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AN INVESTIGATION OF THE EFFICACY OF THE XF9F-3 FIRE SCREEN INSTALLATION

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SUMMARY

The ability of a fire screen, installed between the engine compressor and tail pipe compartments of a Grumman XF9F-3 airplane, to prevent travel of flame from one compartment to the other was determined by full-scale tests. The results of this investigation indicate that:

1. The fire screen installation does not prevent backflash or upstream travel of fire from the rear compartment to a source of fuel located in the forward compartment.
2. The fire screen installation does not prevent fire, ignited in the forward compartment, from traveling downstream into the rear compartment.
3. The fire screen installation is subject to early material failure when local spots are exposed to intermittent fire and cooling air.

Supplementary laboratory tests on 30-mesh monel metal screen indicated that the configuration of a screen installation is an influential factor in its ability to prevent backflash. A screen installed normal to the direction of air flow prevented backflash. Screens installed parallel to the general direction of air flow and in a manner conducive to air turbulence in the vicinity of the screen did not prevent backflash.

INTRODUCTION

The peculiar ability of fine mesh metallic screening to prevent explosion and fire, as illustrated by its use in miners' lamps, has led to its use in a variety of applications. The effectiveness of such a screen, however, has been found by experience to be largely dependent on the conditions of the particular installation. Many important factors involved in the design of an effective fire screen, and the exact circumstances under which a screen will or will not perform its function, are unknown.

PURPOSE

At the request of the Department of the Navy, Bureau of Aeronautics, tests were conducted by the Civil Aeronautics Administration, Technical Development and Evaluation Center on the fire screen installation of a Grumman XF9F-3 airplane. The purpose of this investigation was to determine the degree of protection from fire afforded by the fire screen of this particular installation.

DESCRIPTION OF EQUIPMENT

The test article was a static test tail section of a Grumman XF9F-3 airplane which incorporated a fire screen installed between the forward (engine compressor) compartment and the rear (turbine and tail pipe) compartment. Photographic views of the tail section and the cylindrical fire screen installation are shown in Figs. 1, 2, and 3.

Air flow conditions between the engine and nacelle were simulated by installing an 18-inch pipe and flange in the tail section as shown in Fig. 4. This illustration also shows the general location of the ignitors and fuel nozzles used in the tests. The installation is shown in Fig. 5. For test purposes, the tail section of the XF9F-3 airplane was bolted to a 42-inch air duct. See Fig. 2. Air in various quantities was supplied through this duct by blowers.

Specifications of the installed fire screen were as follows:

Material - 30-mesh monel metal
Diameter of screen wire - 0.013 inches
Diameter of screen cylinder - 28 27/32 inches
Size of screening - 0.013 by 10 by 96 inches
Calculated free area of screen - 2.4 square feet
Measured area of annular entrance to screen - 0.81 square feet
Annular area at rear ignitor location - 2.8 square feet

Fig. 6 is a top sectional view of the tail section, showing the general direction of air flow through the nacelle during the tests. The locations of ignitors and fuel nozzles used in producing fires in either compartment also are shown. During the tests, aviation gasoline was supplied as fuel through an open end one-eighth-inch copper tube at a rate of 6 1/3 gph. All fuel outlets were pointed downstream.

PROCEDURE

The tests were conducted under three simulated conditions described as follows:

Phase I	A fuel leak in the forward compartment and a source of ignition in the rear compartment.
Phase II	A fuel leak and a source of ignition in the forward compartment only.
Phase III	A fuel leak and a source of ignition in the rear compartment only.

Each phase included tests at various air flows through the nacelle. Flow measurements were made at the annular tail exit between the shroud and pipe.

The free area velocities through the screen, at the annular entrance to the screen and at the rear ignitor location were calculated.

RESULTS

The conditions of six test runs are given in Table I and are representative of a considerable number of tests

TABLE I

AIR FLOW CONDITIONS

Test	Free Area Air Velocity Through Fire Screen (fps)	Air Velocity at Annular Opening Forward of Screen (fps)	Air Velocity at Rear Ignitor Location (fps)	Air Temp. (°F)	Air Flow Through Screen CFM (Test Cond.)	Air Flow Through Screen (lb./sec.)
A	7.8	23	6.7	117	1,120	1.28
B	8.1	24	6.9	156	1,160	1.24
C	11.5	34	9.9	157	1,660	1.78
D	16.0	47	14.0	166	2,300	2.43
E	28.4	84	24.0	137	4,100	4.55
F	35.0	104	30.0	120	5,030	5.75

Phase I Conditions - Fire would not travel upstream from the rear compartment ignitor with air flows equal to or greater than those obtained in test D. Calculated velocity at the ignitor section for test D was 14 fps (9.5 mph).

Fire did travel upstream in the rear compartment from the ignitor, to and through the screen, but not through the annular entrance to the screen under air flow conditions obtained in test C. In this instance, calculated velocities were

(1) 9.9 fps (6.7 mph) at the rear ignitor location,
(2) 11.5 fps (7.8 mph) through the screen, and
(3) 34.0 fps (23 mph) at the annular screen entrance.

Fire did travel upstream from the rear compartment ignitor through both the screen and annular entrance and into the forward compartment with air flows equal to or less than those obtained in tests B and A. The calculated velocity at the annular screen entrance for test B was 24 fps or 16 mph.

Phase II Conditions - Fire in the forward compartment readily passed through the annular screen entrance and screen into the rear compartment and out the tail with air flows equal to or less than those obtained in test D. Velocities for this test were 16 fps (11 mph) through the screen and 47 fps (32 mph) at the annular screen entrance.

Fire in the forward compartment did not pass into the rear compartment with air velocities above 84 fps (57 mph) at the annular screen entrance. In this instance, it appeared that the small annular screen entrance acted as a flame stop. At a screen entrance velocity of 84 fps (test E), small trails of flame would pass through the entrance and the screen. The screen itself appeared to have little damping effect on the fire.

Phase III Conditions - Fires in the rear compartment were observed to be self-supporting after ignition as long as fuel was supplied, and at or below air flow velocities of 14 fps (9.5 mph) at the ignitor section. Above this velocity, a fire in the rear compartment would not sustain itself, but would blow out. With ignition held on, the fire occurred in intermittent short bursts. In no instance did fuel or fire travel upstream.

The observed test results are summarized in Table II.

