DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER
ATLANTIC CITY, NEW JERSEY 08405
PROPULSION & FIRE PROTECTION BRANCH NA-420

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DATA REPORT NO. 94

THE FEASIBILITY OF DETECTING A BURNER-CAN BURN-THROUGH BY SONIC MEANS

PROJECT NO. 181-522-01X

Prepared by: Richard G. Hill

Purpose

To determine the feasibility of detecting a burner-can burn-through by sonic means.

Background

Fire detectors in service have detected burner-can failures, but also some have gone undetected and often undiscovered until routine ground inspection. A burn-through impinging on a vital aircraft structure could endanger the entire aircraft if an early detection is not obtained.

Method of Approach

This study was divided into two phases. Phase I being the analysis of the sound spectrum from a jet engine burn-through, and Phase II being the testing of a sonic burn-through detection system.

Equipment and Description:
Phase I

An uncowled J47 turbojet engine mounted in a test stand was used as the test engine for the burner-can burn-through sound spectrum analysis. The No. 8 burner-can was modified to produce a burn-through flame through a 1-inch-diameter hole. Stainless steel plates could be bolted over the hole to reduce it to a 3/4- or 1/2-inch-diameter hole. See Figures 1 and 2 for a photograph of the J47 engine and the burn-through flame produced.

A Sony Model TC-500 tape recorder and microphone were used to record the burn-through tests. The tapes were then sent to the Magnavox Co. and analyzed using a wide band analyzing technique.

Procedure
Phase I

The J47 engine was run using various size burn-through holes. An aluminum plate was fastened over the burn-through hole, and the engine brought up to operating power with the fuel shut off to the No. 8 can. The Sony tape recorder was located in the blockhouse with the microphone located, on the ground, approximately 10 feet from the engine. With the recorder operating at 7.5 inches per second, the fuel was turned on to the burner-can. The added heat in the can caused the aluminum plate to weaken and be blown away. The length of time taken to burn-through the aluminum plate depended on the thickness of the plate and the pressure in the burner-can. The burn-through flame was either allowed to exit into the open air or to impinge on a firewall material. These recordings were then sent to Magnavox for analysis.

Discussion and Results
Phase I

The results of the J47 burn-through analysis can be seen in Figures 3 through 13. The four representative tests shown are:

1. A 1-inch unrestricted burn-through (Figures 3, 4, and 5). The flame was analyzed between 2 KHz and 5 KHz.

2. A 1-inch burn-through impinging on an 8- by 8-inch plate of .015 stainless steel (Figures 6, 7, and 8). The flame was analyzed between 2 KHz and 5 KHz.

3. A 1-inch burn-through impinging on an 8- by 8-inch plate of .032 titanium (Figures 9 and 10). The flame was analyzed between 200 Hz and 10 KHz.

4. A 1/2-inch burn-through impinging on an 8- by 8-inch plate of .032 titanium (Figures 11, 12, and 13). The flame was analyzed between 2 KHz and 5 KHz.

The relative darkness of the graphs (in Figures 3, 4, 6, 9, 10, 12, and 13) for any given frequency, indicate the sonic intensity at that frequency.

The results of these tests show that when a burner-can burn-through occurs, a large change also occurs in the overall sound spectrum of the engine. The broad-band-sound spectrum power increases when the burn-through occurs.

Due to the quality of the equipment used to record the burn-through, exact figures on the amount of power increase could not be determined. However, it was determined that the increase was of a sufficient amount as to indicate the feasibility of using it as a means of detecting a burner-can burn-through.

Equipment and Description
Phase II

A fully cowled J57 engine (see Figure 14) mounted on a B-57 was used as a test engine and environment for the sonic burn-through detection tests. Four Sony microphones and a Sony Model TC800B tape recorder were used as sensors and amplifier for the sonic detector.

The sonic detector (see Figure 15) was manufactured by Magnavox. It was a rather simplified instrument designed to test a method of detecting a burner-can burn-through and not to be evaluated on its mechanical design. The detector was designed so that a steady state sound level produced by an engine could be set in the detector, and a 3db increase would produce an alarm. The detector worked in the range of 2 KHz to 10 KHz. A 1-second delay was built into the detector to provide protection against false alarm.

Procedure
Phase II

Four Sony microphones were mounted on a J57 fully cowled engine. The microphones were located around the circumference of the engine on the low-pressure compression case. The exact location of each microphone can be seen in Figures 16 and 17. The microphones were connected to a panel in the blockhouse (Figure 15). Each microphone was connected, in turn, one at a time, to the sonic detector using the Sony tape recorder as a preamplifier.

Because of the number of runs necessary, it was decided to simulate a burn-through on the J57 by using air valves and hot air from the diffuser case and burner-can case (see Figures 18 and 19). Since the noise produced by a supersonic jet is somewhat dependent on the temperature of the jet, the higher temperatures will produce greater noise levels. It is also true that the amount of noise is also dependent on the size of the burn-through hole, with more noise coming from the larger jets. Therefore, the total power output of a 1-inch (the size hole used in these tests) jet, with a temperature of 500°F, is approximately the same as the total power output of a smaller size jet at a temperature of 3500°F. Because the sonic detector worked on the change in the total power, this simulation was deemed adequate.

A thermocouple was placed over the passage of each valve to assure that the valve opened and closed properly. One of the valves was located forward of the firewall on the diffuser case and the other on the burner-can case aft of the firewall.

The detector was tested using each of the microphone locations at 60, 70, 80, and 90 percent rpm. The engine was brought to the desired rpm and then the detector was set for the sound output of the engine. One of the burn-through valves would then be opened and the detector reaction monitored. A tape recording was also made of the imput to the detector on each test. The recordings were made on the tape recorder used as a preamp for the detector.

Discussion and Results
Phase II

The results of the sonic detector tests on the J57 engine are shown in Table 1. At low rpm (60 and 70 percent), detection was obtained from all four microphone locations whether the burn-through occurred forward or aft of the firewall. At 80 percent rpm the right microphone failed to detect the burn-through forward or aft of the firewall, and at 90 percent no detection could be obtained from any of the microphone locations. The probable cause for this lack of detection at 80 to 90 percent rpm was the quality of the microphones and preamp used and not the detector itself. The noise level and 90 percent rpm were higher than the maximum allowable for the microphones and preamp, thereby saturating the system and causing a loss in signal.

Summary of Results

1. It was possible to detect a burner-can burn-through by monitoring the broad band noise level, between 2 KHz and 5 KHz, of a jet engine.

2. A very simplified sonic detection system was tested and the detection principle was found to work quite well.

TABLE 1. EVALUATION OF SONIC DETECTOR

	Bottom Microphone	Left Microphone	Right Microphone	Top Microphone
60% RPM				
Diffuser Case	Detection	Detection	Detection	Detection
Burner-Can Case	Detection	Detection	Detection	Detection
70% RPM				
Diffuser Case	Detection	Detection	Detection	Detection
Burner-Can Case	Detection	Detection	Detection	Detection
80% RPM				
Diffuser Case	Detection	Detection	No Detection	Detection
Burner-Can Case	Detection	Detection	No Detection	Detection
90% RPM				
Diffuser Case	No Detection	No Detection	No Detection	No Detection
Burner-Can Case	No Detection	No Detection	No Detection	No Detection

ACKNOWLEDGMENT

The author wishes to acknowledge the valuable assistance given by the Magnavox Co. in their processing and analyzing of the burn-through tapes.

