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AN INVESTIGATION OF TEMPERATURE CONDITIONS IN THE PROXIMITY OF JET AIRCRAFT EXHAUST SYSTEM FAILURES

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SUMMARY

The increase in ambient temperature and rate of temperature increase resulting from the escape of engine exhaust gases through simulated crack type of failures in the tail cone and tail pipe of one of the J-35 jet engines in an XB-45 nacelle were measured. Test results indicated that such failures as were simulated would not result in serious or immediate damage to the nacelle structure. The increase in ambient temperature and rate of increase resulting from such failures were found to be highly localized to the immediate vicinity of the failure. The detection of such failures, by the use of existing unit type aircraft fire or overheat detector systems, was considered to be impractical because of the large number of units which would be required to cover the potential areas of failure.

INTRODUCTION

Cracks in tail cones and tail pipes have occurred in B-45-A1 aircraft with no warning being provided by the fire detector systems. Circumferential cracks have occurred in the tail cone exhaust assembly, Part No. 8469856, adjacent to the mounting flange of the engine at the 4, 6, 8, and 10 o'clock positions of the cone assemblies. A crack also occurred in a pipe assembly-engine exhaust L. H. Stock No. 147-40-205-1, at the 12 o'clock position. This crack was in the form of a tee, the leg of which extended rearward approximately 12 inches and the crossbar of which was 10 inches long. This rupture was located approximately 3 1/2 feet aft of the union of the tail pipe and the engine tail cone assembly.

At the request of the Department of the Air Force, the Technical Development and Evaluation Center conducted tests in which actual cracks were simulated as closely as possible by openings made in the tail cone and tail pipe with a grinding wheel.

PURPOSE

The purpose of the tests conducted was (1) to determine the maximum temperatures and rates of temperature increase that may occur in the aft section of an XB-45-A1 airplane power plant as a result of cracks in an engine tail cone or tail pipe and (2) to obtain information on fire or overheat detector system requirements for detecting such failures.

DESCRIPTION OF TESTS

Tail cone cracks were simulated by an opening made in the tail cone, 5 inches back of the flanged joint between the tail cone and engine turbine section. This opening was first made 4 inches in length and 1/32 of an inch in width. See Fig. 1. Later this opening was enlarged to 3/32 of an inch in width, Fig. 2, and finally to 5/32 of an inch in width and 9 inches in length, Fig. 3. The crack in the tail pipe assembly was simulated by an opening made in the tail pipe in the form of a tee, the same length as the actual failure, and 5/32 of an inch in width. See Fig. 4. Locations of the simulated exhaust system cracks are shown in Fig. 5.

Four thermocouples were installed to determine the temperature condition near the opening in the tail cone. The first was located adjacent to the opening, the second was 4 inches aft, the third was 8 inches aft, and the fourth was 12 inches aft of the opening. Thermocouples installed near the tee opening in the tail pipe were placed with the first thermocouple adjacent to the bottom end of the tee, and the others were placed in the same order as those for the tail cone.

Normal ambient air temperatures and normal rates of temperature rise at the tail cone and tail pipe were recorded before the openings were made. After making the openings, maximum temperatures and the rates of temperature rise were recorded during tests simulating ground conditions. Only maximum temperatures were recorded during tests simulating flight conditions. Ground conditions consisted of starting, warm up, and simulated taxi run. Flight conditions were simulated by supplying ram air at six inches Hg pressure to the engine air intakes.

RESULTS AND DISCUSSION

Test results are shown in Tables I, II, III, and IV.

TABLE I

Effect of Tail Cone Cracks on Maximum Ambient Temperatures Developed in the Vicinity of the Tail Cone During Engine Starting

Thermocouple Locations	Maximum Recorded Temperature (°F) No Crack	4 in. x 1/32-in. Crack	4 in. x 3/32-in. Crack
Adjacent to crack in tail cone	300	500	610
4 in. aft of crack	300	460	515
8 in. aft of crack	300	375	320
12 in. aft of crack	300	330	310

TABLE II

Effect of Tail Cone Cracks on Maximum Rate of Temperature Rise Occurring in the Vicinity of the Tail Cone During Engine Starting

Thermocouple Locations	Maximum Rate of Temperature Rise (°F/sec.) No Crack	4 in. x 1/32-in. Crack	4 in. x 3/32-in. Crack
Adjacent to crack in tail cone	2.5	7.5	11.5
4 in. aft of crack	2.5	6.5	10.0
8 in. aft of crack	2.5	4.5	5.0
12 in. aft of crack	2.5	3.8	2.5

