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EVALUATION OF THE CONTINUOUS RESETTING TYPE OF FIRE-DETECTION SYSTEM FOR THE B-36 NACELLE

FOR LIMITED DISTRIBUTION

by

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PROCEDURE

The facilities available at the TDEC include a full-scale B-36 nacelle, equipped with a Pratt & Whitney R4360-41 engine, and a wind tunnel which is operated during the tests to provide additional air to simulate flight conditions.

Two continuous type fire detection systems were installed in this nacelle by their manufacturers: Thomas A. Edison, Inc., West Orange, New Jersey, and Walter Kidde & Company, Inc., Belleville, New Jersey. Figures 1 and 2 show the major components comprising each system. Both systems were arranged in approximately the same pattern to provide protection for the engine and lower accessory compartments, arbitrarily designated as Zones 1 and 2 in Fig. 3. The pattern, similar to that shown in Fig. 4, was comprised of several major loops. One loop was attached to the afterbody which is the stationary part of the propeller-hub housing immediately forward of the propeller. A second loop located between the air plug and the cowling was attached to the rear cowl-support ring. A third loop encircling the engine was attached to the middle cowl-support ring. All three loops connected together constituted the Zone 1 or engine portion of the system. For the protection of Zone 2, the lower accessory section, one loop was attached to the louvered access door on the bottom of the nacelle and other loops followed a circuitous path along nacelle formers and tubular engine-mount members. The Zone 1 and Zone 2 portions of the system were connected together to form a continuous length of element, which was ultimately connected to a control box or amplifier. As installed, the system afforded protection for only a small part of Zone 3 and none for Zone 4, which is the tunnel. Extra independent detector circuits were used to study alternate arrangements of the system.

Prior to the detector tests a survey was made of the air flow, pressures, and temperatures normally existing in the various zones of the nacelle during selected representative operating conditions. The air flow and pressure measurements were taken by means of pitot-static heads connected to water manometers. The temperatures were taken by means of thermocouples connected to recording potentiometers.

The fire-testing program involved the starting of more than 600 fires in Zones 1 and 2 of the test nacelle. The majority of these were in Zone 1, which is a large zone with many possible ignition sources. The fires were of a size normally used in detector investigations; namely, the fires produced by burning gasoline sprayed from a nozzle at a rate of approximately 1/2 gallon per minute under a pump pressure of 20 pounds per square inch. Gasoline was supplied to the fires until both detector systems operated but for no longer than ten seconds per test.

During the tests definite aircraft operating conditions were simulated including ground operation, take-off, climb, and three conditions in the cruise range arbitrarily called minimum, medium, and maximum cruise.

The principal objectives of the fire-test program were to determine whether the continuous detector arrangement was effective, to study how fires behave under various conditions, and to revise the system to improve its efficiency if that seemed feasible.

RESULTS AND DISCUSSION

The preliminary study of static pressures, air flow, and normal ambient temperatures in the major zones of the nacelle was of considerable assistance in determining what measures could be employed to improve the installed system. For instance, the static-pressure results confirmed the belief that fires originating in Zone 1 have a tendency to move forward through the nacelle, and this knowledge influenced the decision to protect portions of Zone 1.

The magnitude of the pressure differentials, especially between Zone 1 and the more forward zones, was significant and was influenced largely by the position of the air plug. This fact is most clearly demonstrated by data compiled during a test in which flight conditions were simulated with the engine operating at maximum cruise power. See Table I.

TABLE I

STATIC PRESSURES IN NACELLE ZONES
FOR DIFFERENT AIR-PLUG POSITIONS

Air Plug Position	Static Pressures: Zone 1 (inches H_2O)	Zone 2 (inches H_2O)	Zone 3 (inches H_2O)
Open	4.60	1.30	0.25
One-half open	[illegible]	2.15	0.20
Closed	19.00	[illegible]	0.20

It will be noted that the pressure differential between any two zones increases as the air plug closes. Zone 3 experienced practically no pressure change. Under these conditions there exists a strong tendency for fire to move forward from Zone 1 into Zones 2 or 3, or even from Zone 2 into Zone 3, if the seal between zones is imperfect or becomes imperfect due to heat buckling.

Zone 3 is a critical region because of the electrical harness concentrated within it. In the event that fire enters this region of an inboard nacelle and destroys the harness, a complete power loss could occur in that wing.

In addition to the measurements of static pressure in Zone 1, measurements were made of the air flow at the rear end of the zone. With the air plug open, the highest air speed was indicated in the annular opening between the air plug and the cowl. The velocity head in this region was two to three times as large as the velocity head measured between the air plug and the afterbody.

The air leaving the zone between the air plug and the [illegible] to pass straight out while the air between the air plug and the afterbody tended to follow the contour of the afterbody in a layer approximately 1-1/2 inches thick. Later, during fire tests, flames were observed to follow the same paths as they left the zone.

Closure of the air plug decreased the space through which the air could exit. In the completely closed position, no space remained between the air plug and the cowl through which air could pass, and a space only 3/4 inch wide remained between the air plug and the afterbody.

The temperature survey revealed no extreme temperatures in any of the three zones during normal engine operation. The maximum air temperature recorded in the entire zone [illegible] was [illegible]° F. This was recorded at the base of the right-hand turbosupercharger during single-turbosupercharger operation. The air temperature at all other points was [illegible]50° or less.

During engine operation at a cylinder-head temperature of 375° F with the air plug closed, the ambient temperature of the air in the space between the engine and the skin in Zone 1 reached 250° F while the temperature of the cooling air leaving the cylinder baffles reached 190° F. An air temperature of 400° F was recorded at the downstream side of the flange where the exhaust connects to Row E cylinder. The average ambient temperature in zones 2 and 3 was 150° F, and in Zone 4 the temperature ranged from 75° to 175° F.

The temperature measured at several points around the circumference of the afterbody near the continuous detector did not exceed 250° F. The air leaving the exhaust-shroud exit ducts on the afterbody was [illegible]° F.

As soon as the pressure and temperature survey had been completed, the detector fire-testing program was begun. At first, the fires were intended to resemble those which might originate near the exhaust-stack flanges at the cylinder heads. With the engine idling and the engine cooling fan turning at slow speed, the fires were usually detected within three seconds. Detection occurred in even less time when the fan was turning at high speed. At simulated-cruise power settings and with flight conditions produced by the wind-tunnel air blast of 120 mph, there was a tendency for fires to reduce in size and occasionally to blow out. As a result, the detection usually occurred five to eight seconds after the start of the fires. The detector loops mounted on the afterbody and on the rear cowl-support ring were best situated to intercept these fires.

Test fires intended to simulate fires originating on the crankcase were even more difficult to keep burning, and the detection time increased. In general, the response time of the detector system increased as the engine power increased from idle to cruising and as the fan speed increased from low to high. Undoubtedly, this could be attributed to the poorer quality of the fire in the faster moving air. Figure 5 shows such a fire. Detection was due almost altogether to the loop attached to the afterbody.

Fires which originated near the exhaust-collector ring were relatively large when the engine was idling and somewhat reduced in size under cruising conditions. The detection record was poor. The fires should have been detected by the loop attached to the middle cowl-support ring. However, this loop as installed by the manufacturers was buried in the channel of the ring to protect it from mechanical damage with the result that it was also protected from the fires. The two loops farther aft were, therefore, mainly responsible for any detection that occurred.

In Zone 2 there was relatively little air movement within the zone under normal conditions and as a consequence fires in this zone tended to billow. In particular locations, fires which were large enough emerged to the outside through openings around the exhaust ducts and through the louver openings in the bottom access door.

In making the installations of elements in Zone 2, the two manufacturers used different routings. No particular importance was attached to this fact prior to the tests because the coverage appeared to be adequate in both cases. However, when a variation in performance was noted between the two makes, the layouts of the systems were studied in detail.

The principal deficiency in the more sluggish system was judged to be the lack of sufficient element near the fire wall at the front of the zone. Other features, more minor in nature, were recognized; and while they might have had negligible bearing on the detection of Zone 2 fires, they would have been important because fires can enter the zone from Zone 1.

In those instances where fires escaped through the louvers, the flames appeared to be concentrated in the center of the openings. The original loops of element attached to the access door passed over the outer edges of the openings rather than through the center.

From observation of the fires during this phase of the program, the original system seemed to be fairly effective. Only a few areas seemed to require more detailed study. However, each loop received some attention. After a few experimental changes in location, the loop on the afterbody was found to be most effectively located in its original position. Since it was already mounted on one-inch standoff brackets, there was no need for any change. It was particularly well situated for the detection of crankcase fires. The loop between the air plug and the cowl was limited in effectiveness when retained in its original position, which was influenced partially by the comparatively large connectors used to join elements together. When the size of the connectors was reduced, it became possible to move the loop aft and away from the mounting surface and thus to bring it more fully into the air stream passing between the air plug and the cowl.