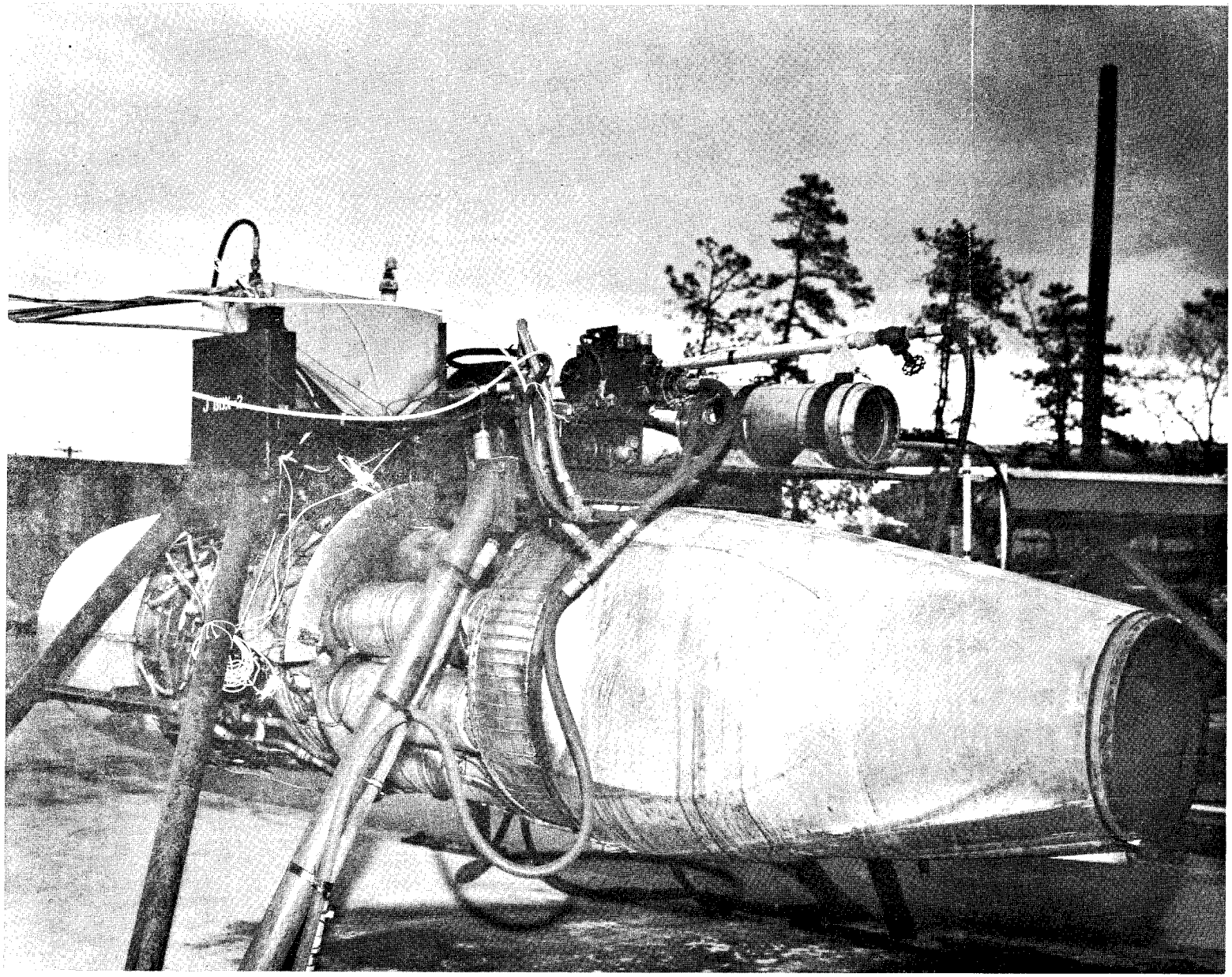


FIGURE 1 J47 ENGINE

FIGURE 2 J47 BURN-THROUGH AT 85 PERCENT RPM

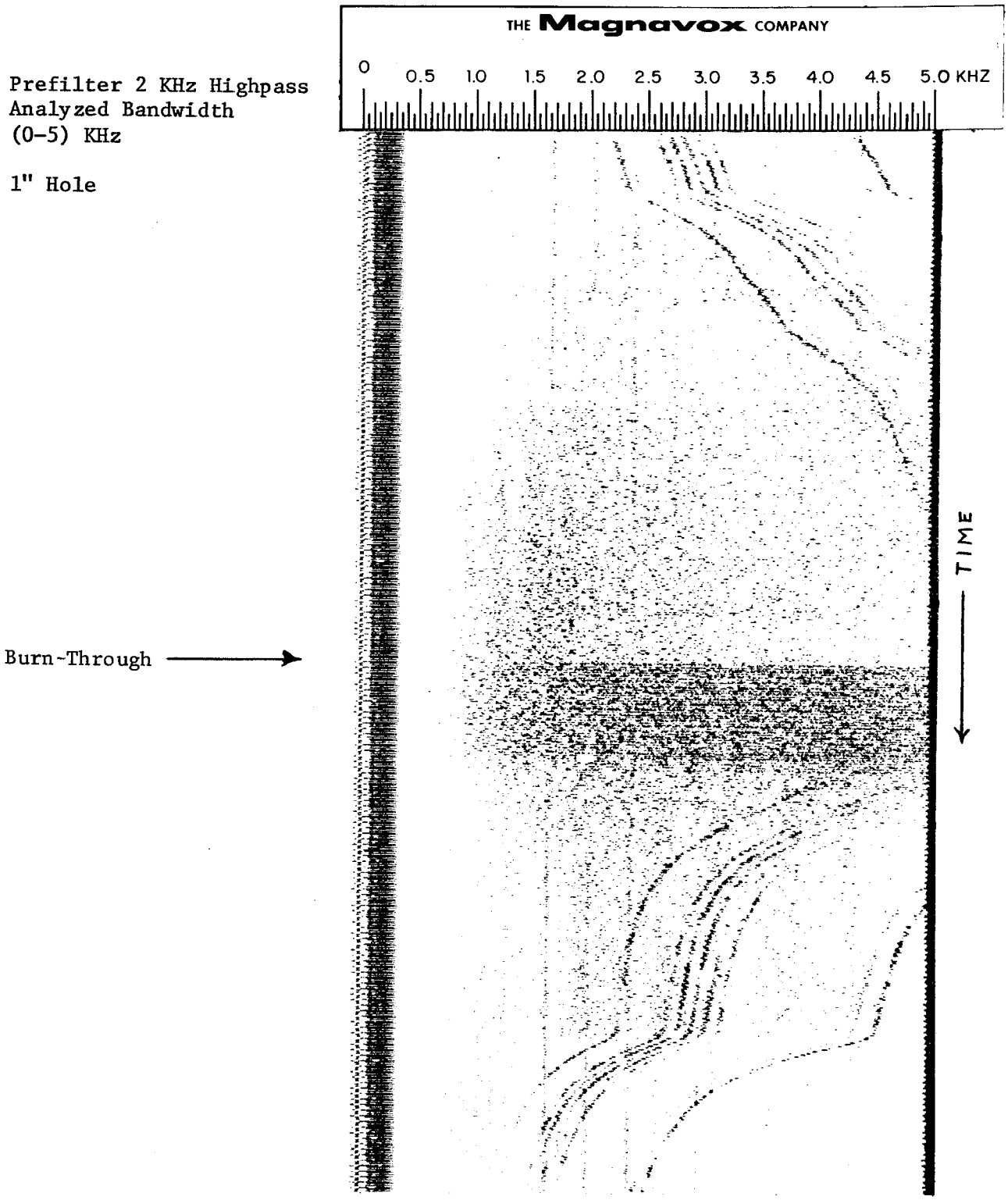
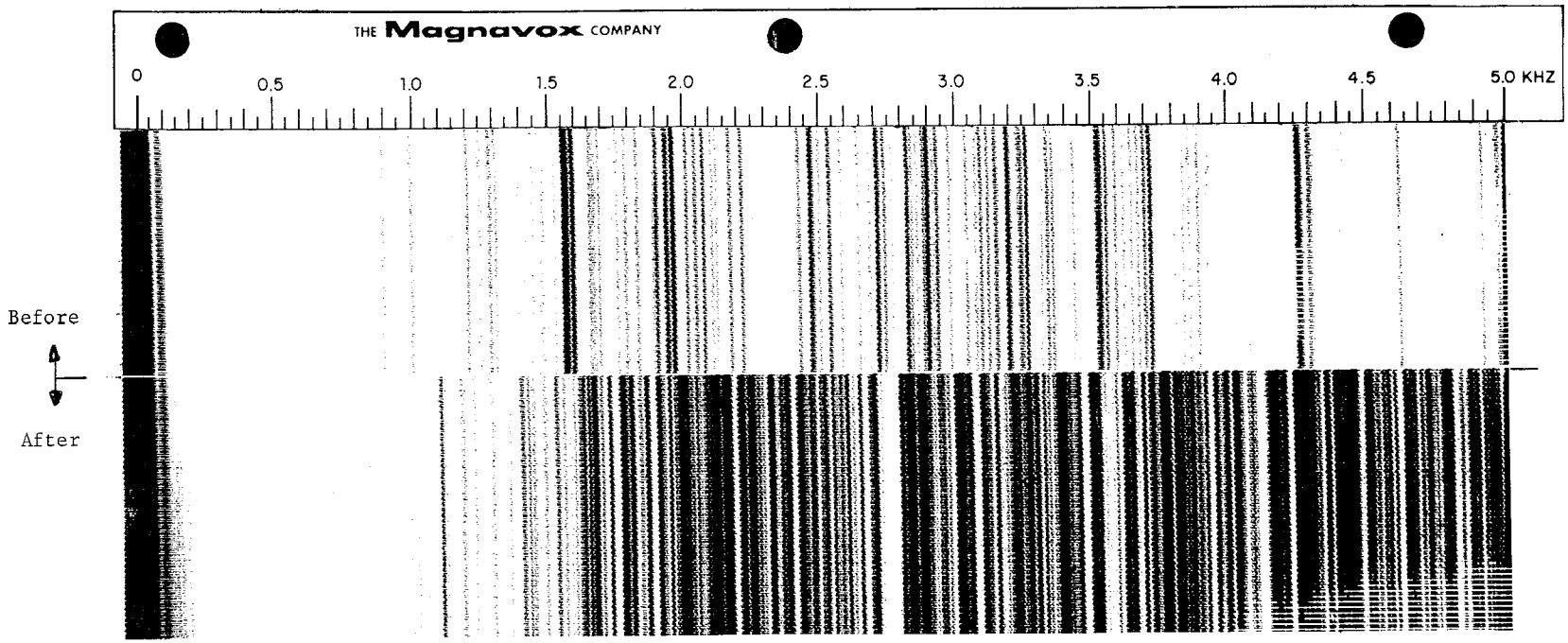