TABLE III

Effect of Tail Cone Cracks on Maximum Ambient Temperatures Developed in Vicinity of Tail Cone During Simulated Flight Conditions

Thermocouple Locations	Maximum Recorded Temperature (°F) No Crack	4 in. x 3/32-in. Crack	9 in. x 5/32-in. Crack
Adjacent to crack in tail cone	315	680	700
4 in. aft of crack	315	470	575
8 in. aft of crack	315	400	345
12 in. aft of crack	315	380	315

TABLE IV

Effect of Tail Pipe Crack on Maximum Temperature and Temperature Rise Occurring in the Vicinity of the Tail Pipe During Engine Starting and Simulated Flight Conditions

Thermocouple Locations	During Engine Starting				Flight Conditions	
	Max. Temp. (°F)		Max. Rate of Temp. Rise (°F/sec)		Max. Temp. (°F)	
	No Crack	Tee Crack*	No Crack	Tee Crack	No Crack	Tee Crack
Adjacent to bottom of tee crack in tail pipe	250	825	2.5	18.0	265	770
4 in. aft of bottom of tee crack	250	750	2.5	14.6	265	730
8 in. aft of bottom of tee crack	250	510	2.5	12.5	265	700
12 in. aft of bottom of tee crack	250	455	2.5		265	490

*Dimensions of tee crack was 10 in. by 12 in. by 5/32 in.

The following is noted from the tables:

1. Simulated cracks in the tail cone and tail pipe caused exhaust gas leakage which increased the temperature in the immediate vicinity of the cracks and increased the normal rate of temperature rise at these locations during engine starting and during simulated flight operations. The maximum recorded temperature at a tail cone crack was 700°F. The maximum recorded temperature at the tail pipe crack was 825°F, and the maximum recorded rate of temperature rise at a tail cone crack was 11.5°F per second. The maximum recorded rate of temperature rise at the tail pipe crack was 18°F per second.

2. Any abnormally high temperatures and accelerated rate of temperature rise were highly localized to the immediate vicinity of the cracks. At a distance of one foot from the largest tail cone crack, the maximum recorded temperature was 380°F (65°F above normal). The maximum recorded temperature at a distance of one foot from the tail pipe crack was 490°F (225°F above normal). The maximum recorded rate of temperature rise at a distance of one foot from cracks in the tail cone was only slightly greater than normal. The maximum recorded rate of temperature rise at a distance of eight inches from the crack in the tail pipe was 12.5°F per second as compared with a normal rate of rise of 2.5°F per second at this location.

3. An increase in the width and length of tail cone cracks resulted in increased temperatures and rates of temperature rise in the vicinity of the crack opening.

CONCLUSIONS

From the tests conducted, it is concluded that ambient temperatures resulting from exhaust gas leakage through relatively large cracks in the engine tail cone and tail pipe are not of sufficient magnitude as to constitute an immediately hazardous condition Fatigue cracks in these areas should be readily noticeable before the area of leakage is great enough to constitute a hazard.

It is further concluded that it is impractical to use unit type overheat or rate of rise detectors for detection of crack failures like those simulated in the tests, since it would be necessary for adequate coverage to space detector units less than one foot apart in the area of the nacelle adjacent to tail cones and tail pipes.

