CALIFORNIA INSTITUTE OF TECHNOLOGY

SOIL MECHANICS LABORATORY

EXAMINATION OF THE SURVEYOR 3 SURFACE SAMPLER SCOOP RETURNED BY THE APOLLO 12 MISSION

by

R. F. Scott and K. A. Zuckerman

(NASA-CR-127521) EXAMINATION OF SURVEYOR 3 SURFACE SAMPLER SCOOP RETURNED BY APOLLO 12 MISSION (California Inst. of Tech.) 79 p

N73-73872

Unclas

00/99 07413

1971

EXAMINATION OF THE SURVEYOR 3
SURFACE SAMPLER SCOOP
RETURNED BY THE APOLLO 12 MISSION

by

Ronald F. Scott and K. A. Zuckerman

California Institute of Technology

1971

EXAMINATION OF THE SURVEYOR 3 SURFACE SAMPLER SCOOP RETURNED BY THE APOLLO 12 MISSION

by

R. F. Scott and K. A. Zuckerman
Division of Engineering and Applied Science

Introduction

The Surveyor 3 spacecraft was launched from Cape Kennedy to the moon on April 17, 1967. It carried the surface sampler (Fig. 1) for the purpose of performing mechanical tests of the lunar surface. Three days later, the spacecraft landed on the moon's surface in Oceanus Procellarum and became operational. After a number of checks of the spacecraft systems, the surface sampler was turned on, and, following calibration tests above the lunar surface, was used on 21 April 1967, to carry out the first controlled tests of the physical and mechanical properties of the lunar surface material (Ref. 1). During the initial calibration sequence it was apparent that the sampler was operating normally except in the extension and retraction mode. In this mode, the commanded movements were about one-third of those recorded in the preflight calibrations. The anomaly persisted throughout the entire period of operation of the sampler on the moon, and no changes in it were observed. It was concluded, on the basis of an evaluation of the possible failure modes of the sampler system, that the problem lay in the electrical circuit of the retraction motor rather than in any frictional characteristics developed in the joints during the landing of the Surveyor spacecraft. The sampler was used for a period of about 18-1/2 hours and responded to a total of 1900 commands. Contact was made with the lunar surface in 25 bearing and impact tests. In trenching tests it is roughly estimated that the bucket of the surface sampler traveled a distance of 20 feet through or in the lunar soil. In impact tests the base of the scoop door came in relatively violent contact with the lunar surface material 13 times, as it was dropped from a range of heights of between 12 and 24 inches above the lunar surface. Figure 2 is an enlargement of a Surveyor 3 television picture and shows the scoop on May 1, 1967. It will be referred to later.

Following the cessation of lunar surface operations at the end of the first lunar day, 3 May 1967, the surface sampler and the spacecraft remained inactive for the lunar night. At this time the sampler had been positioned to the extreme right of its operational area and elevated almost to its maximum extent so that the bucket was at a height of about 30 inches above the lunar surface. The spacecraft evidently did not respond to commands sent at the beginning of the second lunar day. No further responses were received from the spacecraft.

Following the success of the first lunar manned mission, Apollo 11, in July 1969, plans were made for a second spacecraft, Apollo 12, to land as close as possible to the Surveyor 3 landing site in order that the astronauts could visit the spacecraft and its vicinity and possibly remove parts of the spacecraft for return to earth. Apollo 12's flight progressed successfully, and on 19 November 1969 the lunar module landed approximately 510 feet to the northwest of the Surveyor 3 spacecraft, which was visible to the astronauts on their emergence from the lunar module.

The astronauts, Captains Conrad and Bean, made two excursions outside their spacecraft; on the second of these the Surveyor spacecraft was visited, photographed, and examined. Figure 3 is an enlarged picture of the right* side of the surface sampler taken on the Apollo 12 mission; Fig. 4 shows the left side. The pictures were originally taken by the astronauts in black and white.