FIGURE 3 SONIC ANALYSIS OF A 1-INCH BURN-THROUGH IN A J47 ENGINE

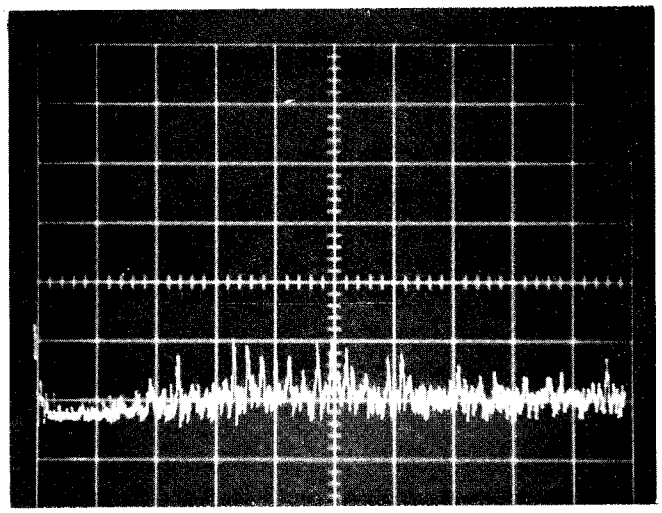


Prefilter 2 KHz Highpass
Analyzed Bandwidth (0-5) KHz

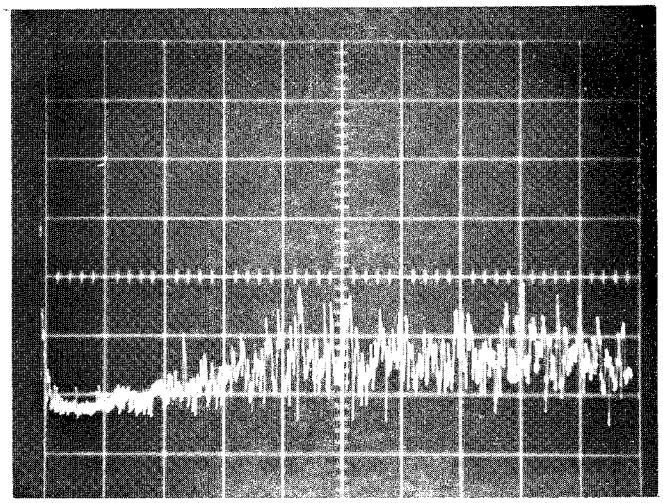
1" Hole

FIGURE 4 DETAILED SONIC ANALYSIS OF A 1-INCH BURN-THROUGH IN A J47 ENGINE

Prefilter 2 KHz Highpass
Analyzed Bandwidth (0-5) KHz
1" Hole



Before Burn Through



After Burn Through

FIGURE 5 SONIC ANALYSIS OF A 1-INCH BURN-THROUGH IN A J47 ENGINE AS SEEN ON AN OSCILLOSCOPE

Prefilter 2 KHz Highpass
Analyzed Bandwidth (0-5) KHz
1" Hole -0.015 S.S.

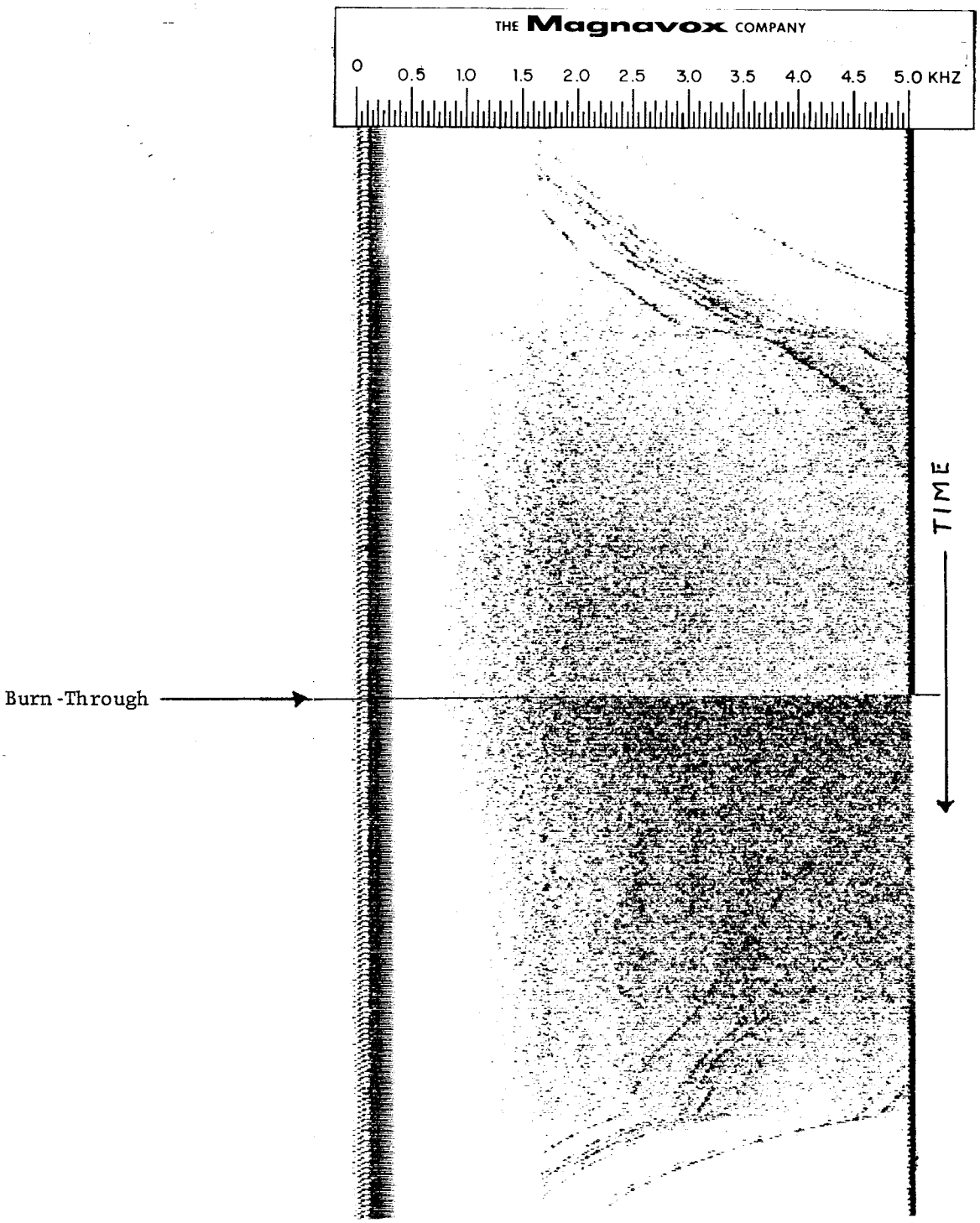
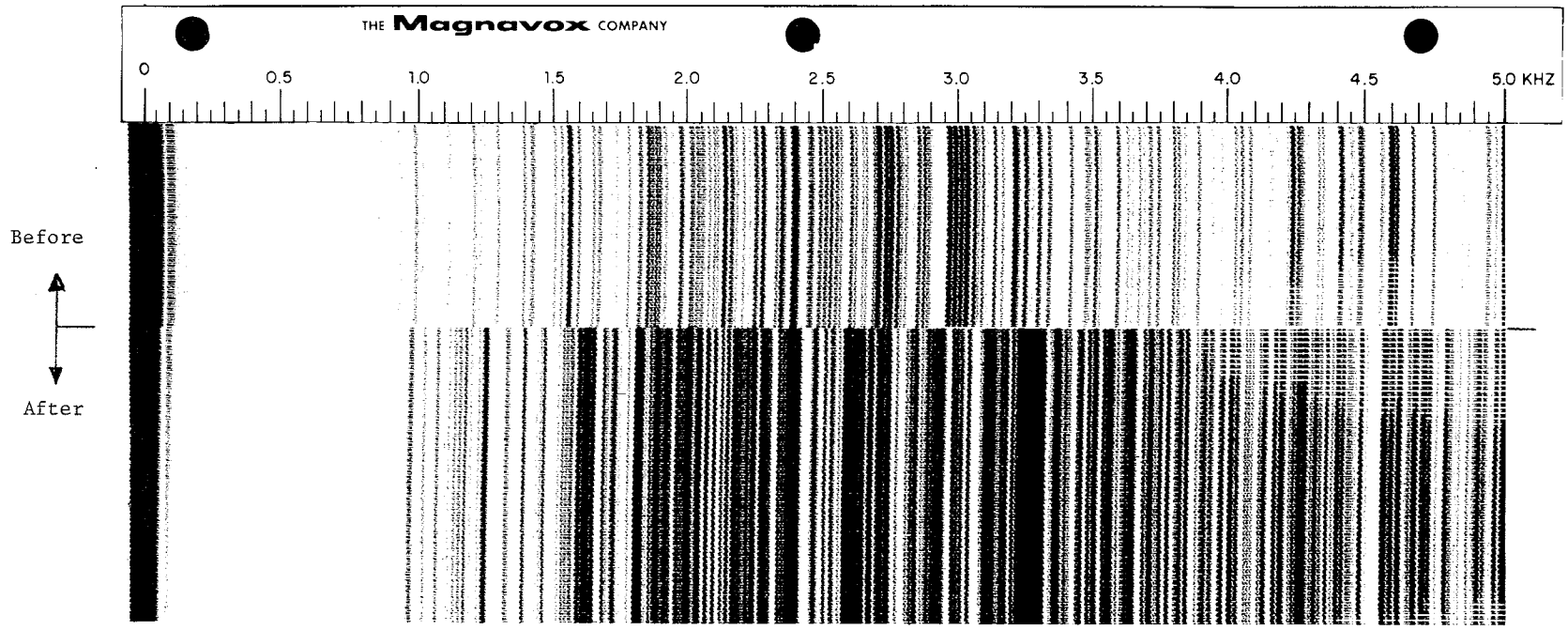