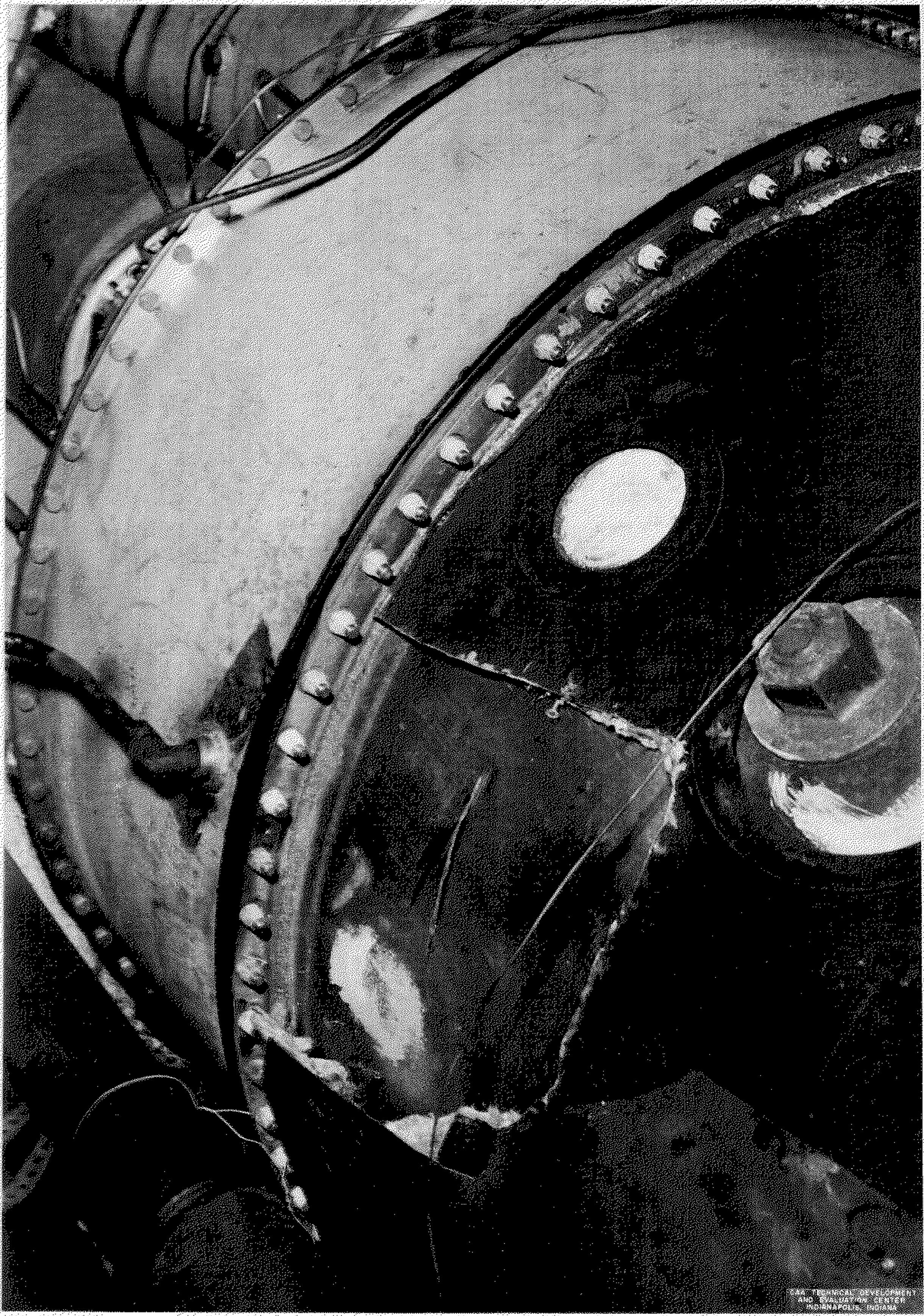

FIG. 1 4" X $1/32$" SIMULATED CRACK IN TAIL CONE

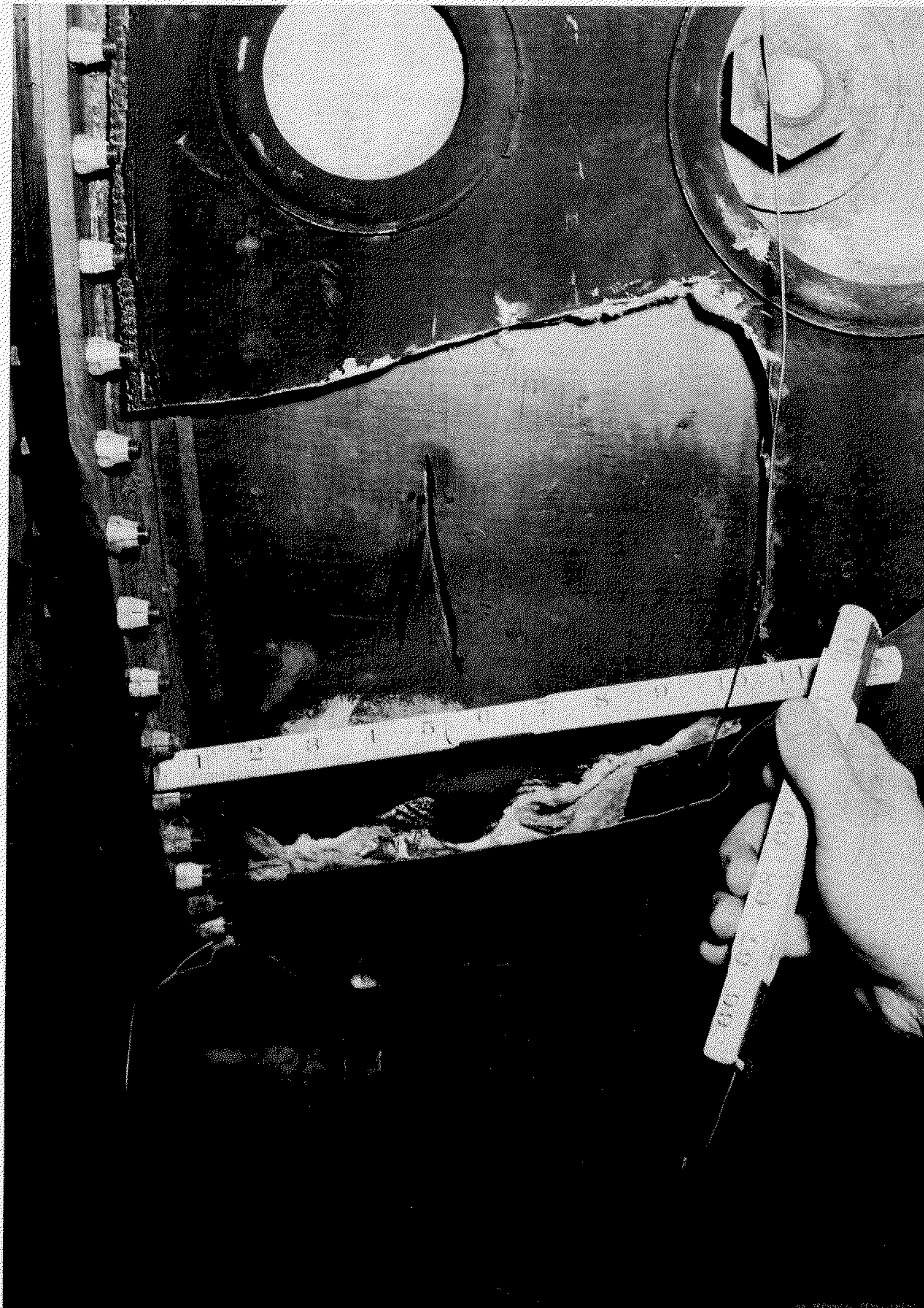