During the operations around Surveyor 3 the astronauts were successful in recovering a number of parts of the spacecraft, including a portion of the surface sampler comprising the scoop and the first joint of the instrument. It was not thought possible prior to the flight that the scoop could be brought back because the cable cutting tool supplied to the astronauts for removal of the other components had not proved suitable in preflight tests for cutting the retraction tape of the surface sampler. However, astronaut Conrad reported that when he applied the tool to the Surveyor 3 retraction tape and twisted it the extension tape broke away from the sampler. Since no part of the tape was returned, it is likely that the tape broke at a point where the tape was welded to itself near the scoop. Conrad then severed three arms of the scoop behind the first joint. The scoop and the attached portions of the arms up to the first joint were put in a plastic bag and returned to the lunar module. The retrieval of the scoop was facilitated by the fortuitous positioning of the sampler at its maximum elevation in 1967.

Eventually, the portion of the sampler in the bag was transferred to the command module, returned to earth, and stored in quarantine in the Lunar Receiving Laboratory (LRL) at the NASA Manned Spacecraft Center, Houston, Texas until its first release on 7 January 1970. During this time, no attempt

---

*"Right" and "left" are used from the point of view of the Surveyor 3 television camera.

was made to maintain the surface sampler scoop in vacuum and, in fact, it was removed from the bag at least once and exposed to the atmosphere inside the quarantine facility. It was not, therefore, to be expected that the lunar soil accompanying the scoop would exhibit the same properties as lunar soil in the high vacuum conditions existing at the lunar surface.

When the Surveyor 3 operations ended in 1967 the sampler scoop door was closed, and an unknown amount of lunar soil was contained inside the bucket. Since the scoop, while inside the plastic bag, was subjected to a good deal of handling during the various stages of its journey back to earth and in the LRL, the soil inside emerged through openings between the scoop door and the body and had free access to all other parts of the mechanism. Consequently, although only the scoop had direct contact with the lunar surface during the Surveyor 3 mission, it was found that the entire outer surface of the bucket, the motor mechanism and housing, and the portions of the arms which were returned were all coated with lunar soil when the plastic bag was opened for preliminary examination of the scoop in the LRL. The soil was observed to adhere to the different parts of the surface sampler to varying degrees although it is not known if the mechanism of adhesion is the same as that which existed on the lunar surface. For example, in the conditions of atmospheric humidity in the LRL the soil may have picked up enough moisture so that it adhered to the scoop by virtue of its dampness as fine-grained terrestrial soil sticks to some surfaces. Adhesion of the soil to the scoop had been observed during the Surveyor 3 operations. During Surveyor operations some estimates had been made of the magnitude of the adhesion of the lunar soil to Surveyor spacecraft components, but no measurements of this property had been possible.

In the preliminary examination in the LRL it was noticed that there was a concentration of lunar soil on the right-hand side of the scoop in the area shown in Fig. 3 to be covered with lunar soil on the undisturbed scoop on the lunar surface. Possibly some of this material still represented pristine lunar surface material adhering to the scoop. Elsewhere on the scoop surface it was not possible to identify on the astronauts' pictures areas of definite soil cover which could be correlated with the scoop appearance and soil coating at the time of the initial examinations.

Following preliminary examination in January at the LRL, the scoop was transferred to its designers and manufacturers, the Hughes Aircraft Company (HAC), Culver City, California. In the following two months plans were established for the examination, handling and testing of the scoop and the material accompanying it. The surface sampler scoop remained in the Surveyor test facility at HAC, and further detailed examination, which is described below, took place there.

Detailed Examination of Scoop Surface

In the period before the detailed scoop examination was carried out, a study was made along similar lines of a surface sampler in the Soil Mechanics Laboratory at the California Institute of Technology. This sampler, No. SN 44107, is a flight model conforming in all essential details to the device mounted on Surveyor 3. It contains the same materials and is painted with the same original paint. It differs from the Surveyor 3 scoop in only a few essentially minor exterior details. They are: (1) the Surveyor 3 scoop has short black sleeves painted on the arms of the scoop adjacent to the joints (see Fig. 1); this was not done on any of the other surface samplers, (2) the laboratory scoop possesses two screws inserted in its top surface; these are not present on the Surveyor 3 scoop, (3) some of the screws on the laboratory scoop have a different head size and shape, (4) no epoxy has been applied to the screws and electrical connections of the laboratory scoop. In terms of geometry, design and dimensions, as will be seen in subsequent pictures, the scoops are, however, identical. In the following discussion the "laboratory" and the "returned" scoops will be compared, with reference to pictures taken of the laboratory scoop alone, the returned scoop alone, and some pictures of the two scoops alongside each other.