SUPPLEMENTARY TESTS

After completion of the tests on the XF9F-3 fire screen installation, supplementary tests were conducted to determine the reason for the occurrence of material failure of the screen after approximately six exposures to fire of about ten seconds duration each (see Figs. 9 and 10), and the apparent complete failure of the screen installation to prevent backflash of fire. A brief study of the material failure was made by constructing a 4 by 8 inch panel of new 30-mesh monel screen welded to a steel angle frame and testing it by

(1) heating the screen locally to a red heat with a blow torch for five minutes,
(2) heating the screen locally to a red heat with a blow torch and quenching it in water, through five cycles, and,

TABLE II

OBSERVED TEST RESULTS

TEST	A	B	C	D	E	F
Phase I	Fire back-flashed through screen into forward zone consistently.	Fire back-flashed through screen into forward zone consistently.	Fire back-flashed consistently through screen, but not into forward zone. Screen red hot in local area.	Fire observed in rear zone, but failed to travel upstream to screen.	Intermittent nonself-supporting flame down-stream of rear zone ignitor. No back-flash.	Intermittent non self-supporting flame down-stream of rear zone ignitor. No back-flash
Phase II	Self-supporting fire in forward zone with intermittent flame through screen and out tail.	Steady self-supporting fire in forward zone with steady flame passing through screen and out tail.	Steady self-supporting fire in forward zone with steady flame passing through screen and out tail.	Steady self-supporting fire in forward zone with steady flame passing through screen and out tail.	Fire in forward zone only when source of ignition "on". Slight flame impingement on screen. No flame in rear zone.	Small fire in forward zone only with source of ignition "on". No flame would pass through annular opening to screen. Raw fuel noted passing through.
Phase III	Self-supporting fire in rear zone.	Self-supporting fire in rear zone.	Self-supporting fire in rear zone.	Self-supporting fire in rear zone.	Nonself-supporting intermittent flashes of fire in rear zone and out tail.	Nonself-supporting intermittent flashes of fire in rear zone and out tail. Flashes infrequent and of short duration.

(3) heating the screen locally to a red heat with a blow torch and quenching it with compressed air, through ten cycles.

Five minutes of steady heating appeared to have no effect on the screen. Five cycles of heating and quenching in water did not result in failure. After ten cycles of heating and quenching with compressed air, the screen had developed a failure approximately three-fourths inches long. The failure appeared to have resulted from the combined heating and cooling, which was noted to cause considerable local expansion and contraction. Screening taken from the area of failure was highly oxidized and had very low strength and ductility, as compared with new screen material.

A brief study of fire screen characteristics was made by installing 30-mesh monel metal screens in an 18-inch air duct. One of these was installed normal to the direction of air flow at the end of the duct as shown in Figs. 7 and 8A. Also, two horizontal screen arrangements were installed in the duct as shown in Figs. 8B and 8C. The horizontal screens represent roughly the configuration of the upper and lower portions of the XF9F-3 installation in the sense that the screen at those locations is horizontal and mounted parallel to the general direction of air flow. A turbulent condition in the vicinity of the screens for this configuration is probable.

In these tests, fuel was released into the air duct about two feet upstream of the screen, and the ability of the installation to prevent backflash or upstream travel of flame through the screen was observed when ignition was effected downstream. Under these conditions, it was observed that

(1) the screen installed normal to the direction of air flow through the duct, prevented backflash.
(2) the screens installed horizontally and parallel to the direction of air flow through the duct (see B, and C, Fig. 8) did not prevent backflash.
(3) at duct velocities exceeding approximately 15 mph, the fire would not travel in free air upstream to the screen.

DISCUSSION

A basis for discussion and evaluation of the XF9F-3 power plant cooling air and fire screen configuration, from the standpoint of fire prevention, may be provided by the following list of design characteristics desirable in a jet installation.

1. Possible sources of combustibles should be separated from possible sources of ignition to prevent the occurrence of fire.
2. A ventilation and flame stop should be provided between potentially hazardous zones to prevent the spread of fire.
3. The installation should prevent the drawing of flames or heat from the exhaust or from fires in the aft section into the forward section when negative pressures exist at the compressor inlet.
4. The installation should avoid the possibility of drawing combustibles into cooling air passages and high temperature areas by the ejector action of jet exhausts.

In an installation as represented by the XF9F-3, which has cooling air passages between the fore and aft zones, preventive measures, Items 1, 3, and 4, are not incorporated. The test results indicate limited compliance with Item 2. Under air flows equal to or greater than those of Test E, a fire in one compartment did not travel into the other, and a fire in the rear compartment was not self-supporting. The prevention of interzone flame travel, however, was observed to be not by virtue of the fire screen, which appeared ineffective, but as a result of high air velocities at the annular entrance to the screen and in the rear compartment annular areas between the shroud and pipe. A determination of blowout velocities in an actual airplane was not within the scope of this investigation. Such velocities are dependent to a great extent on the number and kind of obstructions present in the air stream and upon other conditions not simulated in these tests.

Results of the supplementary tests on fire screens installed in an 18-inch air duct indicated that a screen was most effective in preventing upstream travel of fire when installed normal to the general direction of air flow. Tests also indicated that high air velocities and the absence of turbulence at the screen are desirable and improve the effectiveness of the screen.

CONCLUSIONS

The general conclusion based on results of this investigation is that the fire screen installed in the XF9F-3 airplane is not effective as a fire preventive or protective measure.