FIG. 2 4" X 3/32" SIMULATED CRACK IN TAIL CONE

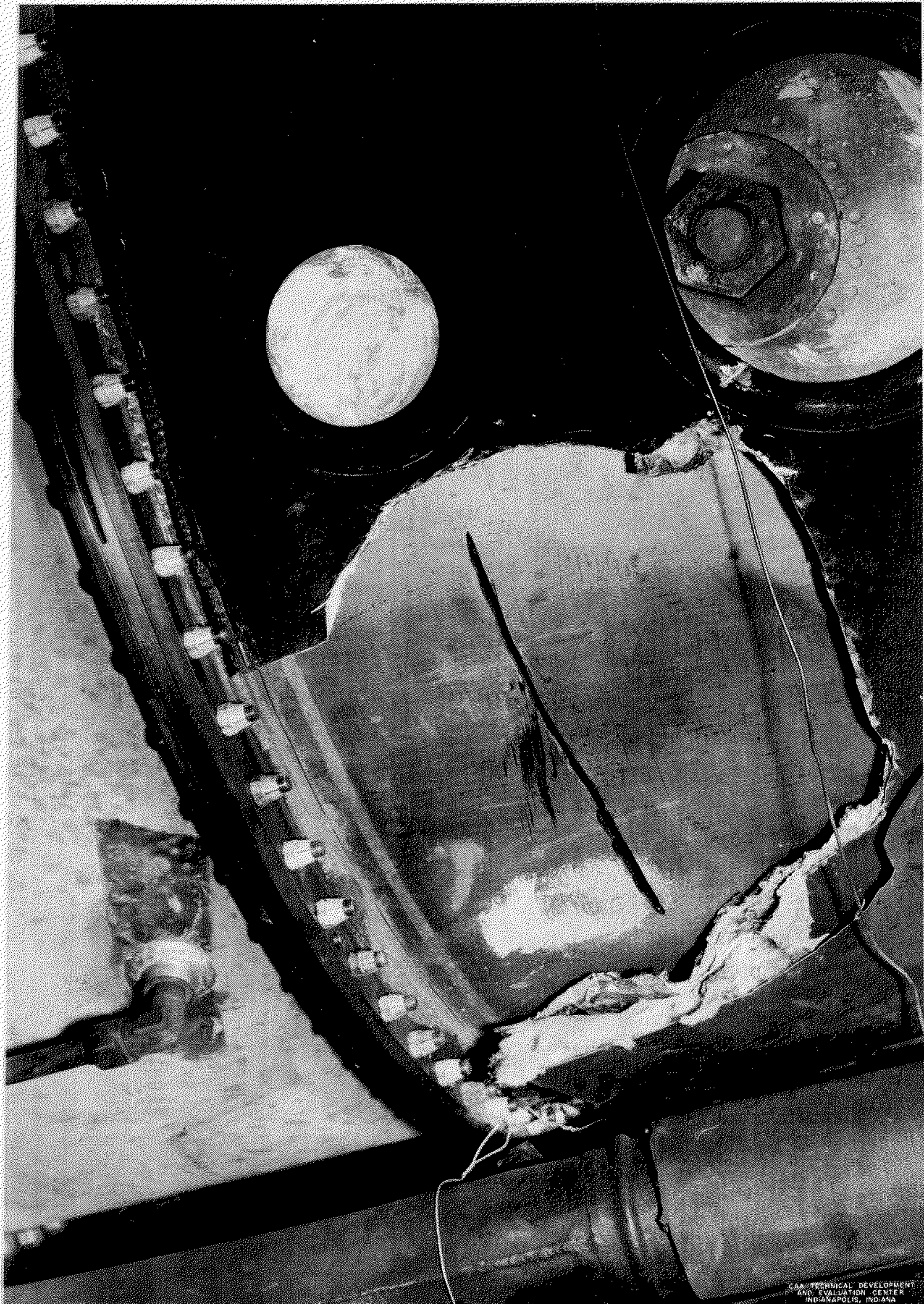

FIG. 3 9" X 5/32" SIMULATED CRACK IN TAIL CONE

