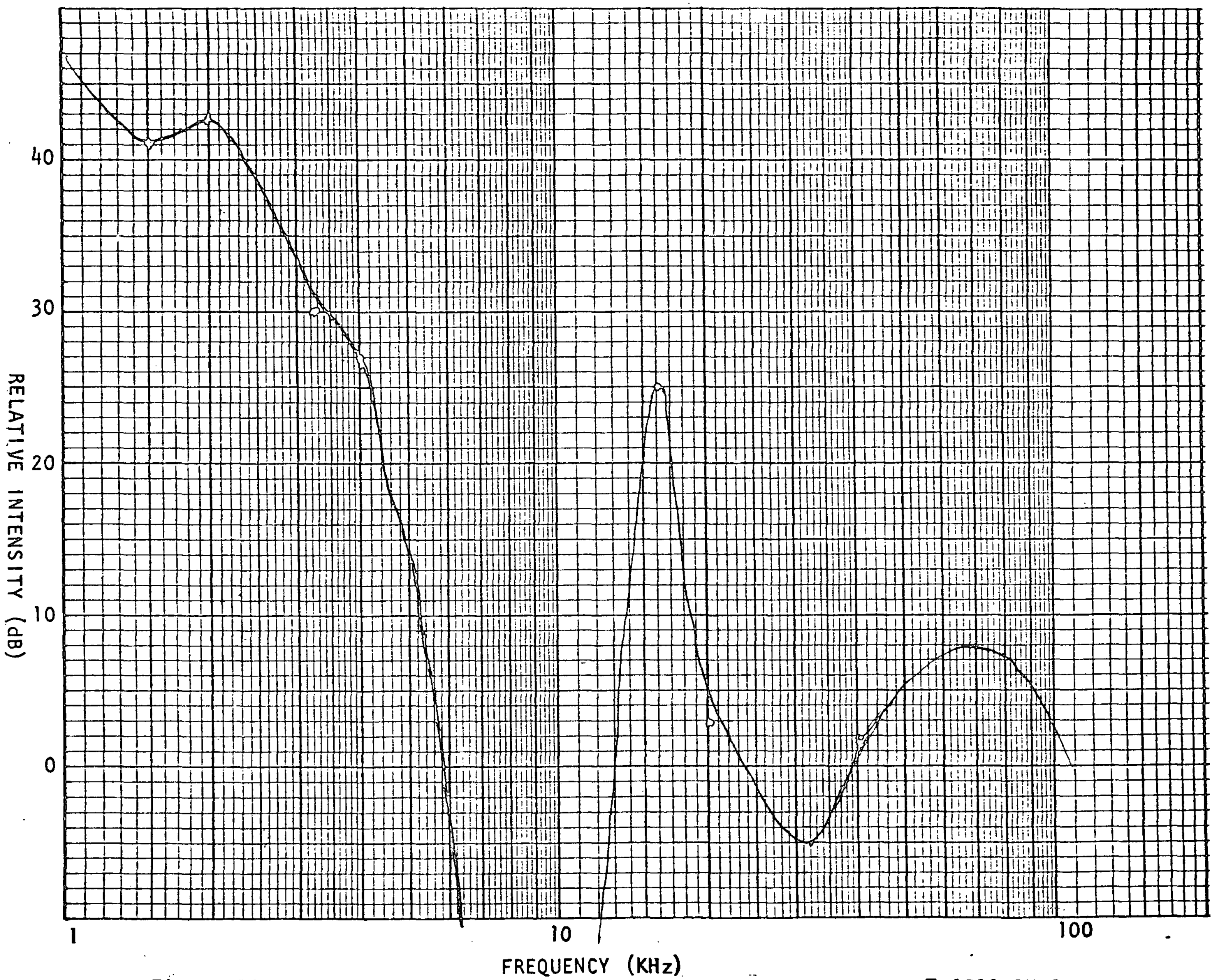


Figure 23

T=1929 CH 3
Disconnect Sampling Equipment

SECTION III

RECOMMENDATIONS

3.1 FUTURE APPLICATIONS

Applications of the contact sensor leak detector cover both the aerospace and nonaerospace fields. Aerospace field applications cover both ground and flight systems. The following examples provide an insight to the potential uses of the system but do not attempt to cover all applications.

3.1.1 Ground Systems and Ground Checkout of Flight Systems. Contact sensors can be mounted externally on or near valves, regulators, check valves and seals. Each sensor can detect leakage, can compare the flow through the components to previous flows, can detect cracking pressures and seating pressures of check valves and can locate flow restrictions. An application of the contact sensor system would be for ground tests of the Skylab oxygen supply check valves. Here it could detect back leakage through these valves without breaking into the system. It could also detect and locate external leaks; however, under field conditions the existing state of the art sensor cannot go to the bubble tight range.