The plans for the examination of the returned Surveyor parts were complete by the end of March, and a detailed study of the scoop began on 1 April 1970.

External Appearance

Prior to removal of any of the lunar soil coating the exterior of the scoop the surface was examined and photographed in detail at various levels of magnification and in electronic flash, 3200^{o}K tungsten (standard artificial light for Type B color film), infrared, and ultraviolet illumination conditions.

In appearance, a number of changes were manifest in the returned sampler. The blue paint which covers most of the surface appears to have faded in color from the original light blue color to a whitish blue in the relatively protected or concealed areas of the arms and scoop. The original color of the paint is 5.0 PB 7/6 on the Munsell scale and the paint on the returned sampler is now 10.0 B 8/2 on the Munsell scale in the cleaner (not soil-covered) areas and 10.0 B 7/2 on less-clean parts. However, on the upper surfaces of the arms and on the upper and side surfaces of the scoop itself the color of the paint has been changed to a light tan. This tan is most pronounced on the upper surfaces and shades into the whitish-blue on the underside of, for example, the arms. A microscopic examination of the paint surface at a magnification of 80 (Figs. 5 and 6) appears to indicate that the tan is a change in the painted surface rather than a light coating of particles covering the surface.

Figure 5 is an enlarged photograph of the painted surface on the left-hand side of the base of the scoop door. It is thought that during transit from the moon, and subsequent handling in the Lunar Receiving Laboratory and elsewhere, some of the paint around the edge of the scoop door may have been abraded and removed. Probably some of the paint was also removed during operations on the lunar surface. In Fig. 5, a gradation from the light blue color of the paint, which is very close to its original color, near the edge of the scoop door to the tan color, which is more characteristic of the major portion of the scoop surface, is observable. It can also be seen that many lunar soil particles, including a substantial proportion of small glassy spheres, are present. The irregular bumpy texture of the painted surface is characteristic of the original painted coating. The color change is not everywhere uniform, as can be observed by a comparison of Figs. 5 and 6, and it seems to depend on the degree to which the surface was exposed to solar radiation. In Fig. 6, which is the right-hand side of the scoop door base, the color change is less than on the scoop door portion shown in Fig. 5.

Coloration patterns on both the right- and left-hand sides of the scoop are shown in Figs. 7, 18 and 20 in black and white and natural color; the pattern is also apparent in varying degrees under different lighting conditions in Figs. 17 (infra-red), 19 (ultraviolet), 21(UV), 22(UV) and 24 (UV). To some extent, the patterns of color change can be correlated with the extent to which the scoop was covered with lunar soil before it was touched by the astronauts. On the right-hand side of the scoop a comparison of Figs. 3 (taken by the astronauts) and 7 clearly indicates that the bottom portion of the scoop side which was covered with lunar soil has not changed in color to the same extent as the rest of the scoop. This would seem to indicate that the color change process is related to the irradiation of the painted surface. It can be seen in Figs. 20 and 21 that the top of the scoop also has a blotchy appearance; the tan color is lighter inside the blotches. In this area, the effect again appears to be related to a protective covering of soil clumps or aggregates as can be seen by comparing Figs. 20 and 21 with the Surveyor 3 photograph, Fig. 2.

A visual examination of the scoop as shown by a comparison of Figs. 18 and 20, indicates that the intensity of tan coloration is greatest on the upper surface of the scoop, less on the sides, and still less on areas which have been shaded to some extent. Although a detailed examination of this point has not been made, it appears that the degree of alteration of the painted surface is related to the duration and angle of surface exposure to the sun on the lunar surface. Even the base of the scoop, which was exposed to some solar radiation in the lunar morning, has been changed somewhat in color, as seen in Fig. 23. On the left-hand side of the scoop, (Fig. 4) a pattern of color is apparent, wherein the tip of the scoop appears lighter than the rest of the area on this side. This effect is still observable on the returned scoop, but is less clear than shown in Fig. 4. Possibly the illumination condition of Fig. 4, as well as the soil-coated condition of the returned scoop, made the contrast between the tanned and less tanned zones not so obvious. It seems likely that the blotchy appearance of the grooves or dents on the upper surface of the scoop, as seen in Fig. 22 for example, developed from an accumulation of some lunar soil in the bottom of the grooves, with a resulting protective action.