FIGURE 6 SONIC ANALYSIS OF A 1-INCH BURN-THROUGH IMPINGING ON A 0.015 STAINLESS STEEL PLATE

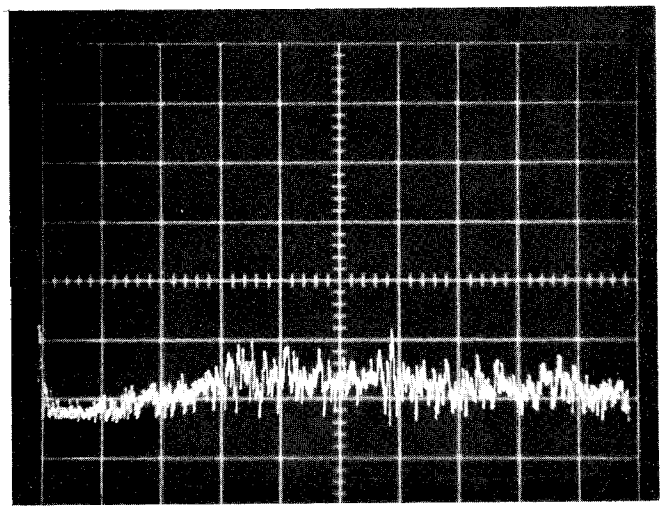


Prefilter 2 KHz Highpass
Analyzed Bandwidth (0-5) KHz

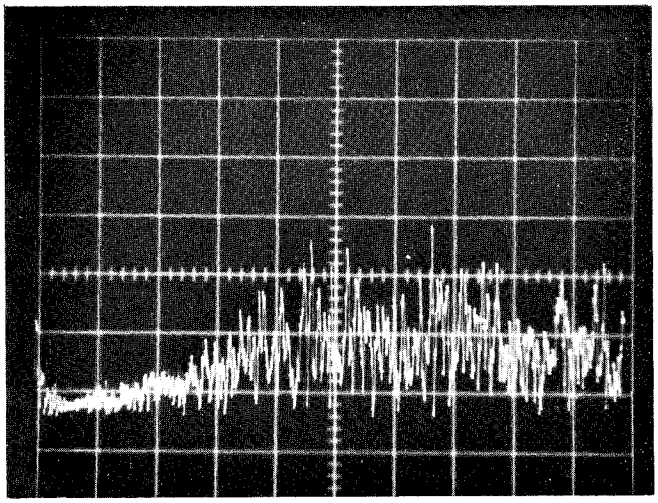
1" Hole - 0.015 S.S.

FIGURE 7 DETAILED SONIC ANALYSIS OF A 1-INCH BURN-THROUGH IMPINGING ON A 0.015 STAINLESS STEEL PLATE

Prefilter 2 KHz Highpass
Analyzed Bandwidth (0-5) KHz
1" Hole 0.015 S.S.



Before Burn Through



After Burn Through

FIGURE 8 SONIC ANALYSIS OF A 1-INCH BURN-THROUGH IMPINGING ON A 0.015 STAINLESS STEEL PLATE AS SEEN ON AN OSCILLOSCOPE

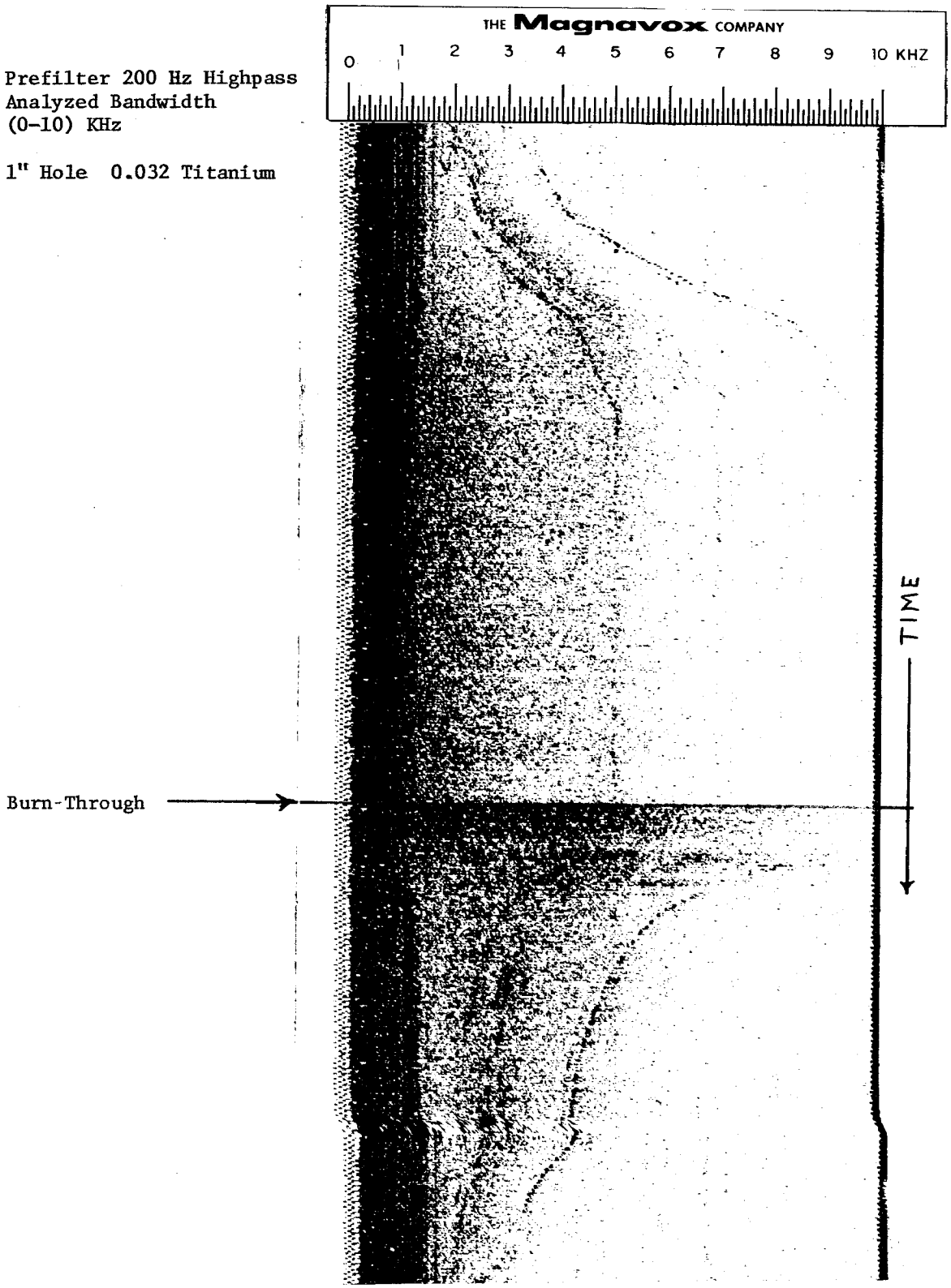
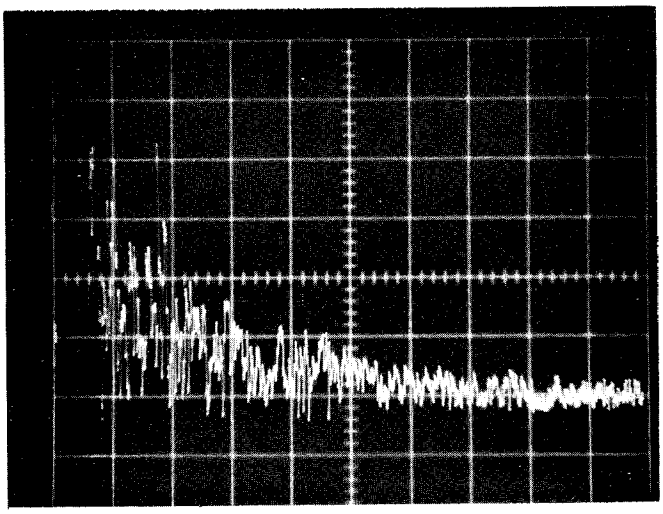
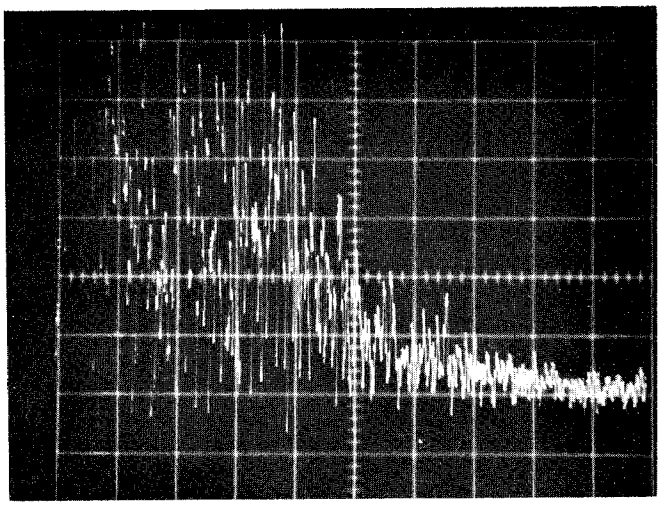