The bulk of the flames produced by fires on the outer periphery of the engine followed this air stream. Because of the length of Zone 1, it was found necessary to retain the loop attached to the middle cowl-support ring. The only change required was to place it in an exposed position where it could intercept fires in the forward end of the zone.

An investigation was conducted to determine whether this loop on the middle ring could be eliminated if a new loop were added to the system near the fire wall. This investigation was prompted by the fact that some of the fires started in Zone 1 gained entrance to Zone 3. It was thought that a loop mounted on the fire wall concentric with the exhaust-collector ring might be as effective as the original loop for average fires and more effectively located for detecting fires threatening to enter Zone 3. Unfortunately, the new loop did not prove to be capable of replacing the original loop; and, in addition, no practical method was found for mounting it on the fire wall where it would not interfere with an engine change. In lieu of this, it seems desirable to retain the loop on the middle former and to mount an element on the Zone 3 side of the fire wall as was done by one of the manufacturers in making the original installation.

The loop on the middle former ring was made more effective by moving it radially inward. This was accomplished by attaching two-inch standoff brackets to the ring and mounting the element on these. Thus, the element was brought into an exposed position, whereas it previously had been shielded to a large degree by the ring and by cables attached to the ring.

The lower portion of the loop had to pass over the deicing duct on two-inch standoff brackets in order to be effective in detecting fires concentrated in the lower part of the zone.

While there is a natural reluctance to locate loops in exposed positions because of their vulnerability to mechanical damage, it is essential that any heat-actuated detector be placed within moving air streams. Mounting such detectors directly to, or behind structural members or power-plant components can make them completely ineffective as fire detectors.

A series of tests was conducted to determine whether the double loop of element attached to the access door on the bottom of Zone 2 could be eliminated or at least simplified. This loop was disconnected from the remainder of the Zone 2 system and monitored separately. It was found that certain fires did not cause this element to alarm, but it was also found that certain other fires were detected by this element only. It was apparent that it could not be eliminated altogether. On the other hand, it was more elaborate than necessary. Instead of the double loop, one loop routed directly over the center of each row of louvers not only simplified the installation but reduced the amount of element required and improved its efficiency.

Consideration was given to extension of the detecting system into the lower part of Zone 3 immediately forward of Zone 2 because some fires passed from Zone 2 into Zone 3 through this area. A separately monitored loop was installed in Zone 3 for test purposes on one occasion, but it was found that such a loop was superfluous because the Zone 2 system could more easily detect the main body of fire in Zone 2 than the Zone 3 portion of the system could detect the small extension of the fire in Zone 3.

It would be helpful if some general rules could be laid down to assist those who wish to make a proper detector installation. Several factors including the structural design of the airplane, the routing of the element, and the potential fire paths all have a bearing on the methods which should be employed. The objective in all cases should be to place the detecting element in an exposed position where fire, as it normally exists in the region in question, will contact it.

The loop of element mounted on the afterbody was most effective when it was separated one inch from the surface of the afterbody by means of standoff brackets. The loop between the air plug and the cowl was attached to the cowl but separated from it so that it occupied a position approximately in the center of the annular opening. This separation was approximately two inches. The loop attached to the middle former ring was two inches radially inward from the ring. Greater separation was used in this case in order to place the element where it would be clear of electrical cable attached to the ring. Moreover, at the sides and bottom of the zone, the cowling was several inches away from the engine. By placing the element closer to the engine this large open space is more thoroughly monitored.

In Zone 2, the element attached to the engine mounts and structural formers were fastened one inch away from these surfaces. However, the element on the access door was mounted closer to the louvers because it was not necessary to have a separation in order to intercept the fires emerging from the zone.

The element used in the top of Zone 3 was fastened directly to the radial members supporting the fire wall. Since these members were perpendicular to the element, they did not shield the element to any great extent; and since the element in this position was separated from the fire wall by approximately two inches, it was sufficiently exposed so that the extension brackets were not needed.

So far in the discussion, only the system has been considered, with no mention being made of the performance of either make of detector. On the whole, both makes performed with equal satisfaction. Both experienced the same kinds of troubles at various times. Both required replacement of elements that had developed shorted spots, breaks at connectors, or were damaged as a result of careless handling. Considering the large number of fires to which the systems were subjected and the amount of handling they received, the number of failures was not exceptional. The manufacturers were kept informed of the performance of their respective systems and continually improved their products during the course of the program.

The elements mounted on the afterbody were adversely affected by the type of vibration to which they were subjected. To minimize the number of failures resulting from this cause, the manufacturers reduced the sizes of the connectors in an effort to equalize the difference in mass between the connectors and the rest of the element. Firm support for the connectors must be provided. As for the rest of the element, the spacing of supports may be whatever circumstances demand. Tests conducted on a vibrating table gave no indication that a spacing of eight inches was excessive for frequencies up to 50 cps.

On the average, where the Kidde and [illegible]dison systems were comparable, the latter was approximately two seconds slower than the former in detecting fires. The majority of the fires were detected within six seconds by both systems.

In the course of the test program, some definite conclusions were reached as to what constituted an efficient continuous-detector system for a C-36 nacelle. In order to verify these conclusions, it was decided to remove all of the element which had been originally installed for the te[illegible] and to make a completely new installation in accordance with test r[illegible]. Since nearly all of the components of the [illegible] system had undergone developmental changes and since the changes were such that it was [illegible] to replace individual components except by replacing the system in its entirety, this afforded an opportunity to use the latest type of Kidde equipment.

The newer Kidde system, from the electrical standpoint, is a single-wire system rather than the original double-wire system. The core of the new element is identical with the old except that in the new element one of the wires is welded to the connector and the other is [illegible] to the central contact. The connectors between elements have [illegible] 15 [illegible] [illegible] and have been satisfactory [illegible].

The general layout of the [illegible] similar to the [illegible] [illegible] modifications which the tests indicated [illegible] [illegible] series of photographs, taken at the time that the [illegible] new system was installed for final checking, show the locations of the various loops of the recommended system.

Figure 6 is a general view showing several of the loops [illegible] [illegible] loop of the complete system are shown in other [illegible] [illegible] two or more elements are joined together [illegible] by [illegible] shielded wire. [illegible] element is used [illegible] [illegible] to detect fires.

Figures 7 and 8 give [illegible] [illegible] forming the [illegible] loop on the afterbody. The [illegible] [illegible] the connector between [illegible] [illegible] the [illegible] of the nacelle.

The location of the loo between th. air plug and the cowl is shown in Figs. 9 and 10. In order to obtain the photographs, the air plug was removed. The element passes throu h holes in the air-plug actuator assemblies. Although these holes normally exist in the assemblies, th y must be enlarged slightly to accommodate the connectors. The connectors for this loop were also on the left side of the n celle.

At the middle cowl-support ring, two 10-f ot elements were connected tog ther to complete the loo . Figure 11 shows how two-inch stand-off brackets were used in order to bring the elements into th [illegible] n. The terminal connectors were at the left side of the zone.

The routing used in Zone 2 is difficult to describe and difficult to show by sketch or photogr ph. Five elements co sisting o three 5-foot and two 10-foot lengths were used. One of th 5-foot lengths [illegible] on the louvered access door as shown in Fig. 12. The other two 5-foot lengths were symmetrically mounted on op osite si es of the zone. Start ng at the hinge lin of the access door and following the contour of th [illegible] former out ard to [illegible], the elements then proceeded aft for a [illegible] m tely [illegible] terminated. One of these 5-foot lengths is shown in Fig. 13.

The two 10-foot elements were also symmetrically arrang d. They followed the outer periphery of the fire seal for approximately two fe t downward from the longeron near the wing line, then r dially inw rd toward the tunnel for approximately two fe t, part of the way around the underside of the tunnel, then diagonally along the horizontal engine mounts to the forward fir wall, and finally along a horizontal line across the fir wall. Portions of this loop are shown in Fi . 14.

The loop in the upper port on of Zone 3, shown in Fig. 15, is concentric with, and approximately one inch radially outward from, the engine-mount rin in that zone. The element is attached to the [illegible] side of r dial structural members which extend from the engine-mount ring to the cowl-su port ring.

A moderate number of tests with fires at representative locations indicated that the system was satisfactory and th t the new Kidde equipment operated as well as the original equipment.

CONCLUSIONS

1. Under simulated flight conditions, the static pressure in Zone 1 is of greater magnitude than the static pressure in Zone 2 or 3, and the static pressure in Zone 2 is of greater magnitude than the static pressure in Zone 3.

2. The pressure differential between the two zones increases as the [illegible] flow s.

3. Air can progress forward in the nacelle from Zone 1 into Zones 2 and 3 and from Zone 2 into Zone 3.

4. In progressing from Zone 1 into Zones 2 and 3, the fires usually passed through gaps between the mating surfaces of the [illegible] and the exhaust-collector-ring shroud.