It is not known why general gradational differences in the degree of color change exist on apparently uniformly exposed plane sides of the scoop. These may arise from local changes in the scoop paint thickness or composition, or may be due to the presence on the moon of differing thicknesses of dust coatings resulting from lunar surface operations. It has been shown (Ref. 2) that, at some point between the end of Surveyor 3 operations in 1967 and the visit of Apollo 12 astronauts, two of the spacecraft's legs had collapsed. It is likely that some soil was shaken from the scoop at this time. This may have contributed to variations in the degree of color change in the paint in areas where no soil covering can be seen in the Apollo photographs. Alternatively, since the left side of the scoop was more exposed to the sandblasting of the Apollo 12 descent engine (Ref. 3), soil removal and further color changes may have been effected on this side during the Apollo 12 landing. A further possibility is that the abrasion of the paint which took place during the lunar surface testing resulted in different sensitivities of the paint to the possible irradiation in different areas. Since the color change is more visible in the ultraviolet photographs and less so in white light, it may be inferred that the change largely resulted from the exposure of the paint to radiation of ultraviolet wave lengths.

A second item of interest concerning the painted surface is the crazing or cracking of the paint on the sides and base of the scoop door. Polygonal fracture patterns are apparent in Figs. 5, 6, 7, 23 and 24. This portion of the scoop was made of a glass fiber-impregnated resin coated with the standard paint. The fracture pattern does not appear on the painted metallic surfaces of the rest of the scoop, and may therefore be related to the different thermal conduction and expansion characteristics of the paint, the resin and the metal. It is also possible that radiation damage to the paint could have resulted in volume changes in it. In this case, the appearance of fracture patterns on the scoop door would be related to either the different thickness of the paint or different nature of bonding of the paint to that surface as compared with the other metallic surfaces. The chipping of the paint from the scoop door tips indicate that the bonding between the paint and the resin was weaker there than elsewhere, since paint at the edges of the scoop body was equally subjected to contact with the lunar surface. A careful study of the Surveyor 3 television pictures was inconclusive as to the presence of chipping or flaking at these points during the lunar surface operations in 1967. Observations during handling of the returned sampler indicated that the paint at the corners of the scoop base chips quite easily. Fragments of paint were observed in the lunar soil which was collected from the inside and outside of the scoop.

Even a cursory examination of the returned scoop shows that it has been subjected to a considerable amount of scratching and abrasion. Some of the typical larger scratches are apparent in Fig. 7, and photographs made at higher magnification show them clearly. For example, a pair of pictures at a magnification of 11.5 illustrates the condition of the laboratory scoop (Fig. 8), in comparison with that of the returned scoop (Fig. 9) in the same area of the surface. The terrestrial scoop has been employed in a variety of soil testing operations in a number of different soils on earth, and it is observed in Fig. 8 that the general effect of this soil contact has been to smooth down the irregularities in the painted surface without the development of scratches. Considerably less soil contact took place with the Surveyor 3 scoop, but it is evident, as shown in Fig. 9, that its surface has been abraded. A general smoothing of the surface of the paint is also evident in Fig. 9. An undisturbed painted surface close to its original condition is shown in Fig. 14 (the laboratory scoop gear box) which demonstrates the rough nature of the surface developed by the spray painting process. It was initially thought that the scratches on the Surveyor 3 scoop formed in lunar surface operations but it has since been learned that the painted surface of the scoop may have been lightly sandpapered (and in places repainted) prior to launch to remove defects. Some months after the initial examination of the Surveyor 3 scoop, it was disassembled for study of the individual components. When this was done, it was found that the inside surface of the scoop presented an appearance essentially identical to that of the laboratory scoop in Fig. 14. Since the inside had been subjected to almost as much sliding contact with the lunar soil as the outside, it must be concluded that the lunar material has not substantially abraded the painted surface and the scratches visible in Figs. 7 and 9 result from preflight surface treatment.

Another comparison of the two surface samplers is shown in Fig. 10 (laboratory) and Fig. 11 (Surveyor 3 scoop) in which it can be seen that terrestrial operations have also resulted in the removal of paint chips from the side of the scoop tip, and that some crazing of the paint in this area has also occurred.