FIGURE 9 SONIC ANALYSIS OF A 1-INCH BURN-THROUGH IMPINGING ON A 0.032 TITANIUM PLATE

Prefilter 200 Hz Highpass
Analyzed Bandwidth (0-10) KHz
1" Hole 0.032 Titanium



Before Burn Through



After Burn Through

FIGURE 10 SONIC ANALYSIS OF A 1-INCH BURN-THROUGH IMPINGING ON A 0.032 TITANIUM PLATE AS SEEN ON AN OSCILLOSCOPE

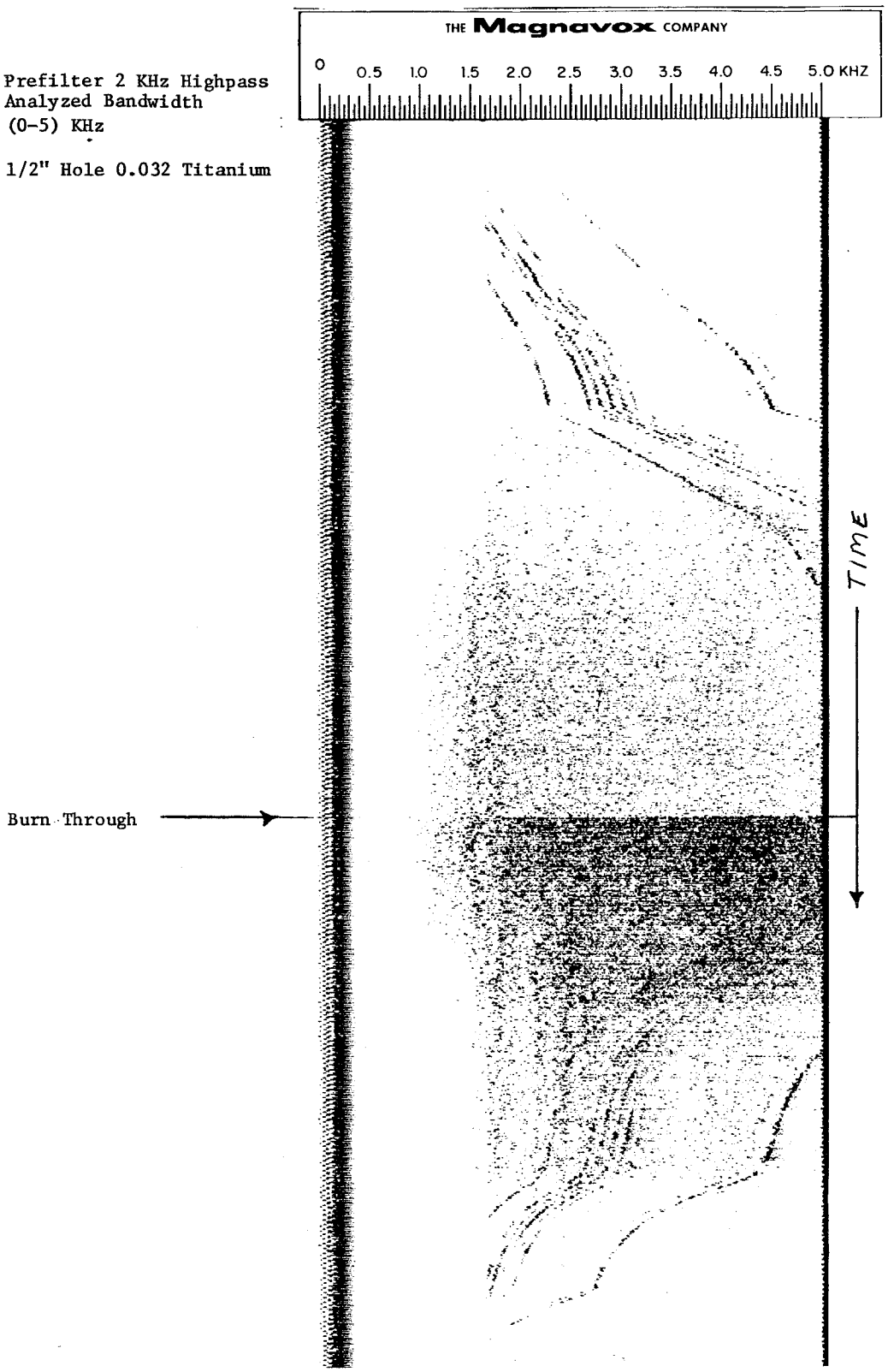
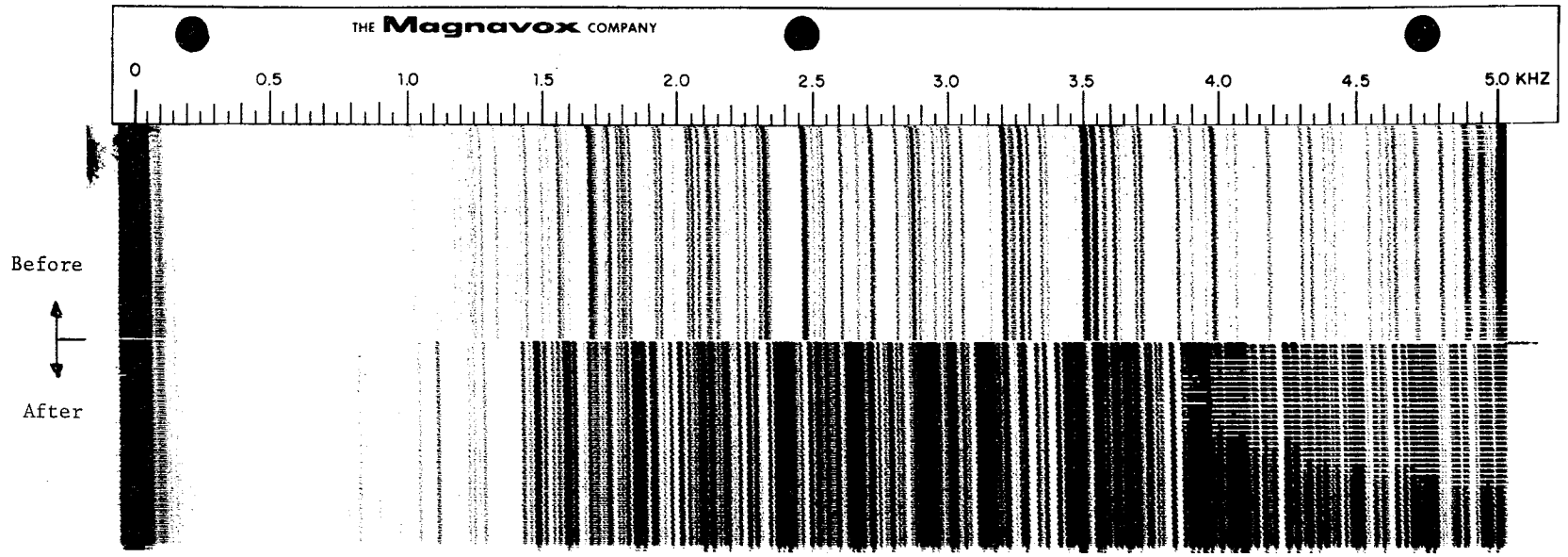