5. In progressing from Zone 2 into Zone 3, the fires usually passed through the horizontal flexible seals at the top of the Zone 2 or through oversized openings provided for the passage of tubing and cable through the fire wall.

6. Zone 1 crankcase fires are best detected by the continuous fire-detecting element mounted on the afterbody.

7. Fires originating in the rear half of Zone 1 are best detected by elements mounted on the afterbody, and [illegible] on the air plug and the [illegible]

8. Fires originating [illegible]

[illegible]

[illegible]

[illegible]

10. [illegible] to have a loop of element near the [illegible] of Zone 3.

[illegible]

[illegible]

[illegible]

[illegible]

RECOMMENDATIONS

1. In making an installation of a continuous fire-detecting system for the B-36 nacelle, the system described in the text and shown in Figs. 6 through 15 is recommended.

2. Detecting element should be separated from any surface on which it is mounted so that flames in their most normal course will impinge on the element.

3. Terminal fittings should be located for easy accessibility and preferably all on the same side of the nacelle to facilitate maintenance.

4. Disconnect points should be located where they are accessible to facilitate quick engine changes.

5. To simplify manufacturing, supply, and maintenance problems, the continuous detector system for the B-36 should be arranged so that its assembly would require no other sizes of element than five-foot and ten-foot lengths.