Adhesion of the lunar soil to all surfaces of the returned scoop is readily apparent in Figs. 9 and 11. Even the teflon seal of the scoop door is seen to be heavily coated with lunar soil particles in Fig. 11. The lunar soil scattered about the surface sampler during and following its return to earth appears to adhere differentially to the different surfaces of the sampler. The most obvious observation is that the lunar material adheres more readily, in order, to (1) painted, (2) Teflon, and (3) metallic surfaces. Figures 12 and 13 show for comparison the operating mechanism of the scoop door of the terrestrial sampler, and the same area of the Surveyor 3 sampler door. It can be seen that lunar soil is adhering to the painted surface of the door in considerable quantities whereas the metallic surface, the screw heads and the door axle are all relatively free from lunar soil. It should be noticed, of course, that the metallic surfaces are not absolutely clean. It was not possible to tell in a superficial examination if there was selective adhesion of various components of the lunar soil, except in the case of glassy spheres, as noted later. In Fig. 13, adhesion of the soil to the Teflon can also be clearly seen, as well as a slight color change of the Teflon itself. The Teflon appears slightly brown on its outer edges shading to the original milky white next to the metal part of the scoop door. It is apparent that this change took place rather quickly on the lunar surface by referring to Fig. 2 which clearly indicates the same shading on the visible portion of the Teflon door after only 10 days on the lunar surface. The discoloration is also clearly apparent in Fig. 25, and to a lesser degree in Figs. 23 and 24. As with the color change of the paint, the discoloration of the Teflon probably resulted from its exposure to solar radiation.

In spite of the considerable amount of contact with a variety of soils in laboratory bearing tests and trenching work, the surface of the gear housing (Fig. 14) of the terrestrial sampler exhibits almost the original appearance of the painted surface. The strong contrast between this and the lunar sampler is evident in Fig. 15. It is evident in Fig. 15 that the gear box had been repainted prior to launch a number of times.

In order to examine in more detail the changes which had occurred in the surface sampler, photographs were taken of both the laboratory device and the returned Surveyor 3 sampler under different lighting conditions. Using Ektachrome infra-red color film with a medium yellow filter, the appearance of the terrestrial sampler is shown in Fig. 16. The pinkish appearance of most of the sampler, in contrast to its light blue color under normal lighting and film conditions, indicates its reflective characteristics in the infra-red portion of the spectrum. The different appearance of the returned sampler is obvious in Fig. 17 made under identical lighting, film and filter conditions. The metallic parts of the surface appear to be least changed, and the painted surface itself no longer exhibits the pink appearance of the terrestrial sampler. This indicates that the sampler has become more highly absorbing to infra-red radiation. Such a change in the painted surface is of interest from the point of view of thermal control of various spacecraft compartments in extended missions in space.

The changes in the surface condition of the returned sampler are most strongly evident in those pictures in which the surface samplers were illuminated by soft ultraviolet light and photographed on color film through a No. 2A filter which excluded ultraviolet light. The film, therefore, records the emission of visible light stimulated by the ultraviolet light source. In Fig. 18 is shown a comparison of the terrestrial and returned lunar samplers under normal lighting and film conditions. The marked change in the appearance of the returned surface sampler, which had been cleaned prior to this picture, is obvious. For comparison, the appearance of the two samplers under ultraviolet light is shown in Fig. 19. This technique enhances a number of the details of the painted surface that are not obvious under ordinary illumination. In the second black marking from the bottom of the picture (Figs. 18 and 19) in the striped area of the returned surface sampler, a light streak can be seen. This streak was a defect in the anodized aluminum surface and existed prior to launch of the Surveyor spacecraft. It can just be seen in Fig. 1, for example. In Fig. 19, various stages in the painting or repainting of the terrestrial surface sampler can be seen by the different shading of the paint. The wiggly light-colored line half-way down the laboratory scoop on Fig. 19 (the same mark appears in darker blue in Fig. 18) is the result of carrying out tests with the terrestrial sampler in a soil saturated with water in order to simulate bearing capacity tests at lower g-levels. The mark at the side of the terrestrial surface sampler at the tip appears to be a finger print; other finger prints are also apparent on the painted surface. However, the most striking change under these lighting conditions is the completely different color of the returned surface sampler. It is obvious that under lunar conditions the surface properties of the painted surface have been substantially altered.