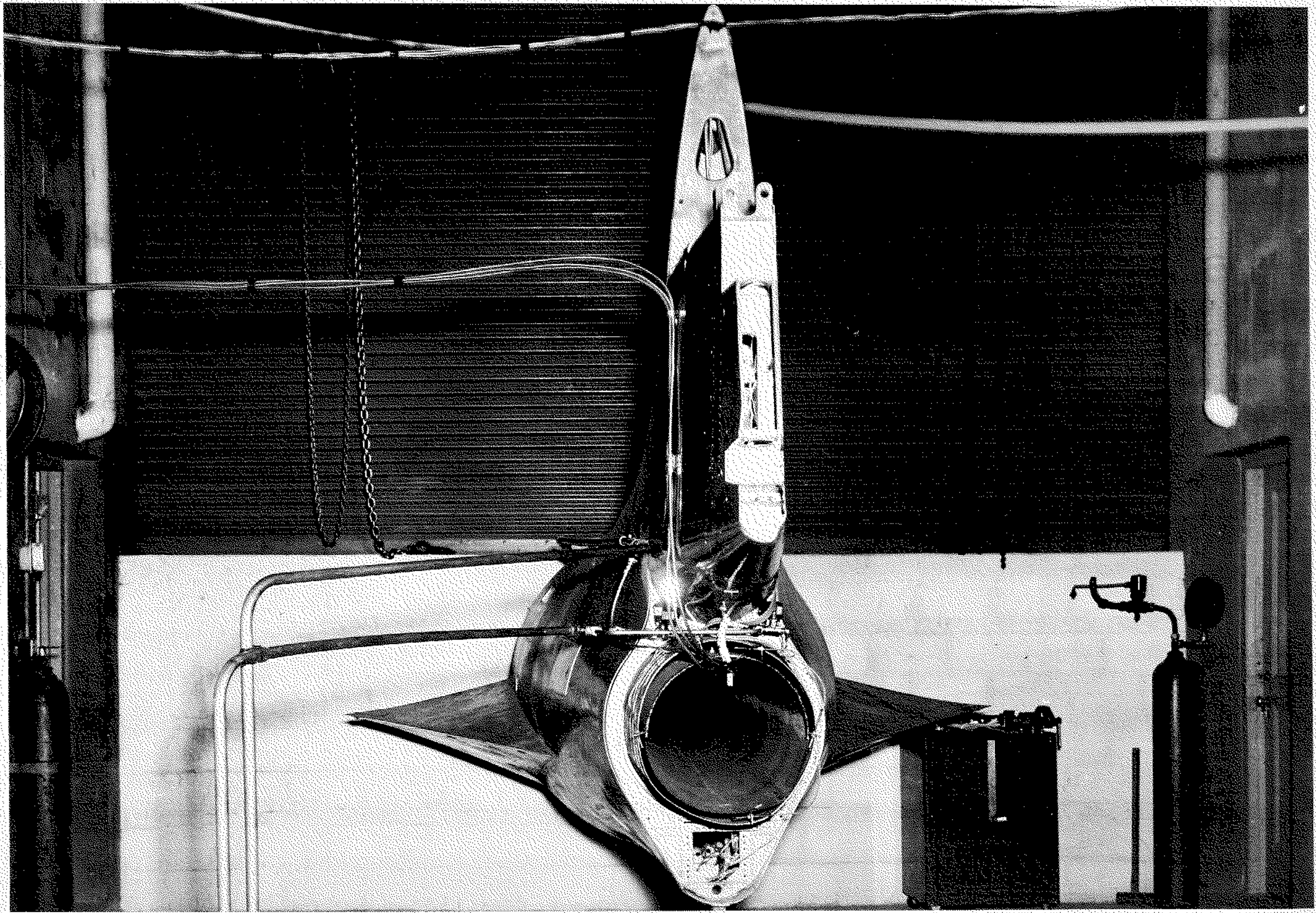

FIG. 1 REAR VIEW OF XF9F-3 TAIL SECTION INSTALLATION AS MOUNTED IN TEST CELL

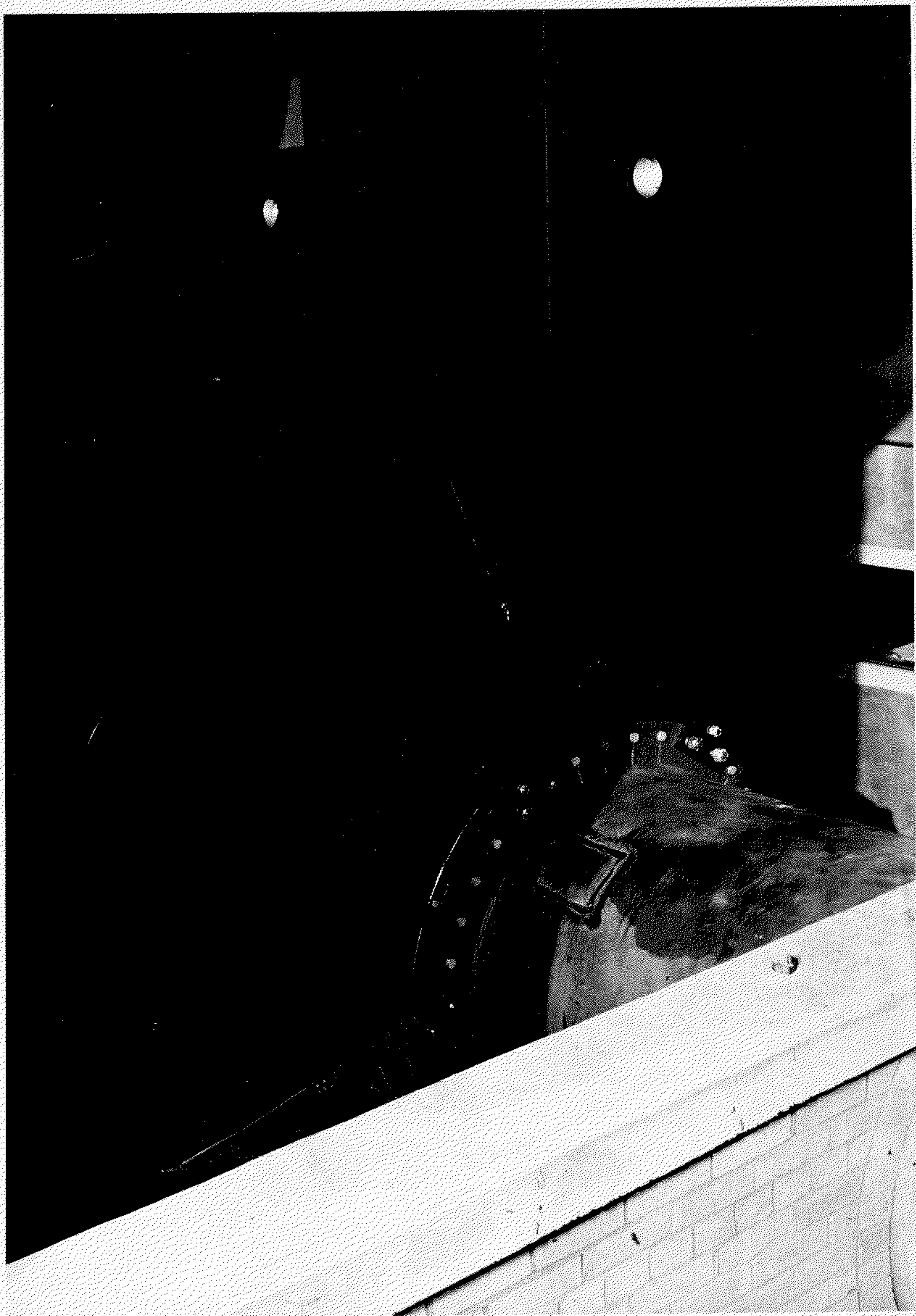

FIG. 2 VIEW OF TEST INSTALLATION