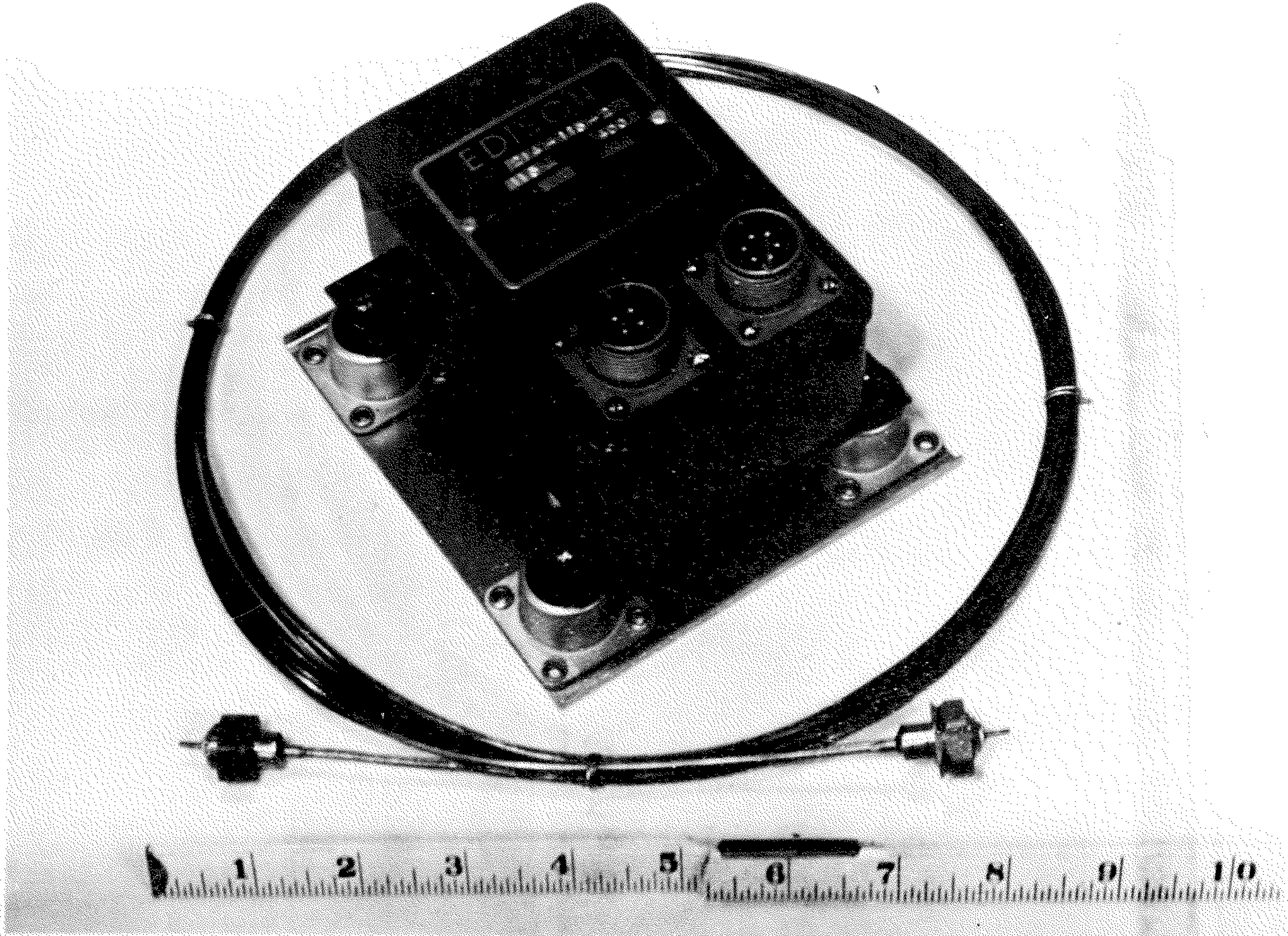


FIG. 1 MAJOR COMPONENTS OF THE EDISON CONTINUOUS RESETTING FIRE DETECTOR SYSTEM

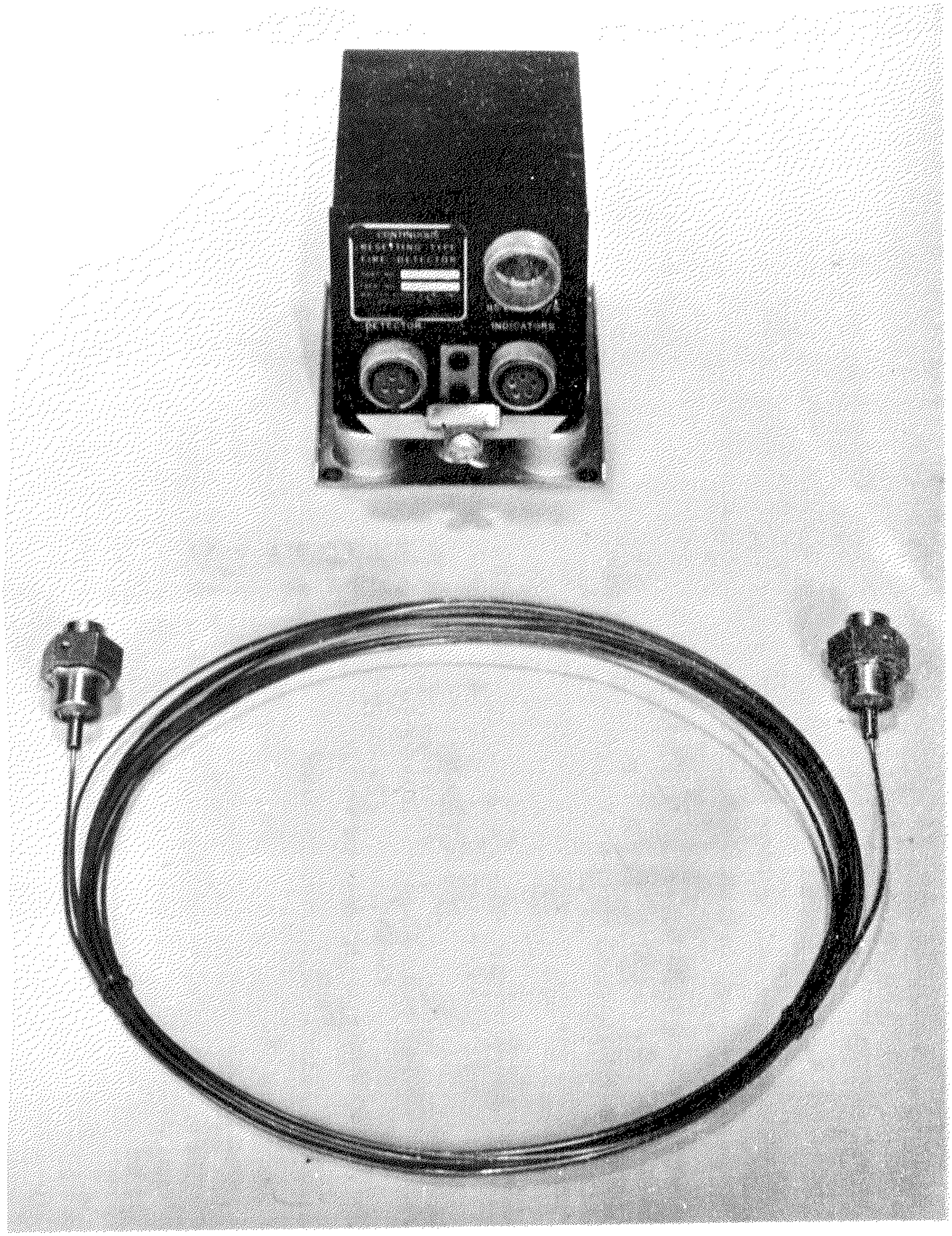


FIG. 2 MAJOR COMPONENTS OF THE KIDDE CONTINUOUS RESETTING FIRE DETECTOR SYSTEM