FIG. 4 "TEE" SHAPED SIMULATED RUPTURE IN TAIL PIPE

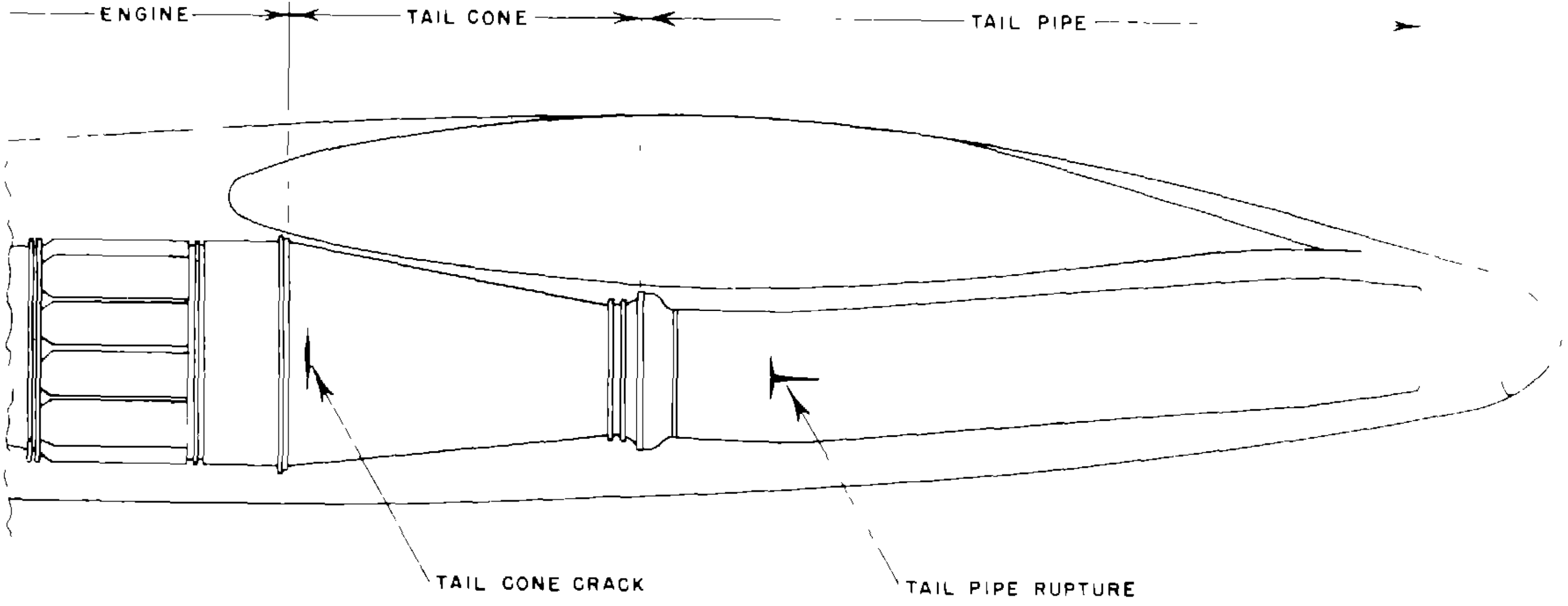

FIG 5 LOCATIONS OF SIMULATED FAILURES (AFT COMPARTMENT, XB-45 NACELLE)