SHOWING CONNECTION OF TAIL SECTION TO 42 INCH AIR DUCT

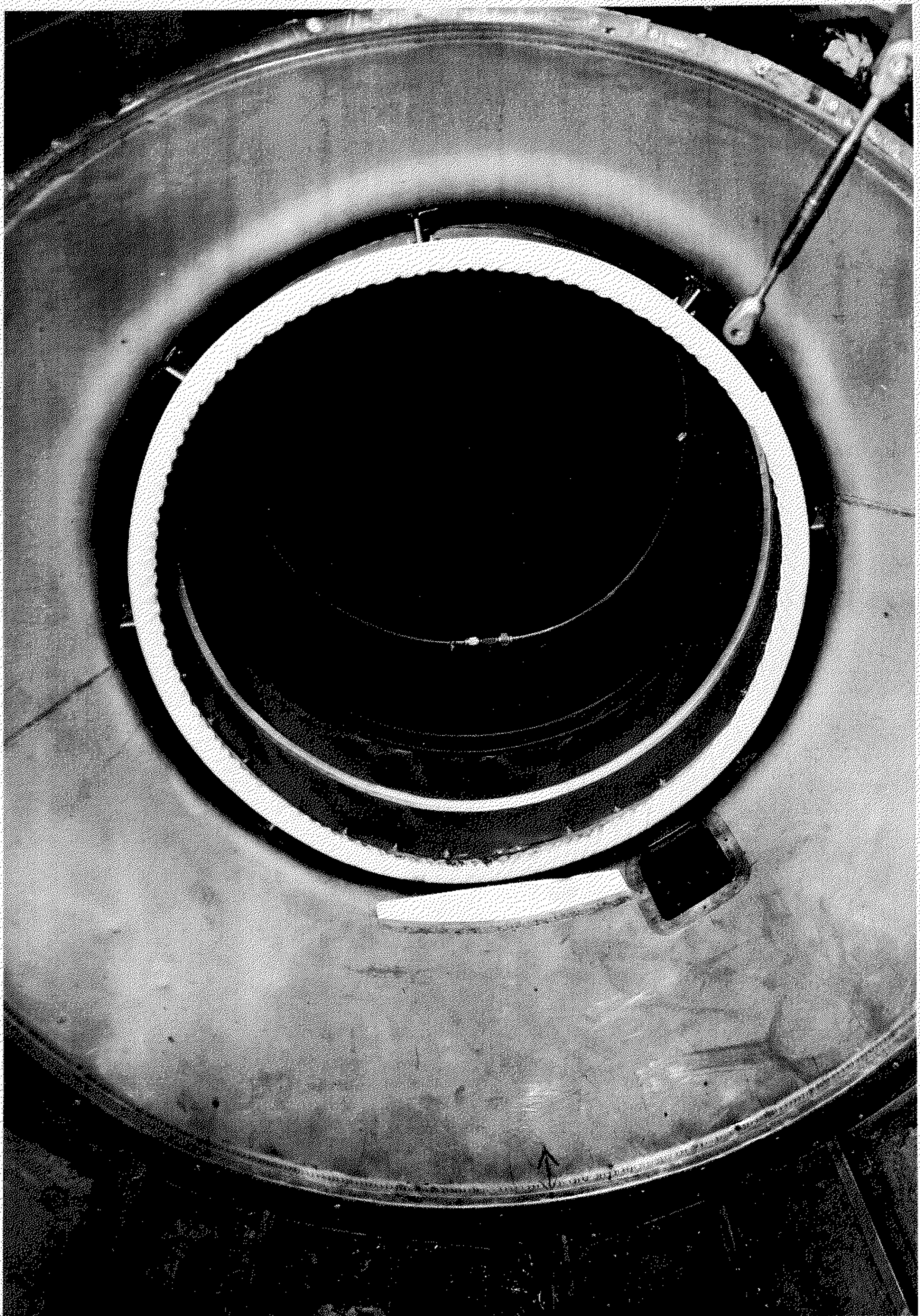

FIG. 3 PHOTOGRAPH OF FIRE SCREEN INSTALLATION
IN XF9F-3 TAIL SECTION