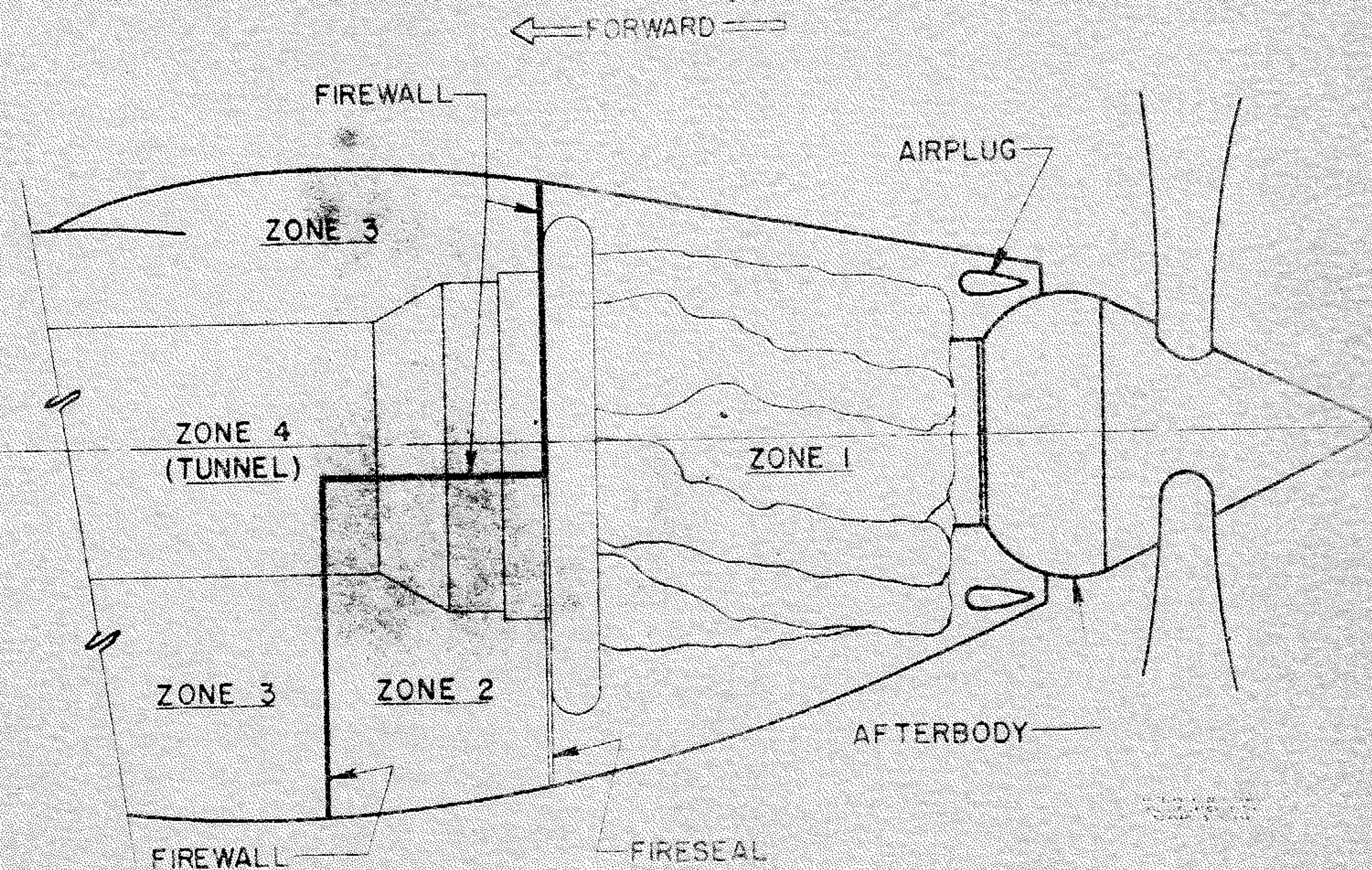


FIG. 3 MAJOR ZONES IN THE B-36 NACELLE

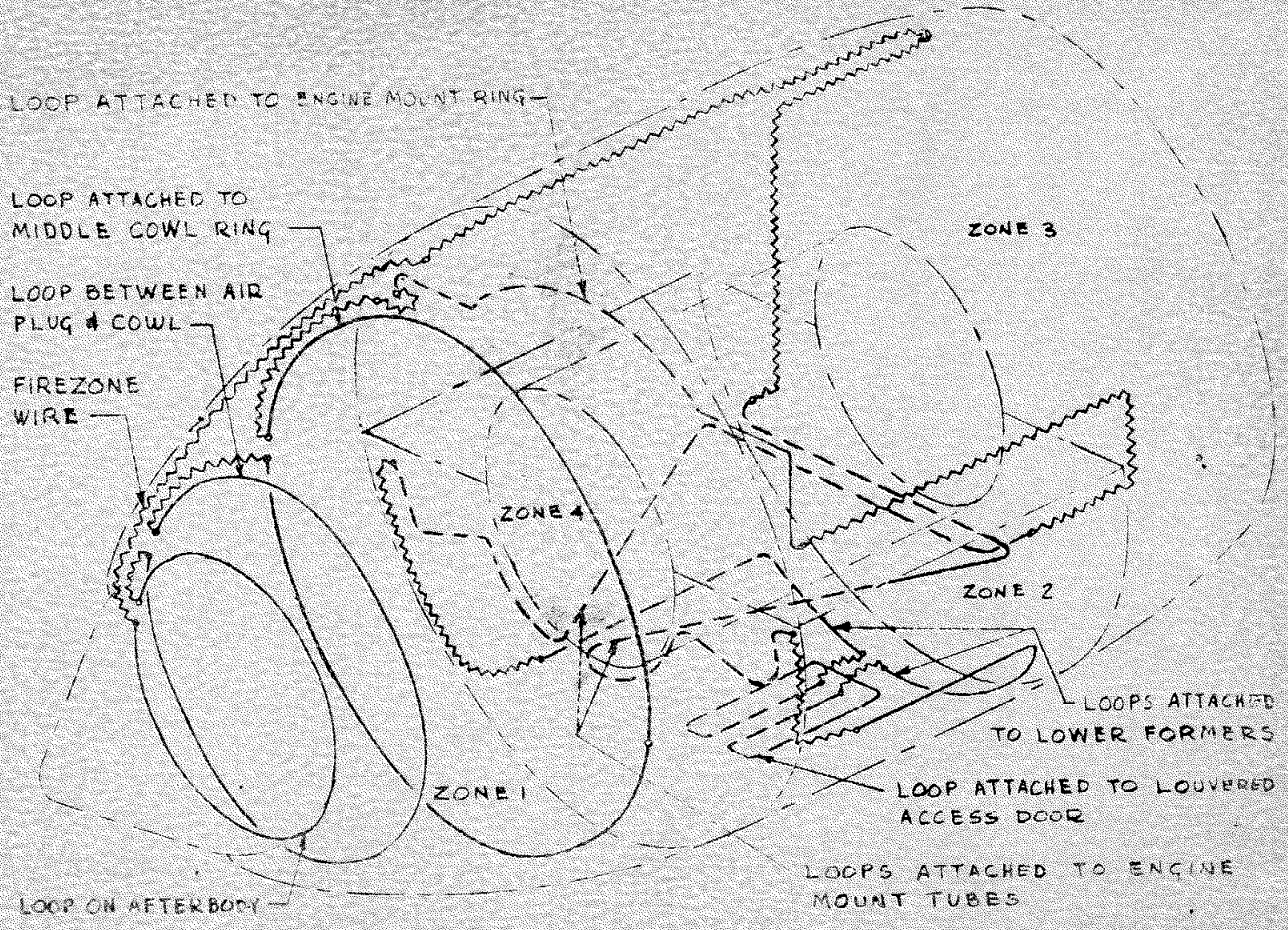


FIG. 4 FINAL CONFIGURATION OF CONTINUOUS TYPE FIRE DETECTION SYSTEM IN THE B-36 TEST NACELLE

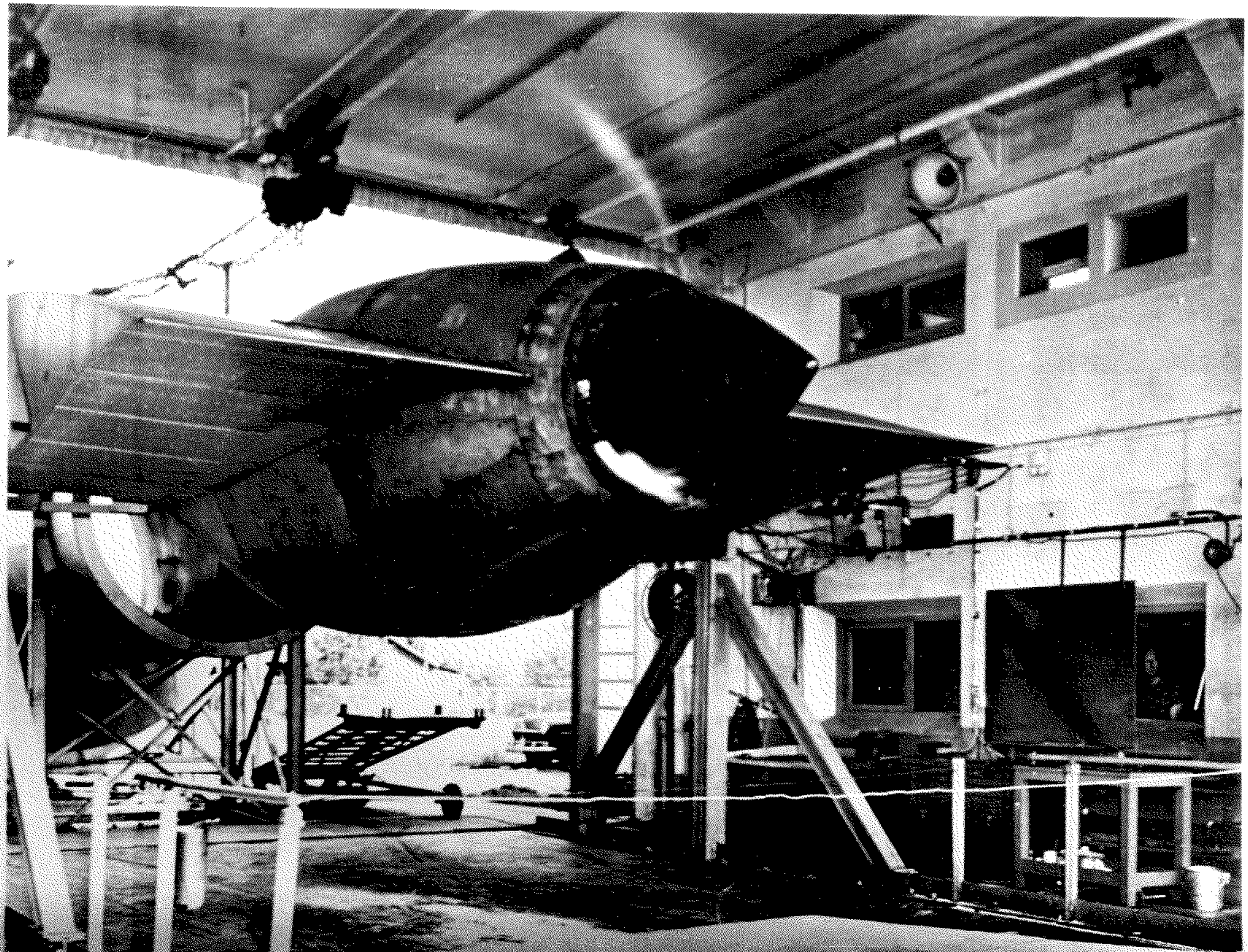