A second but related application is for the failure prediction and failure detection of valves, bearings or any sliding or rotating moving parts. Periodic acoustical signatures can be taken of these components and compared to previous signatures. By comparing the sonic and ultrasonic frequencies generated by these components at various stages of movement, any change in surface roughness, drag or electrical arcing can be detected. Any change in flow characteristic can also be detected by comparing previous flow generated sounds. Restrictions in these components can be detected by this method.

The use of the ultrasonic leak detector unit as a flow detector was demonstrated during laboratory tests. Both flow and pressure decay test followed repeatable patterns and by establishing a base line, pressures of the flowing gas could be determined without looking at the gages.

For critical tanking operations of cryogenic fluids, the contact sensor can identify gas flow, start of liquid flow, cool down and solid liquid flow. This was demonstrated at the NASA Cryogenic Facility. It can also locate a failure in insulation or vacuum by detecting the boiling of the cryogenic fluid. This was very apparent during the cool down of cryogenic lines at the Cryogenic Facility. These capabilities could be applied to tanking of flight systems where it is necessary to know when the maximum amount of cryogenics are on board.

3.1.2 Flight Systems. Many of the capabilities discussed in the ground system apply to flight systems. For permanent location on flight systems the transducer case would be eliminated. Critical valves and other critical components would have the transducer built in. By designing a very small crystal and mounting it and its loading mechanism in a machined hole in the valve body little weight is added. In the event of a crystal failure a screw off cover would be removed and the crystal changed.

Ultrasonic sensing systems should be developed and qualified in parallel with the flight hardware. An example of this is the Space Shuttle engines. The engine contractor and the ultrasonic sensor contractor should work together during the design portion of the contract. The engine contractor would identify the critical areas and the sensor contractor would design the best system for each application. The engine contractor would design-in mounting fixtures for these transducers. The ultrasonic sensors would then be used during development testing to provide engine data as well as to provide further sensor development data.

This parallel development should hold true for all flight applications. Add-on sensors increase the overall weight and cannot match the sensitivity of built in transducers.

A third area requiring further development is a small portable contact sensor system designed for leak detection and location under vacuum conditions. This would be used for repair and maintenance of Skylab, Space Shuttle, space station and satellite systems in earth orbit. It would be designed for external and internal leak checks as well as to locate wear conditions on flight hardware.

3.2 SUMMARY

Testing to date has established that the ultrasonic contact sensor leak detection system has an important role to play during future space programs. Its ability to detect internal leakage, its ability to operate in a vacuum, its ability to monitor valve actuation, its ability to measure fluid flow, its ability to detect cryogenic fluid phase changes and its ability to detect wear conditions in moving parts all make it a valuable tool for use on future flights and for ground checkout. It should be emphasized that to take full advantage of this system it should be designed into each flight system and the time to do this is during the preliminary design of the flight hardware.

DISTRIBUTION

KSC

Name	Org	Copies
G. Williams	DE	1
D. Buchanan	DD	1
G. Merritt Preston	FP	1
A. Pickett	FP	1
S. Beddingfield	FP-A	2
H. McCoy	FP-B	1
R. Cerrato	FP-C	2
R. Smith	FP-A	1
J. Atkins	SF	1
A. Zeiler	DD-MDD	1
W. Clautice	DD-MDD-1	1
E. Davis	DD-MDD-3	1
B. Tolson	DD-MDD-32	20
A. Carraway	DD-SED-4	1
P. Toft	DD-SED-4	1
R. Sannicandro	DD-SED-4	2
J. Deese	DD-SED-4	1
P. Rogers	DD-EDD-22	2
J. Johnson	DD-EDD-22	2
T. Lamontagne	SO-LAB-1	1
R. Yorio	SO-LAB	1
J. Larson	SO-LAB-3	1
H. McCluer	SO-ENG-4	1
R. Laakso	SO-ENG-4	1
F. Williams	LS-ENG-3	1
W. Lackie	LS-ENG-31	1
W. Risler	LS-TEC	1
D. Moxley	LS-ENG-32	1
S. Ewing	LS-ENG-32	1
H. Lamberth	LS-ENG-3	1
J. Harrell	AD-PAT	2
W. Howard	AD-PRO-33	1
E. Dickinson	LV-MEC-32	1
G. Waldrop	LV-MEC-32A	1
C. Whiteside	LV-GDC-3	1
J. Jamieson	LV-GDC-28	1
F. Penovich	LV-GDC-3	1
R. Upson	IN-MSD-2	1
W. Helms	LV-INS-22	1
R. Brooks	TS-TSM	1

MSFC

Name	Org	Copies
H. Craft	PD-MP-T	1
W. Voss	SNE-ASTR-SE	6
W. Escue	ASTR-IM	1
R. Godfery	PD-RV	1
MSC		
R. Thompson	LA	2
F. Mosby	Rocketdyne	1
D. Kitchel	G.E.	1
R. Weiner	JPL M/S 2333-103 4800 Oak Grove Dr. Pasidenia, Calif. 91103	1
C. Janka	Space Div. NAR 1214 Lakewood Bld Downey, Calif. 90241 M/S AD-75	1

TOTAL COPIES 80