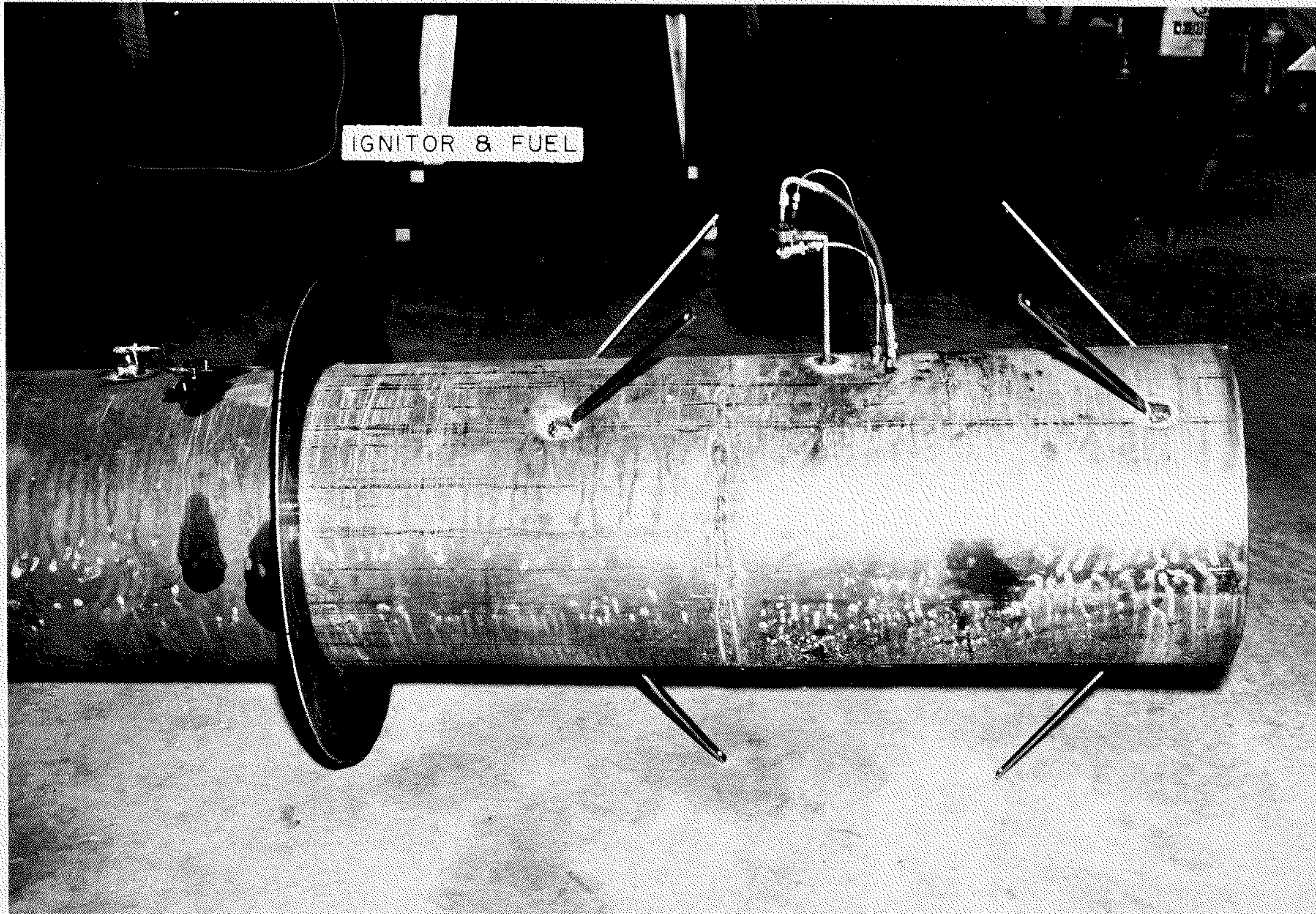

FIG. 4 PHOTOGRAPH OF 18 INCH PIPE AND FLANGE INSTALLED IN TAIL SECTION

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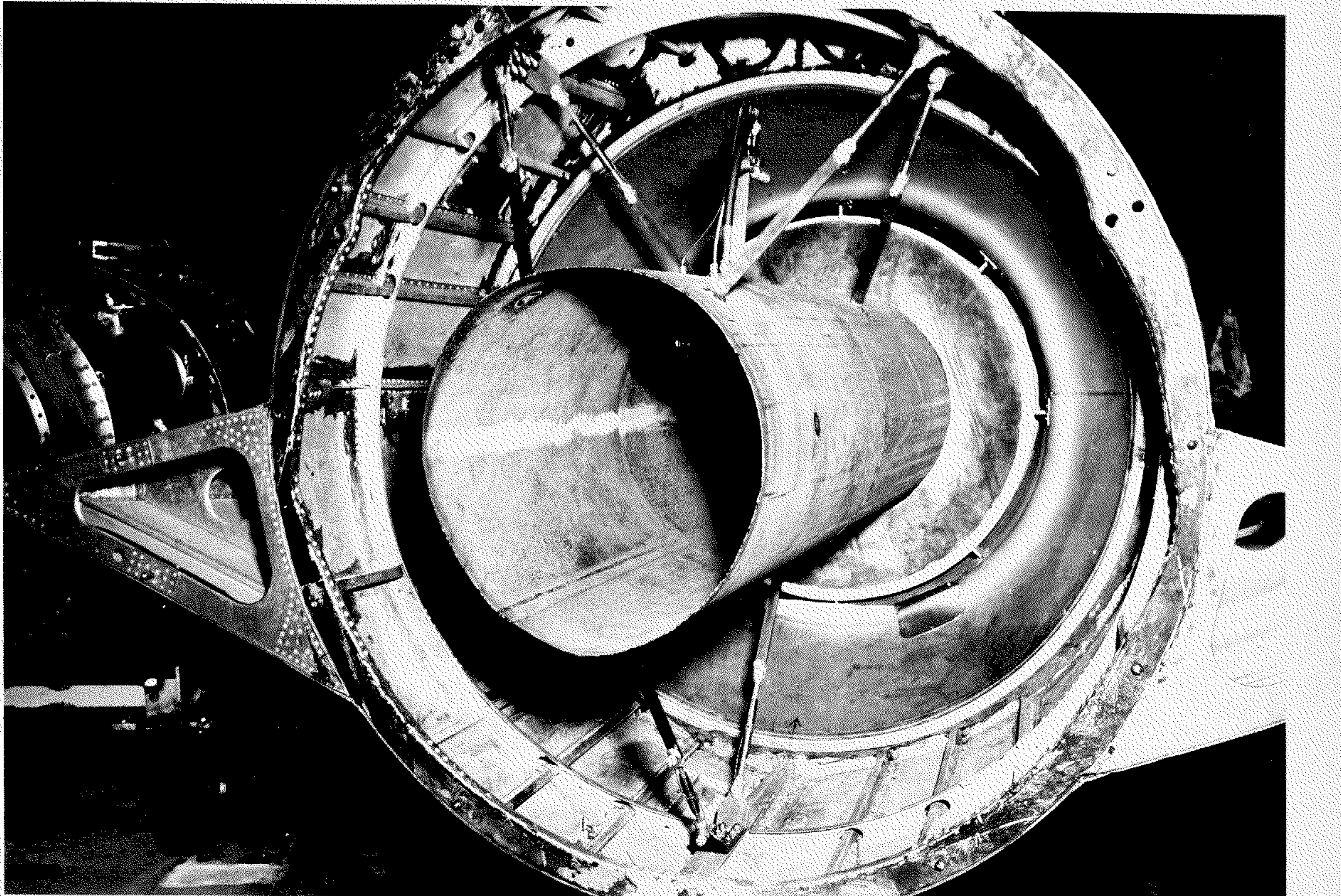