FIG. 5 TYPICAL ZONE I DETECTION TEST FIRE

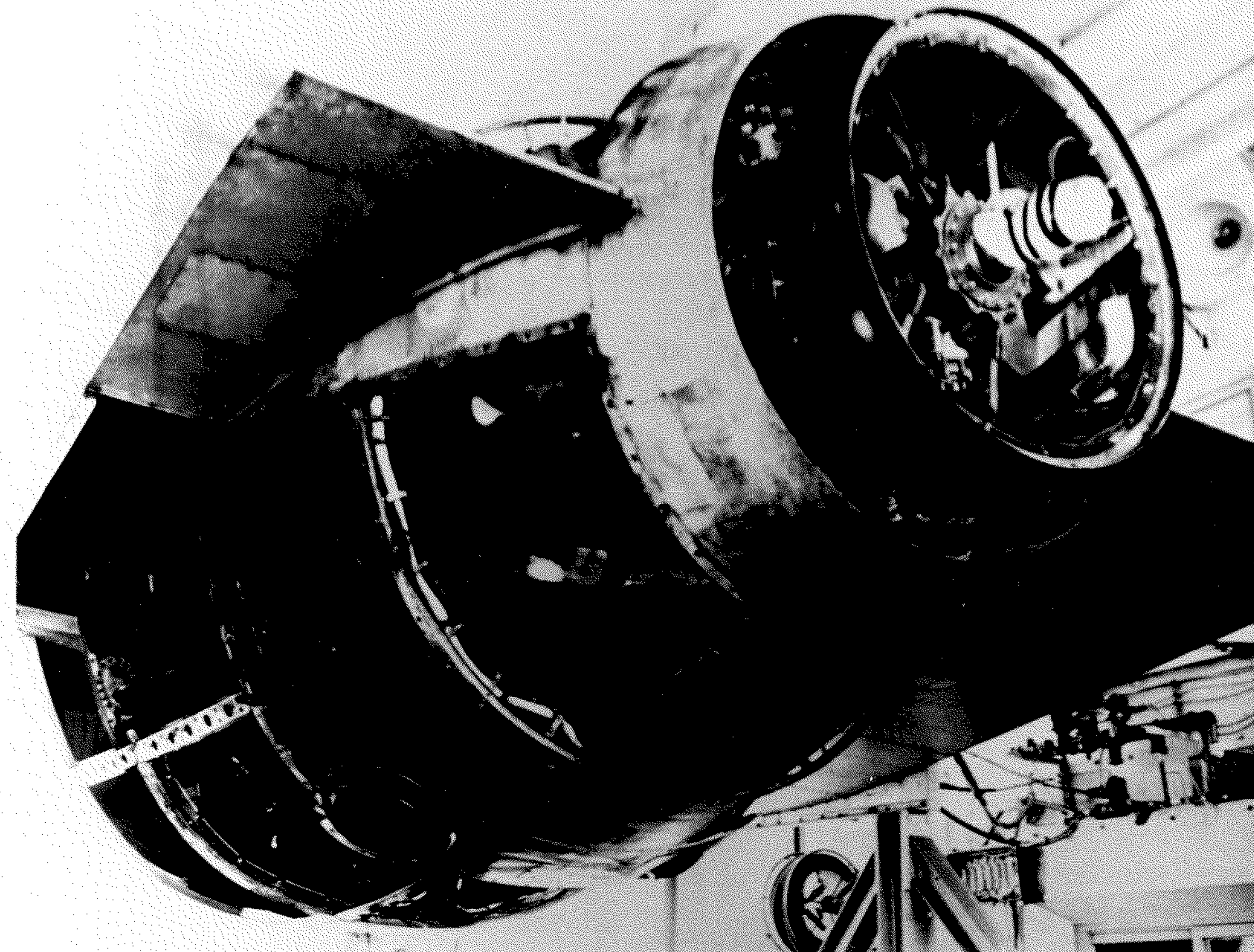


FIG 6 GENERAL VIEW OF TEST NACELLE WITH THE CONTINUOUS DETECTOR SYSTEM INSTALLED

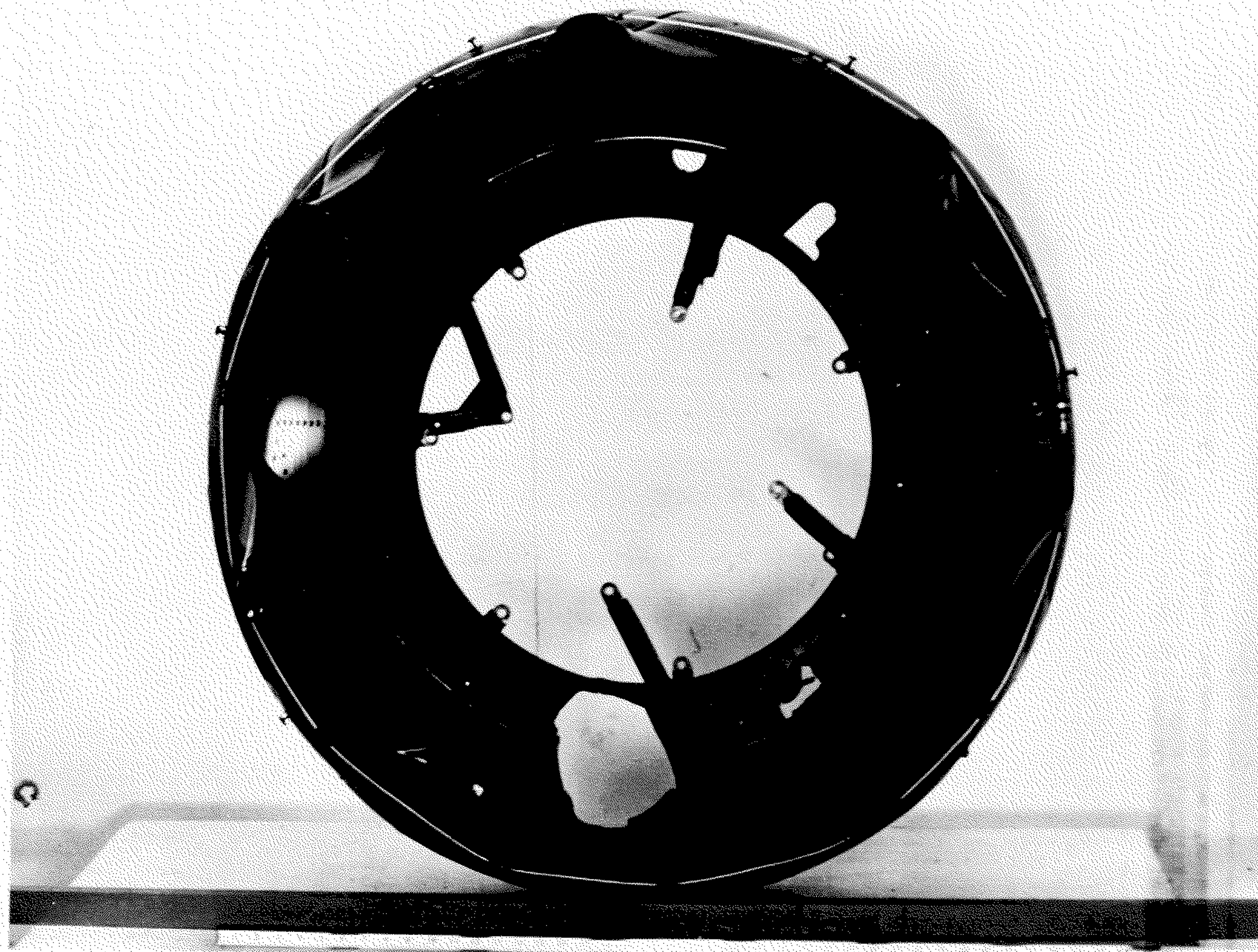


FIG. 7 OVERALL VIEW OF LOOP ON AFTERBODY