FIGURE 11 SONIC ANALYSIS OF A 1/2-INCH BURN-THROUGH IMPINGING ON A 0.032 TITANIUM PLATE

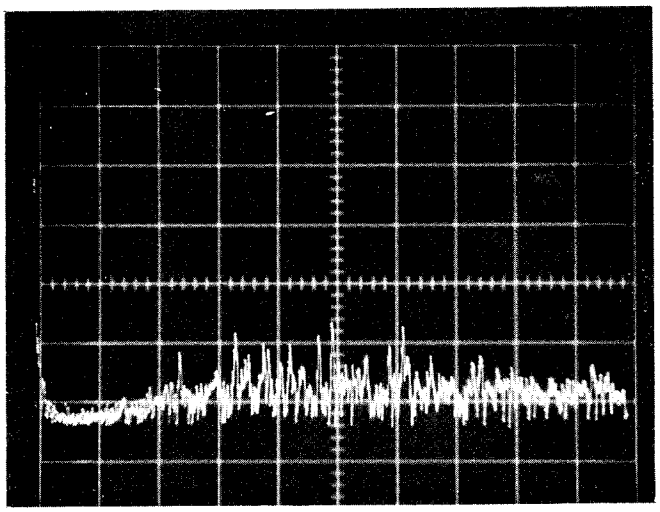


Prefilter 2 KHz Highpass
Analyzed Bandwidth (0-5) KHz

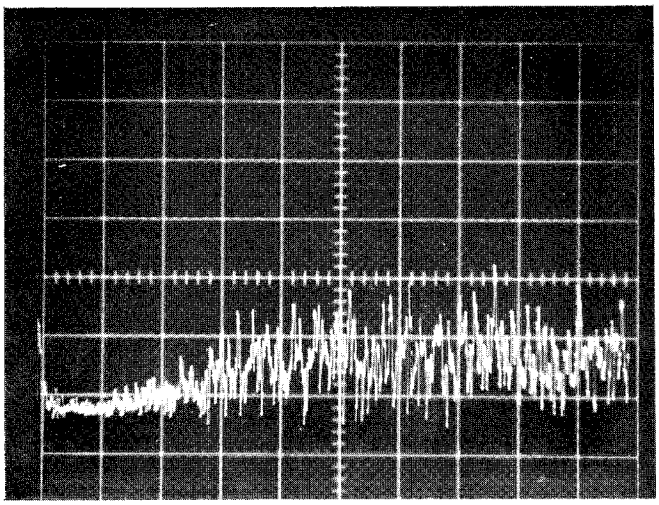
1/2" Hole 0.032 Titanium

FIGURE 12 DETAILED SONIC ANALYSIS OF A 1/2-INCH BURN-THROUGH IMPINGING ON A 0.032 TITANIUM PLATE AS SEEN ON AN OSCILLOSCOPE