FIG. 5 PHOTOGRAPH OF 18 INCH PIPE AND FLANGE INSTALLATION

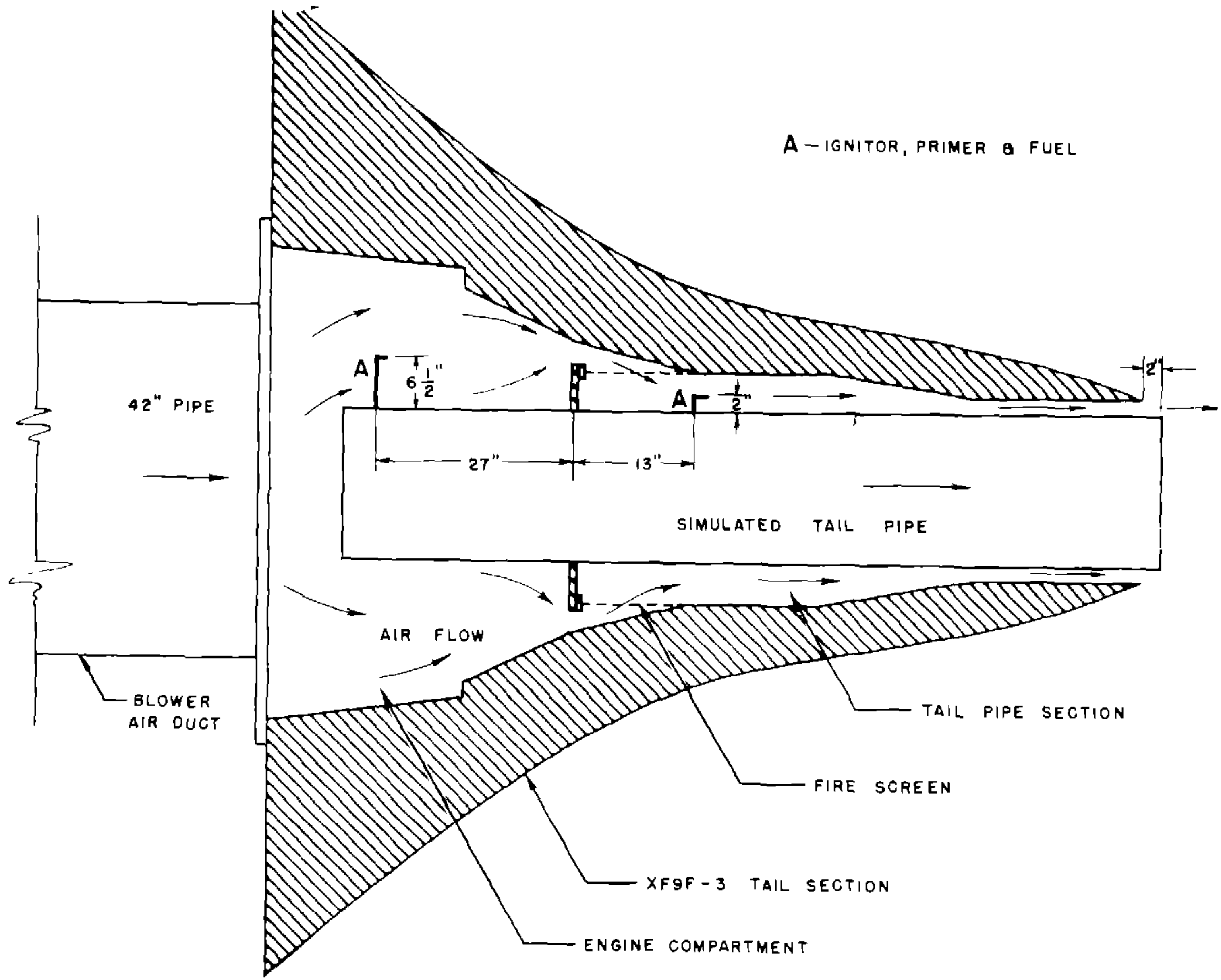

FIG 6 TOP SECTIONAL VIEW OF XF9F-3 TAIL SECTION SHOWING DIRECTION OF NACELLE AIR FLOW

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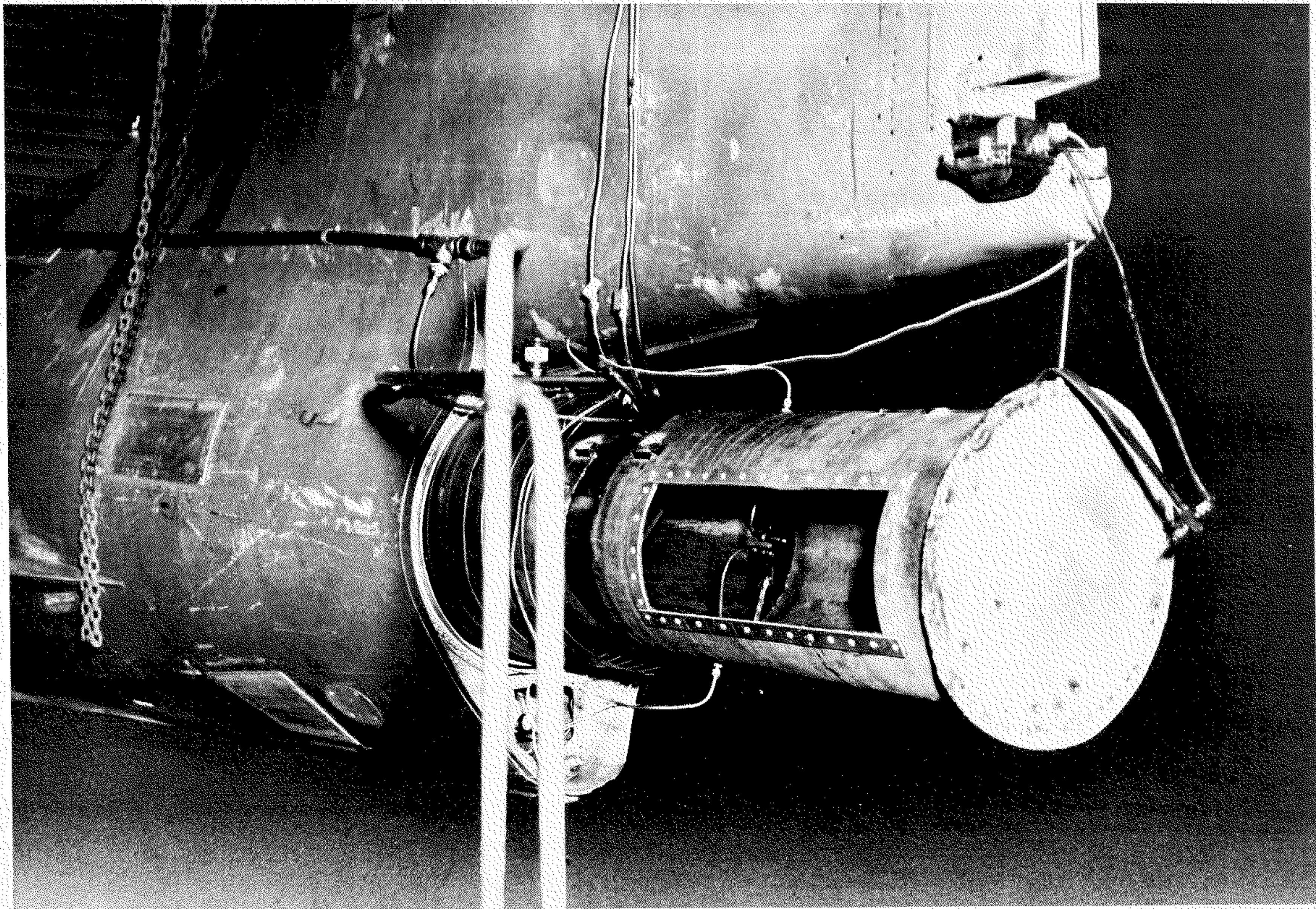