FIG. 8 MOUNTING DETAILS FOR AFTERBODY LOOP

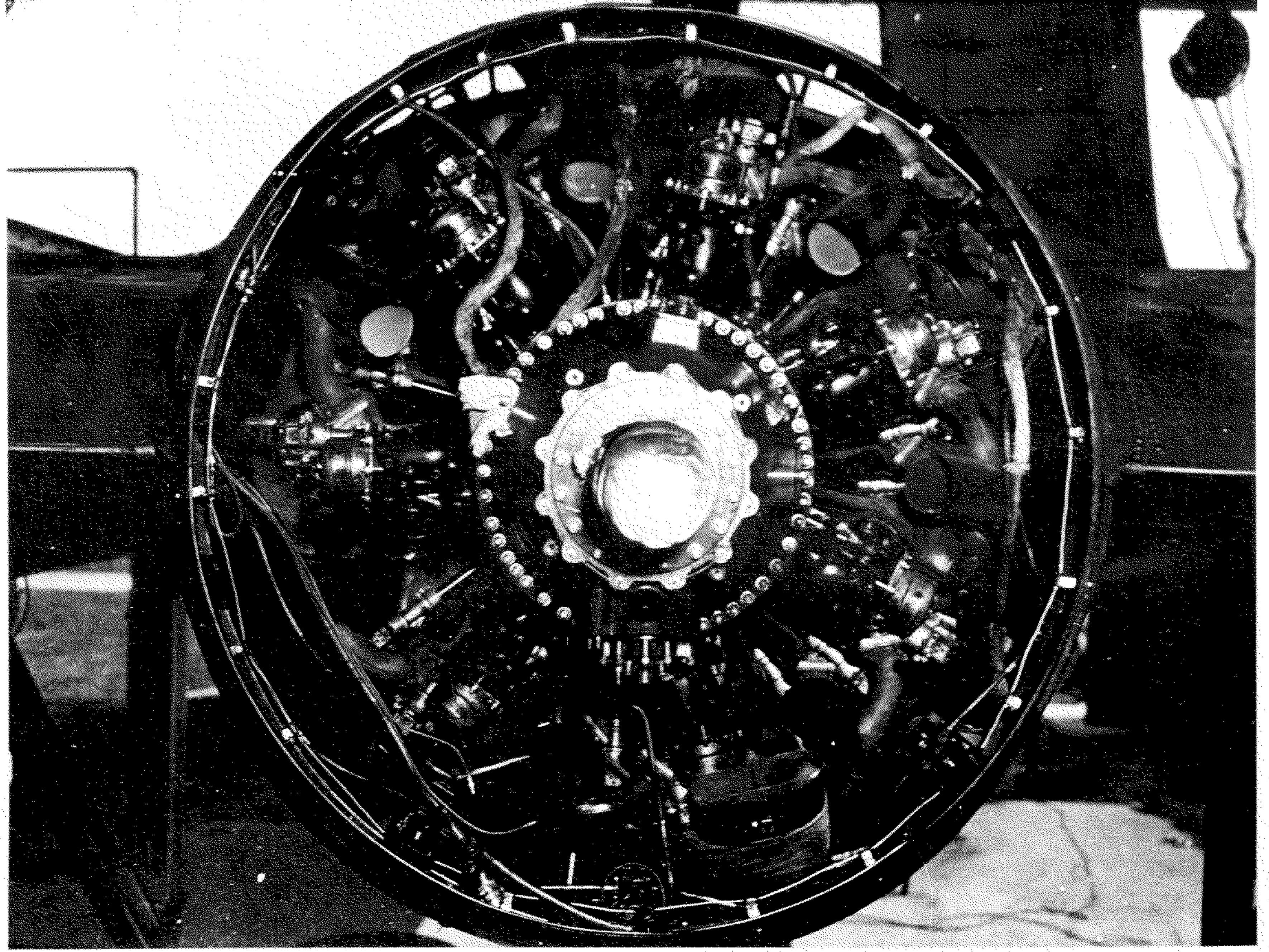


FIG. 9 OVERALL VIEW OF LOOP BETWEEN THE AIR PLUG AND THE COWL

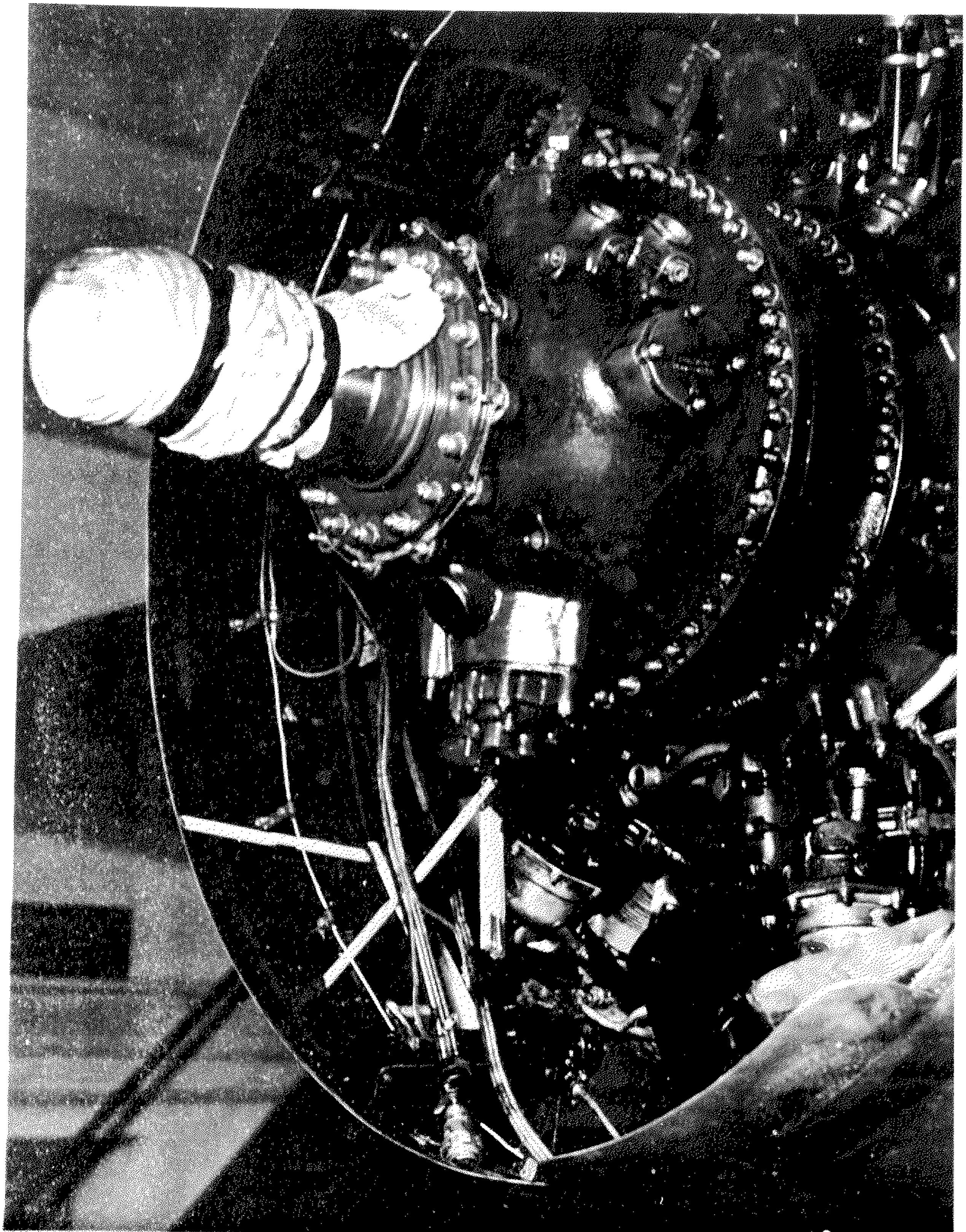
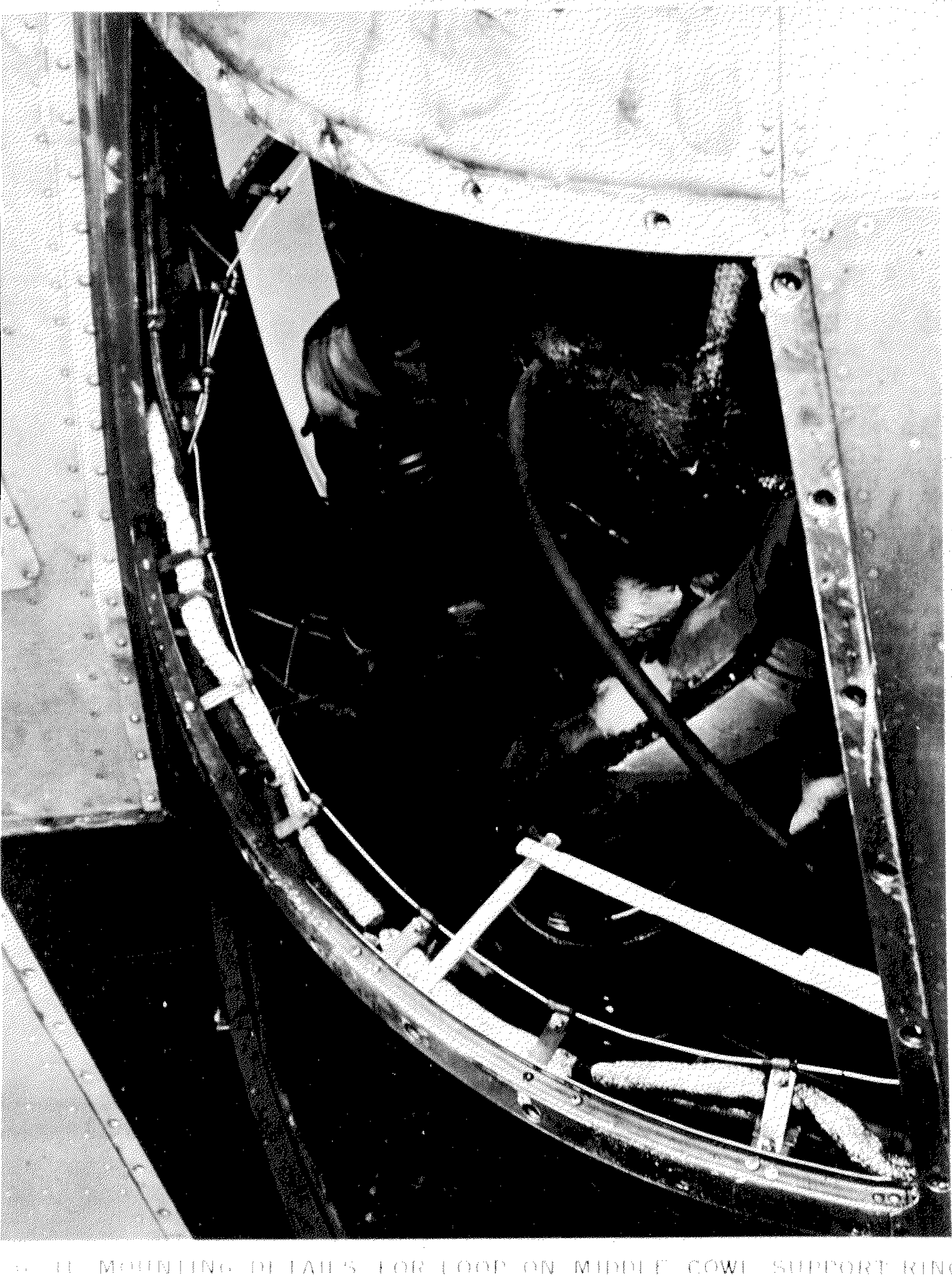