In Fig. 19 the brown color change which is apparent on earlier pictures, such as Fig. 18, appears as a dustier pink, contrasting to the lighter bluish pink, for example, at the scoop tip where the sampler was protected by lunar soil. It is not known why the shading pattern on the side of the returned scoop is apparent; it may be related to the abrasion of the surface during bearing and trenching tests. In the picture, the light blue-green flecks which appear on both scoops and on the table on which they are resting are fluorescent pieces of organic material which were present in the laboratory. They were probably derived from a variety of fabrics which were present.

The most striking change in the appearance of the samplers can be observed by comparing the tops of the two scoops in Figs. 20 and 21. The brown coloration of the returned scoop is deeper on the upper surface, and this is made even more apparent by the photograph (Fig. 21) in ultraviolet illumination. At the bottom of the housing which covers the scoop door motor, a yellow region is seen in Fig. 21. This is probably due to irradiation of a spill of the epoxy coating which was applied to the terminals of the wires for protection, since it does not appear on the laboratory sampler to which no epoxy was applied. Alternatively, it may be the result of the irradiation of this part of the scoop which was altered by heating when the wires were soldered in place. The upper surface of both scoops is shown in Fig. 22 in which it is seen, as remarked earlier, that some protection to the paint was probably afforded by patches of soil at the bottom corners of the grooves. It is likely that the lighter appearance of both scoops around the edges is due to abrasion during transport and handling.

The origin of the dark splotch (which is real) at the bottom of the left-hand groove of the returned scoop is not known. It is also not clear why the protection which it is surmised was offered by lunar soil collecting in the grooves is so clear-cut. If the brown coloration is a result of solar radiation, it might be expected that the brown coloration would shade gradually from the color in the completely shielded area into the appearance of the unprotected surface.

A comparison between the bases of the scoop doors is shown in Figs. 23 and 24. In the case of the laboratory scoop, much of the paint was removed from the scoop door during the test in water-saturated soil; some of it was pulled off by stripping a piece of adhesive tape which was attached to the scoop base at one stage of testing. It is evident that the bonding of the paint to the resin of the scoop base is not very strong. In the returned scoop, on the right in Fig. 23, the pattern of crazing on the base is apparent, as is also the browning of the edges of the Teflon sealing the door. Once again, even though the base of the scoop was relatively protected from solar illumination it has also undergone the color change apparent in the previous photographs. In the portions of the glass-impregnated resins, which are revealed where the paint has chipped away from the scoops, little or no color change is obvious in either Fig. 23 or Fig. 24. This may be an indication that the paint was only removed in these areas during and following the return of the surface sampler to earth. The change in the appearance of the Teflon surface is shown in Fig. 25 for a comparison with the view of the same area as seen by the television camera of Surveyor 3 in Fig. 2.

The wires to the scoop door motor were attached to terminals on the scoop as can be seen, for instance, in Fig. 1 and Fig. 21. These connections were covered with a clear epoxy plastic to protect them. The present appearance of the plastic covering one of these terminals is shown in Fig. 26. This photograph indicates that the epoxy material has changed from its originally water-clear state to a yellow-amber color. A number of bubbles are apparent in the picture. They were probably included when the epoxy was cast originally. A crack reaching to the surface runs through the epoxy in the center of the picture; it is not, of course, known if it was originally present or not. It appears to bear some relation to the large bubble in the middle of the picture. The adhesion of particles of lunar soil to the epoxy surface is clearly seen in Fig. 26.

In October, 1970, after the returned scoop had been disassembled, an examination was made of the individual parts of the sampler. The inside of the scoop which was painted with the standard blue paint was heavily coated with lunar soil. The soil, which was 1 to 2mm thick in the corners, still exhibited its cohesive properties and was not dislodged from the painted surface when the scoop was turned over. An area, inside the cutting edge, which had made frequent contact with the lunar soil was cleaned of its soil covering. The paint appeared unmarked even under 20 power magnification. In fact, the appearance of the painted surface was similar to that shown on the laboratory sampler in Fig. 14. The paint also lacked the tan coloration characteristic of the outside surfaces and retained the pale blue color of the laboratory sampler. It is concluded, therefore, that the scratches observed on the scoop exterior arose from the preflight sandpapering process.

The Teflon seal on the sampler door was also examined. While the color of the outer edges had changed, as reported above, the larger area on the inside which was protected from direct solar radiation had the same milky white color as the Teflon on the laboratory sampler. Two of the nylon ties which had secured electrical wires to one of the extension arms had also been removed. The areas beneath the ties were pale blue in color. These protected areas were subjected to essentially the same thermal and vacuum conditions on the moon as the discolored areas, yet retained their original appearance. It is concluded therefore that solar radiation was the cause of the discoloration.