FIG. 7 PHOTOGRAPH ILLUSTRATING SUPPLEMENTARY TEST SETUP

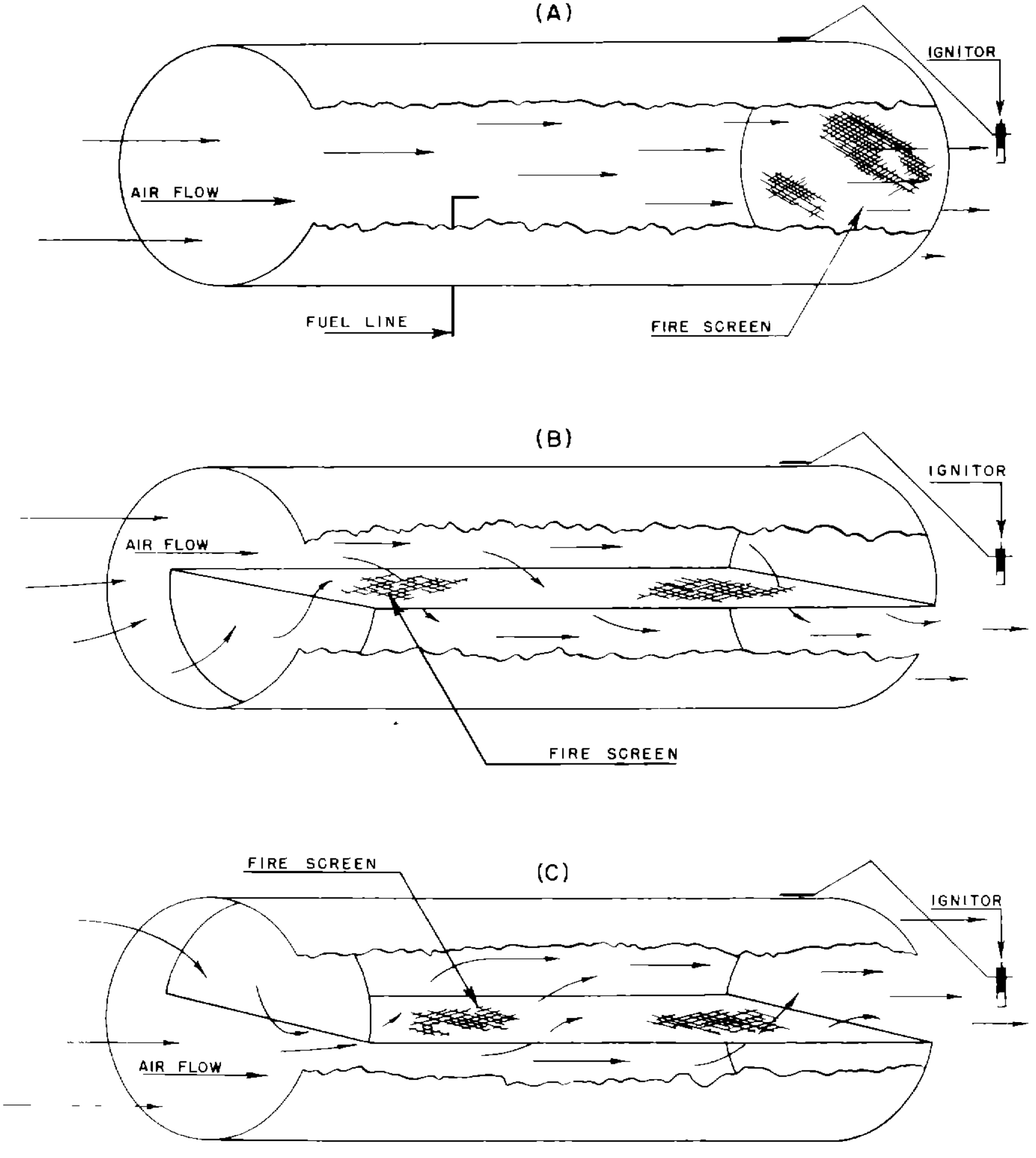

FIG 8 CUTAWAY VIEWS OF FIRE SCREEN INSTALLATIONS USED IN SUPPLEMENTARY TESTS

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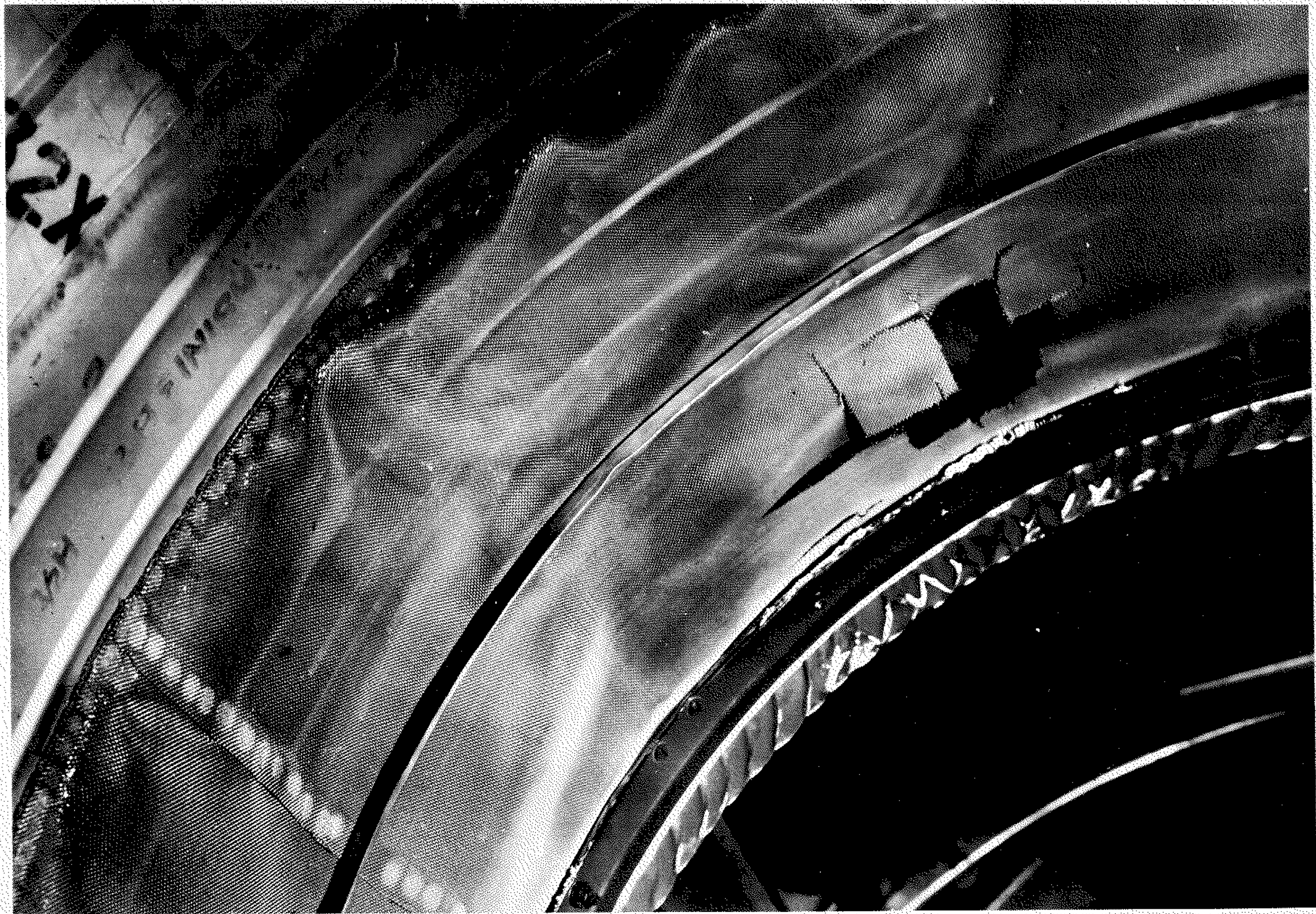