FIG. 10 MOUNTING DETAILS FOR LOOP BETWEEN THE AIR PLUG AND THE COWL



11 MOUNTING DETAILS FOR LOOP ON MIDDLE COWL SUPPORT RING

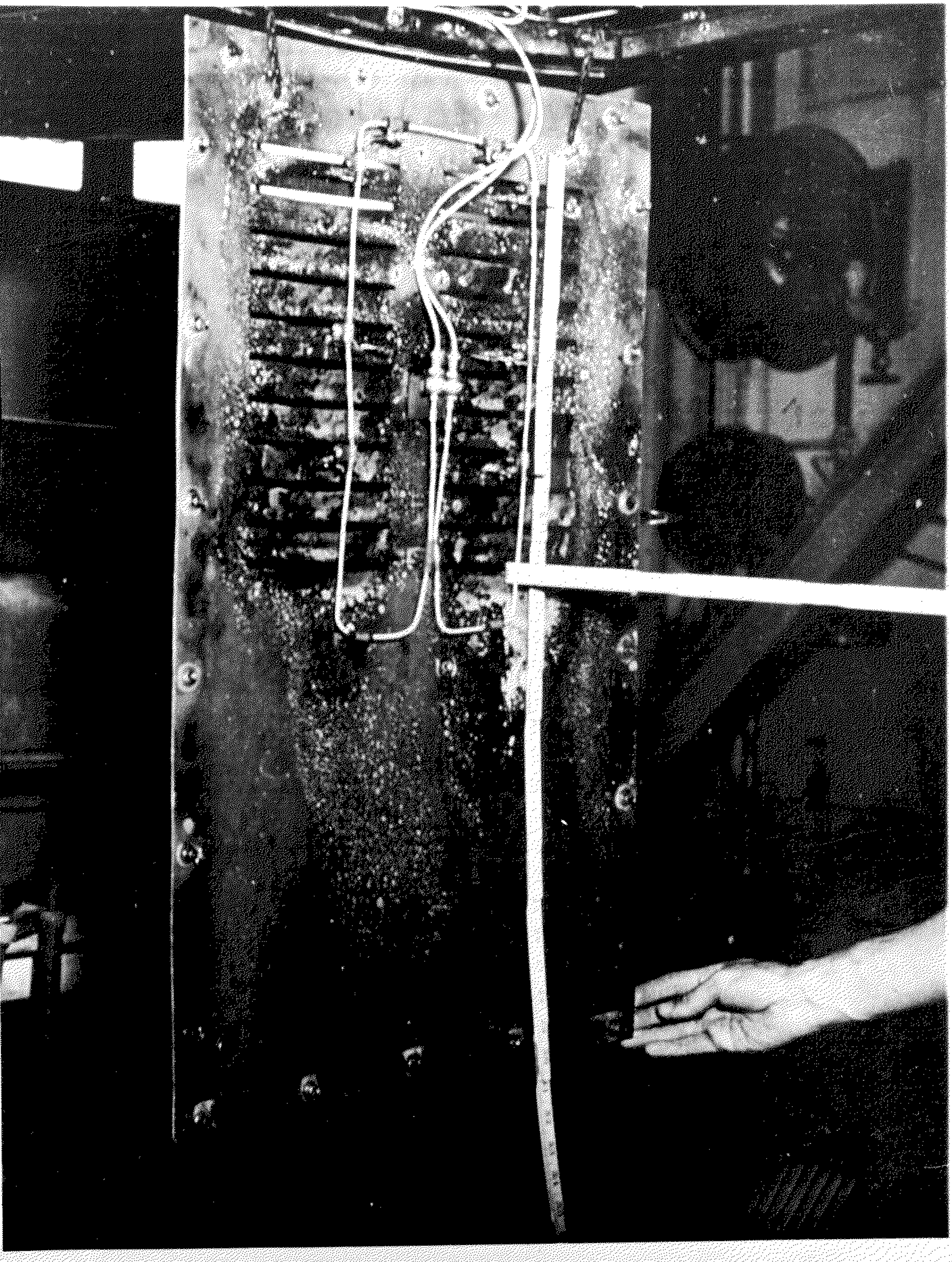


FIG. 12 MOUNTING DETAILS OF LOOP ON ZONE 2 ACCESS DOOR

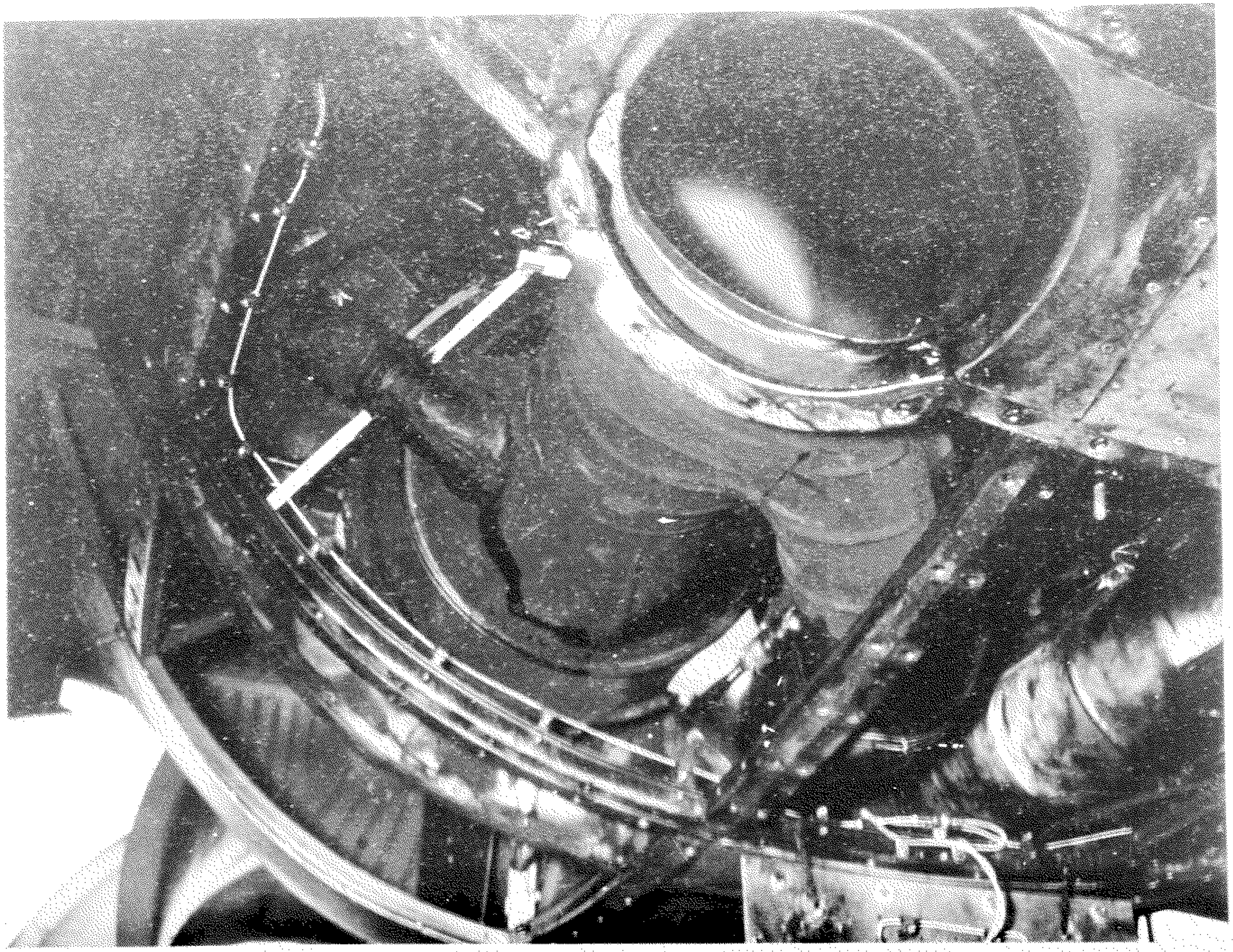


FIG. 3 V-5A SHOWING LOOP ATTACHED TO LOWER FORMERS

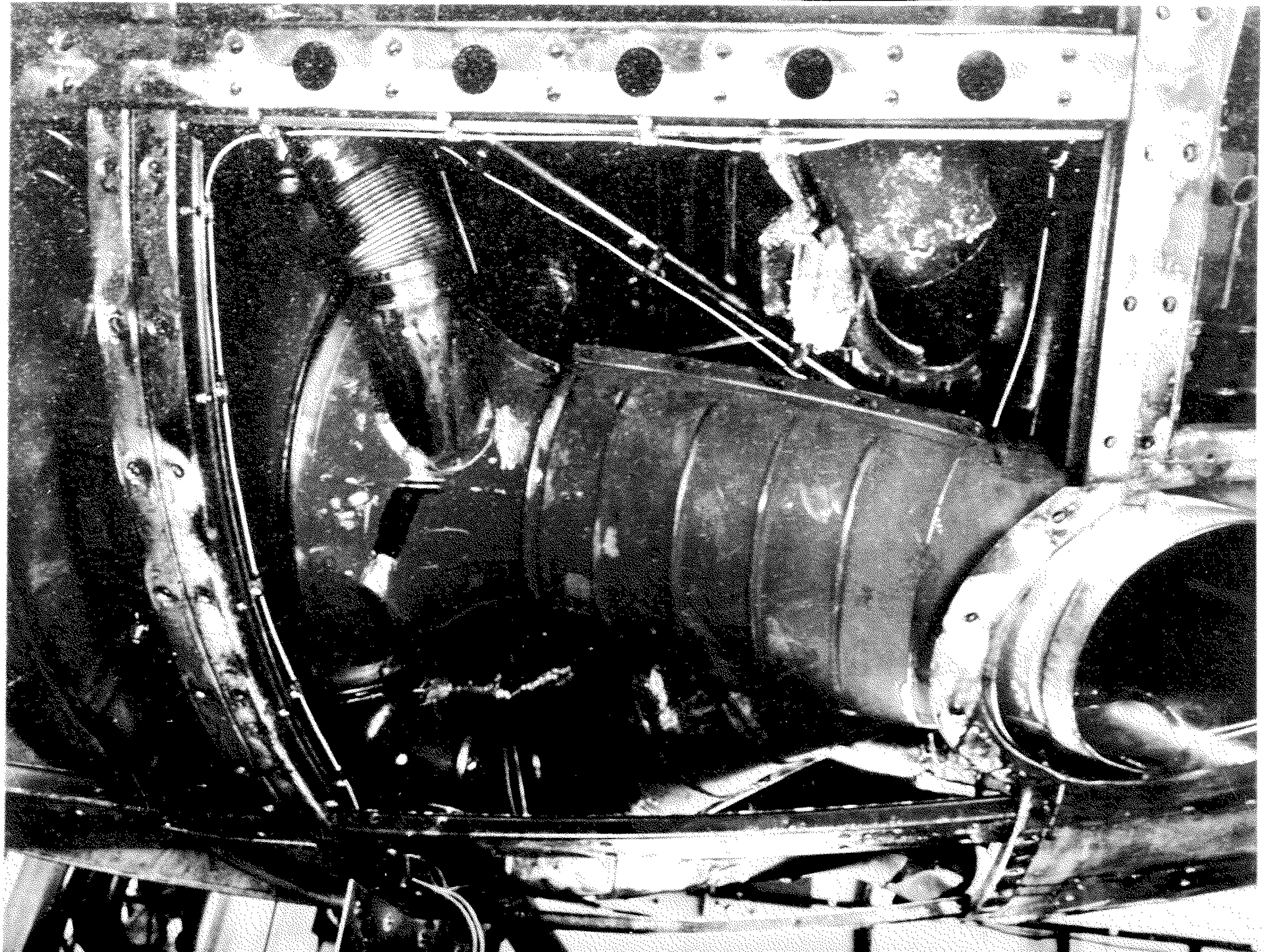


FIG. 14 VIEW OF ZONE 2 SHOWING PORTIONS OF VARIOUS LOOPS