Prefilter 2 KHz Highpass
Analyzed Bandwidth (0-5) KHz
1/2" Hole 0.032 Titanium



Before Burn-Through



After Burn Through

FIGURE 13 SONIC ANALYSIS OF A 1/2-INCH BURN-THROUGH IMPINGING ON A 0.032 TITANIUM PLATE AS SEEN ON AN OSCILLOSCOPE

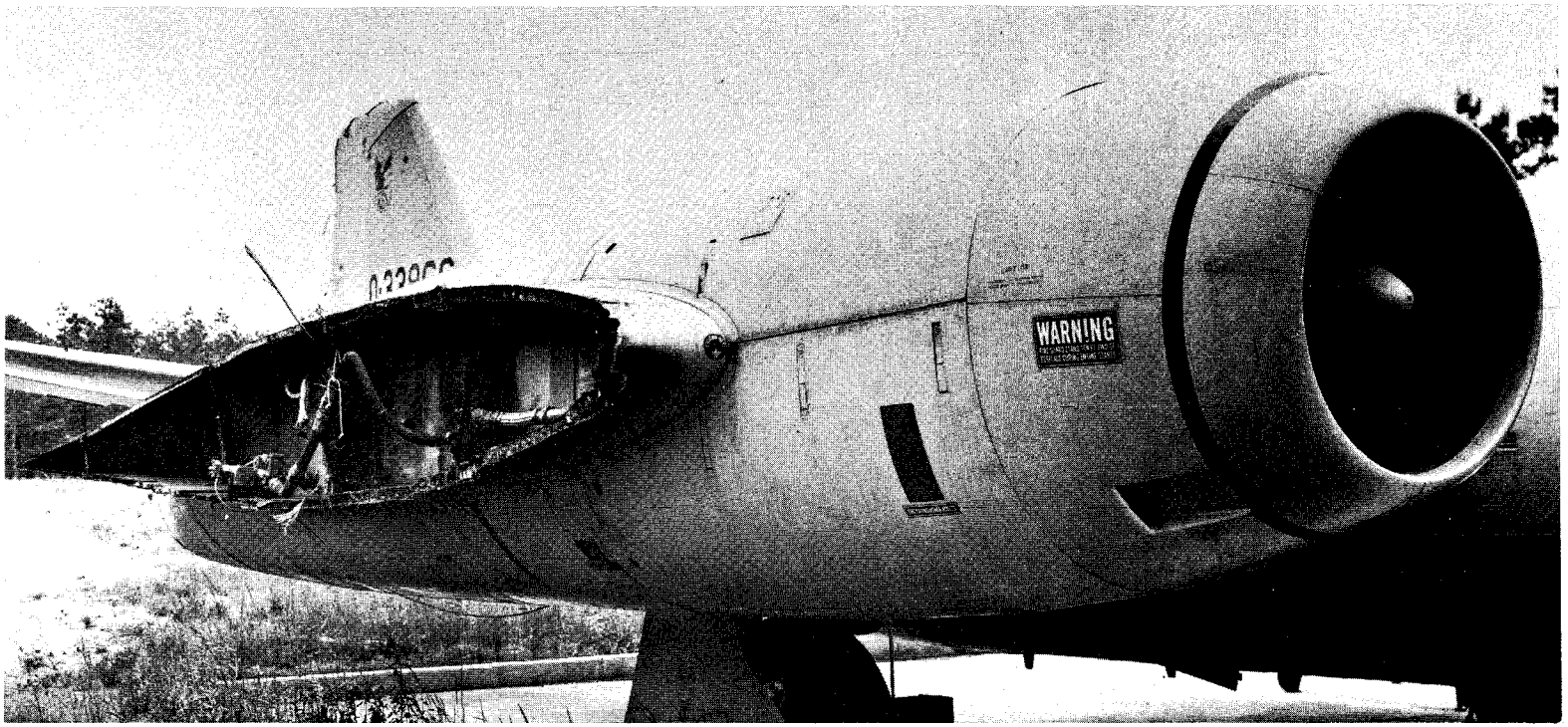


FIGURE 14 J57 ENGINE

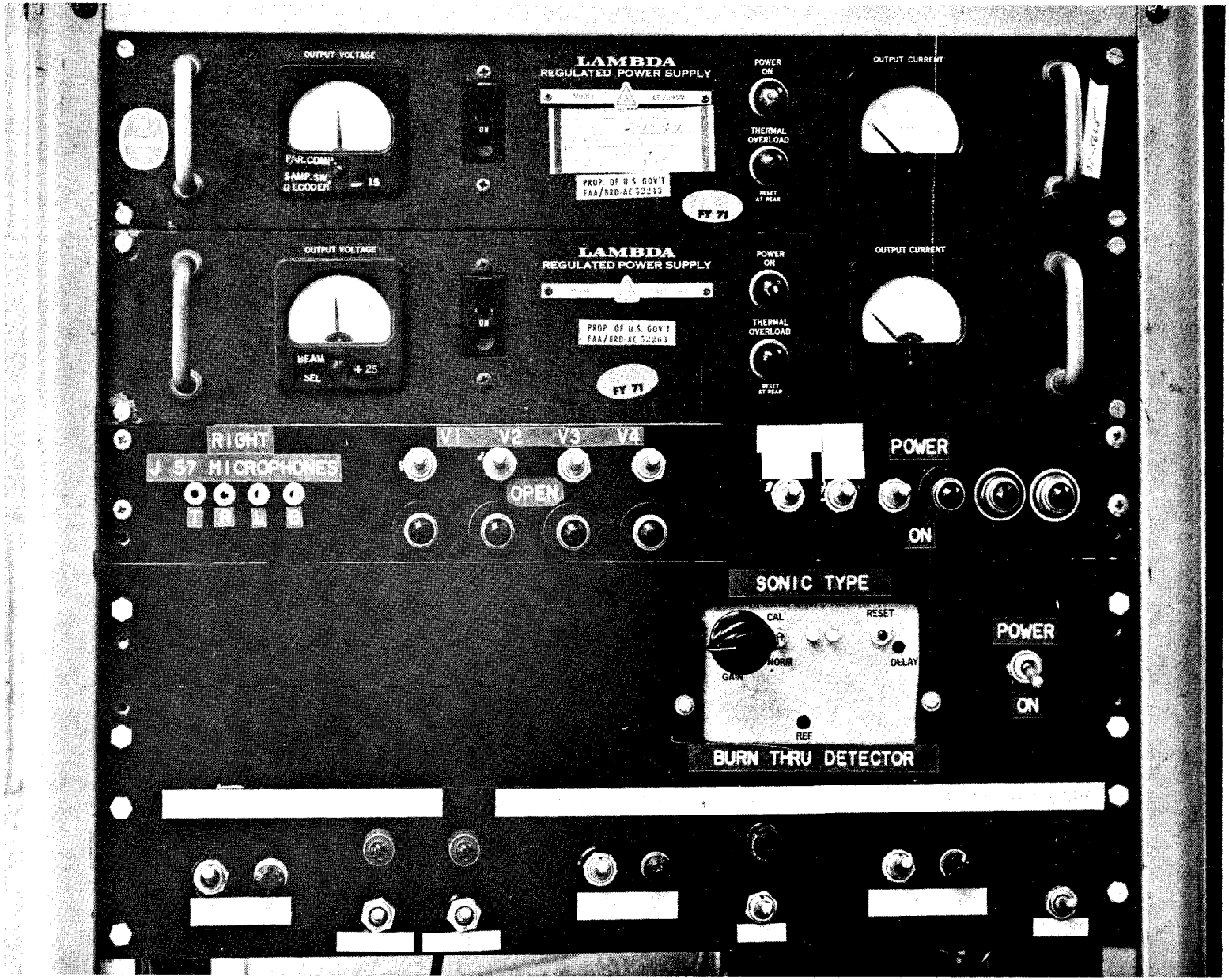


FIGURE 15 SONIC DETECTION AND TEST PANEL