FIG 9 FIRE SCREEN FAILURE RESULTING FROM A FEW TEST FIRES

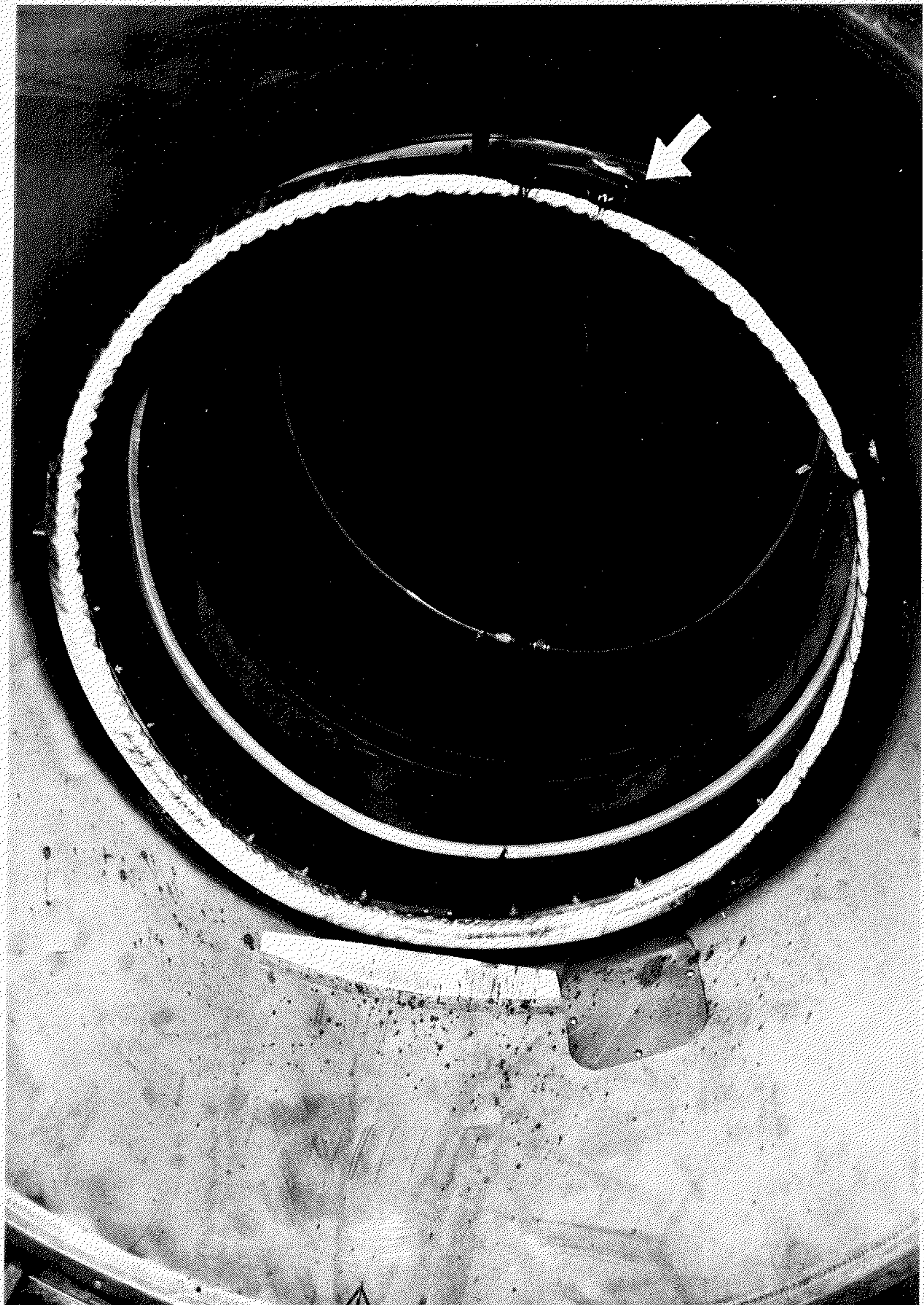

FIG. 10 VIEW OF SCREEN SHOWING LOCATION OF FAILURE

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