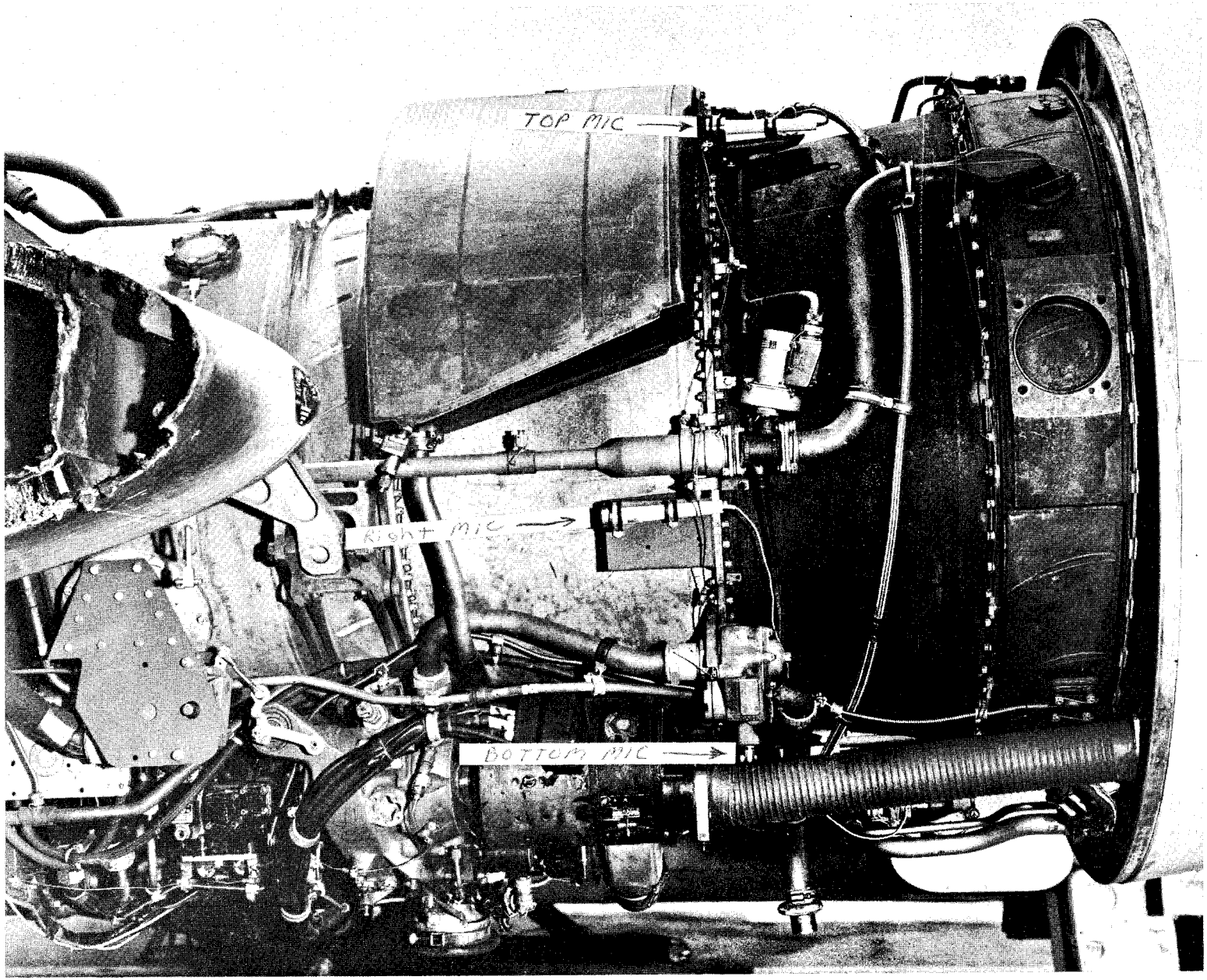


FIGURE 16 LOCATION OF TOP, RIGHT, AND BOTTOM MICROPHONES

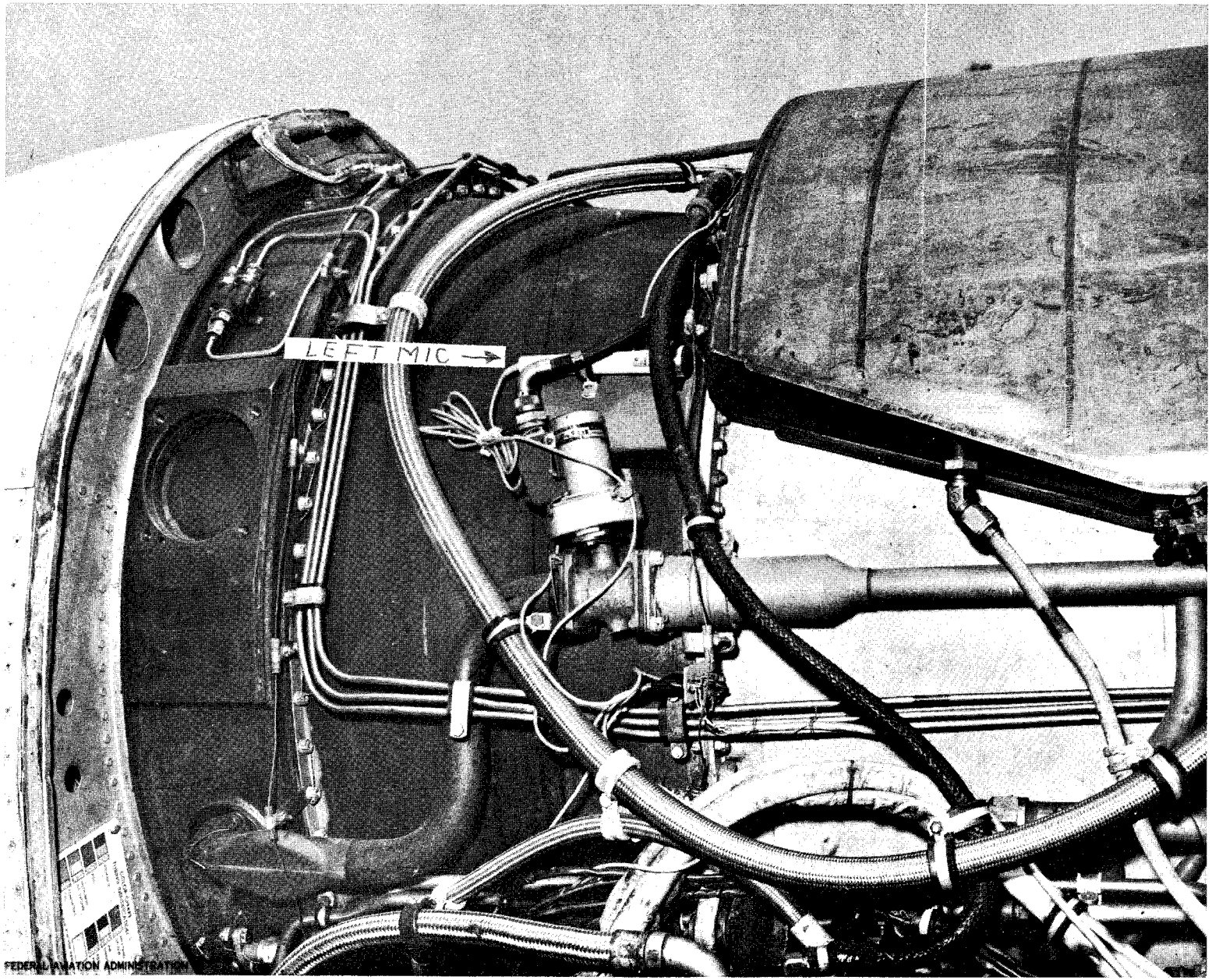


FIGURE 17 LOCATION OF LEFT MICROPHONE

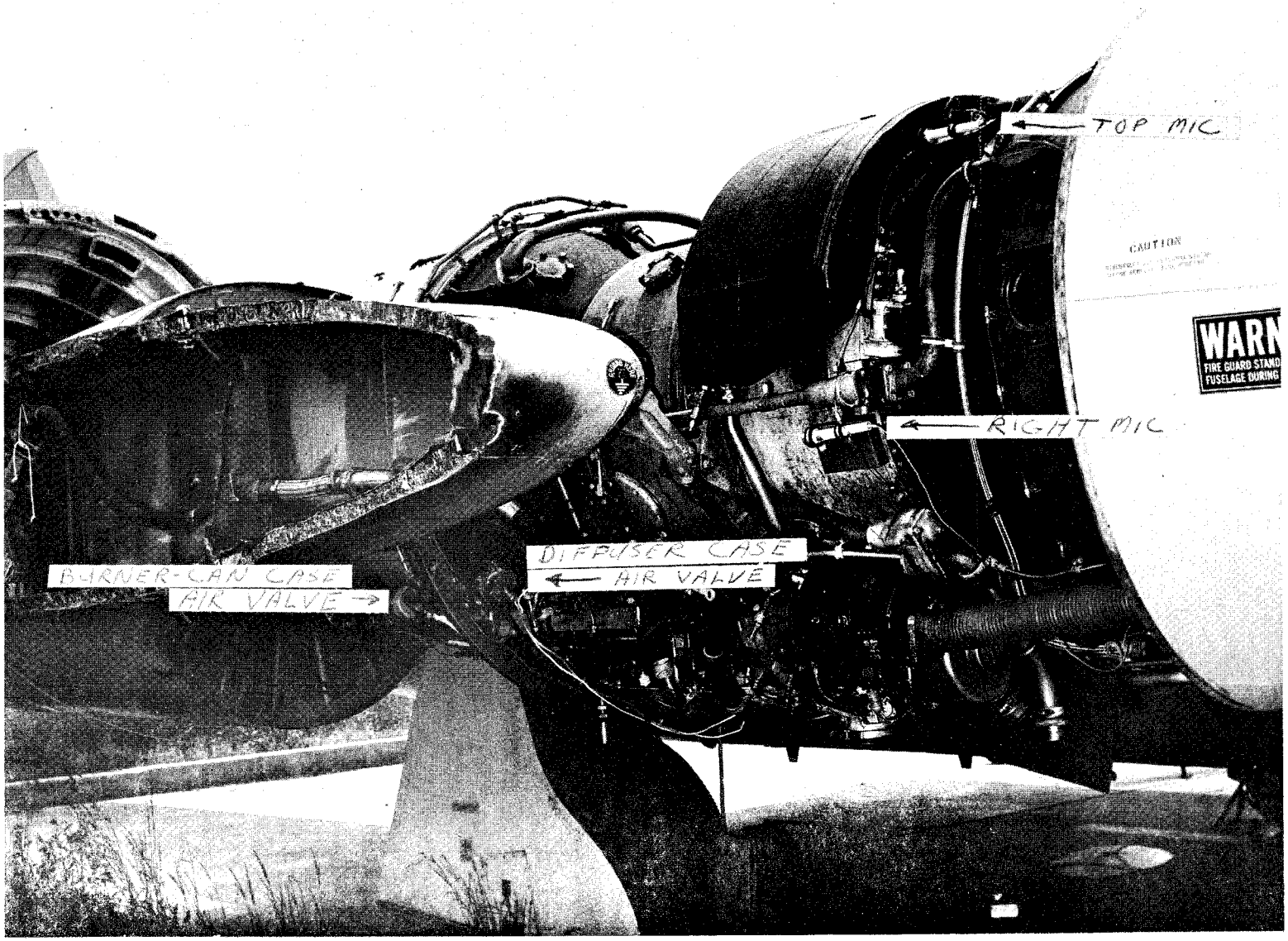


FIGURE 18 LOCATION OF MICROPHONES AND BURN-THROUGH VALVES

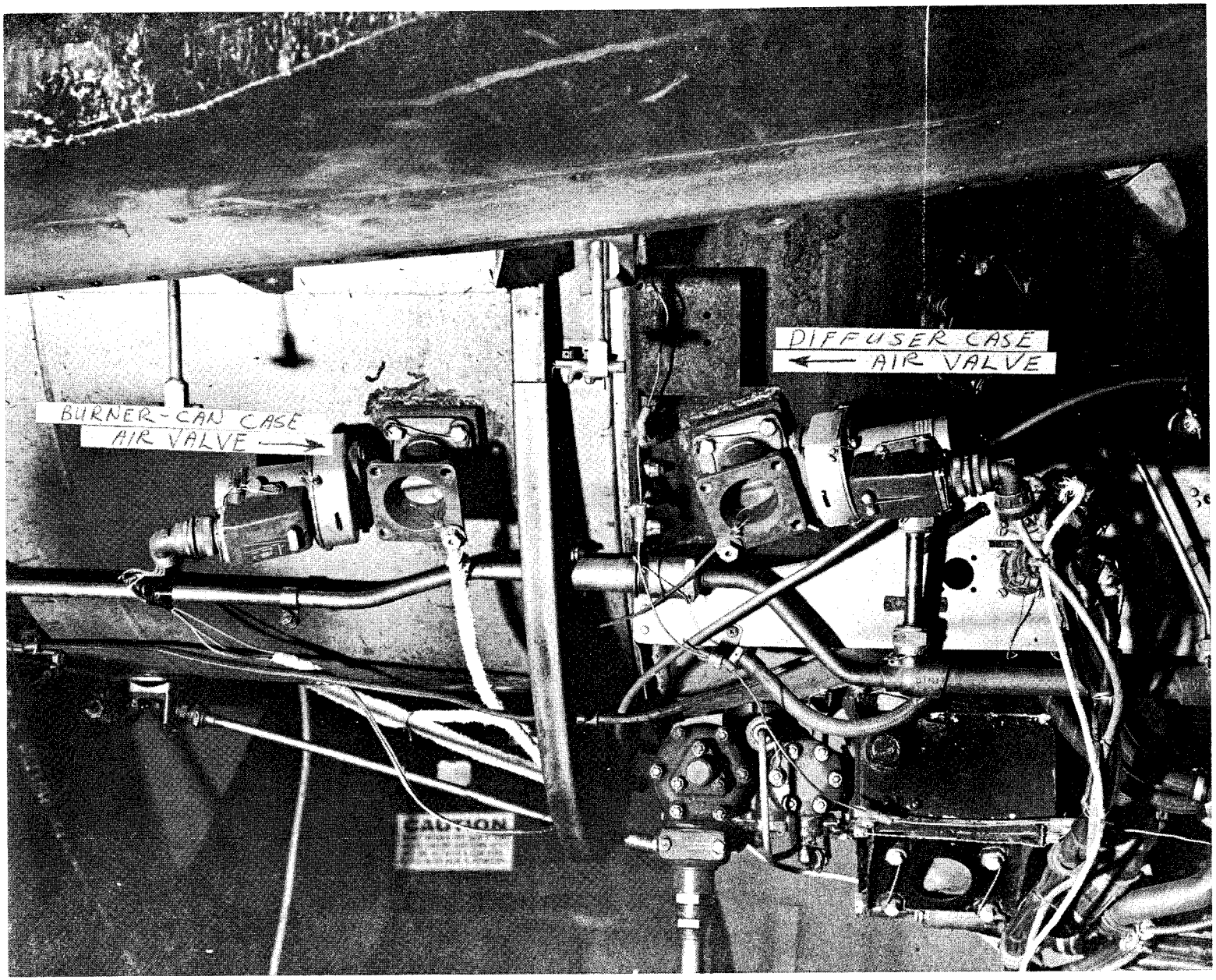


FIGURE 19 LOCATION OF BURN-THROUGH VALVES