Measurement of Adhesion of Lunar Soil to Surface of Returned Scoop

An attempt was made to measure the magnitude of the existing adhesion (whatever its nature) between the lunar soil and the various surfaces of the scoop by the following technique. A small vacuum-cleaning apparatus was built in order to remove the soil from the surface sampler surface. It consisted of a small pump, plastic hose, and two lucite chambers containing different sizes of filter papers. At the input end, a pen holder was supplied to retain a nozzle through which air and the lunar soil was sucked. A number of different nozzle sizes were tested.

In practice, the experiment and cleaning operation consisted of starting the vacuum pump and bringing the nozzle closer to the surface of interest while holding it at right angles to the surface. It was generally observed that at some particular distance from the surface a circular area underneath the nozzle tip would quite suddenly become clean leaving, in most cases, a very abrupt discontinuity between the clean surface and the adjacent soil-covered area. This result was interpreted to mean that the adhesion of the lunar soil to itself was somewhat greater than its adhesion to the scoop surface. Thus, when a critical surface shearing stress was reached due to the air flow over the surface, the soil detached itself from the surface and passed into the nozzle and thus into the collection chambers. In a formerly well-coated painted area, the clear line of demarcation between the clean and dirty surfaces is shown in Fig. 27. By carefully measuring the distance of the nozzle from the surface of the scoop, and the radius of the area which was made clean at the critical distance of approach, an estimate of the surface shearing stress required to remove the soil could be made. To make this estimate, the nozzle was calibrated by measuring the mass rate of flux of air into the nozzle at different distances of approach from various flat plates. From these tests it was estimated that the adhesive strength of the lunar soil to the painted surface was in the order of 0.1 psi (10^4 dynes/cm^2). The adhesion of soil to the metallic surfaces of the sampler seemed to be somewhat less and was in the range of 0.01 to 0.1 psi (10^3 to 10^4 dynes/cm^2).

It was observed that, in an area of painted surface which had been cleaned off by this technique, the remaining particles consisted almost entirely of glassy spheres. This can be seen in a careful examination of Fig. 27. It would appear that the adhesion of the spheres to the paint, at least, was considerably greater than that of granular fragments of other shapes, since one might expect that angular grains would exhibit a greater degree of mechanical interlocking with a rough surface than spherical particles.

List of Figures

Fig.	File Number	Description
18	Z C17-9	Side-by-side comparison SS3 and laboratory SS; white light photo of R. H. S.
19	Z CPS 3-6	Side-by-side comparison SS3 (R. H. S. and laboratory SS (L. H. S.)), UV stimulation, visible recorded on film.
20	Z C 19-11	Side-by-side comparison SS3 and laboratory SS. White light photo of top of scoop and motor box.
21	Z CPS 3-2	UV stimulation, visible recorded on film; comparison with Fig. 20 focus sharp on top of motor box.
22	Z CPS 3-4	Side-by-side comparison SS3 and laboratory SS. UV stimulation, visible recorded on film. Top of scoop showing grooves.
23	Z CPS 3-9	Side-by-side comparison SS3 and laboratory SS. White light photo of base of bearing plate.
24	Z CPS 3-8	UV stimulation, visible recorded on film comparison with Fig. 23.
25	Z C12010	SS3, discolored Teflon (color slide used as B&W).
26	Z Ektacolor 11	Microphotograph of epoxied screw head on SS3.
27	Z PN 55 Pg 96(a)	Microphotograph, cleaned area adjacent to dirty area on painted surface SS3.

References

(1) Scott, R. F., and F. I. Roberson, (1968) Soil Mechanics Surface Sampler: Lunar Surface Tests, Results and Analysis. J. Geophys. Res., 73, 4045-4080.

(2) Scott, R. F., Lu, T.-D. and K. A. Zuckerman, (1971) Movement of Surveyor 3 Spacecraft. J. Geophys. Res. (in press).

(3) Jaffe, L. D., (1971) Blowing of Lunar Soil by Apollo 12: Surveyor 3 Evidence. Proceedings of Apollo 12 Lunar Science Conference, January (in press).

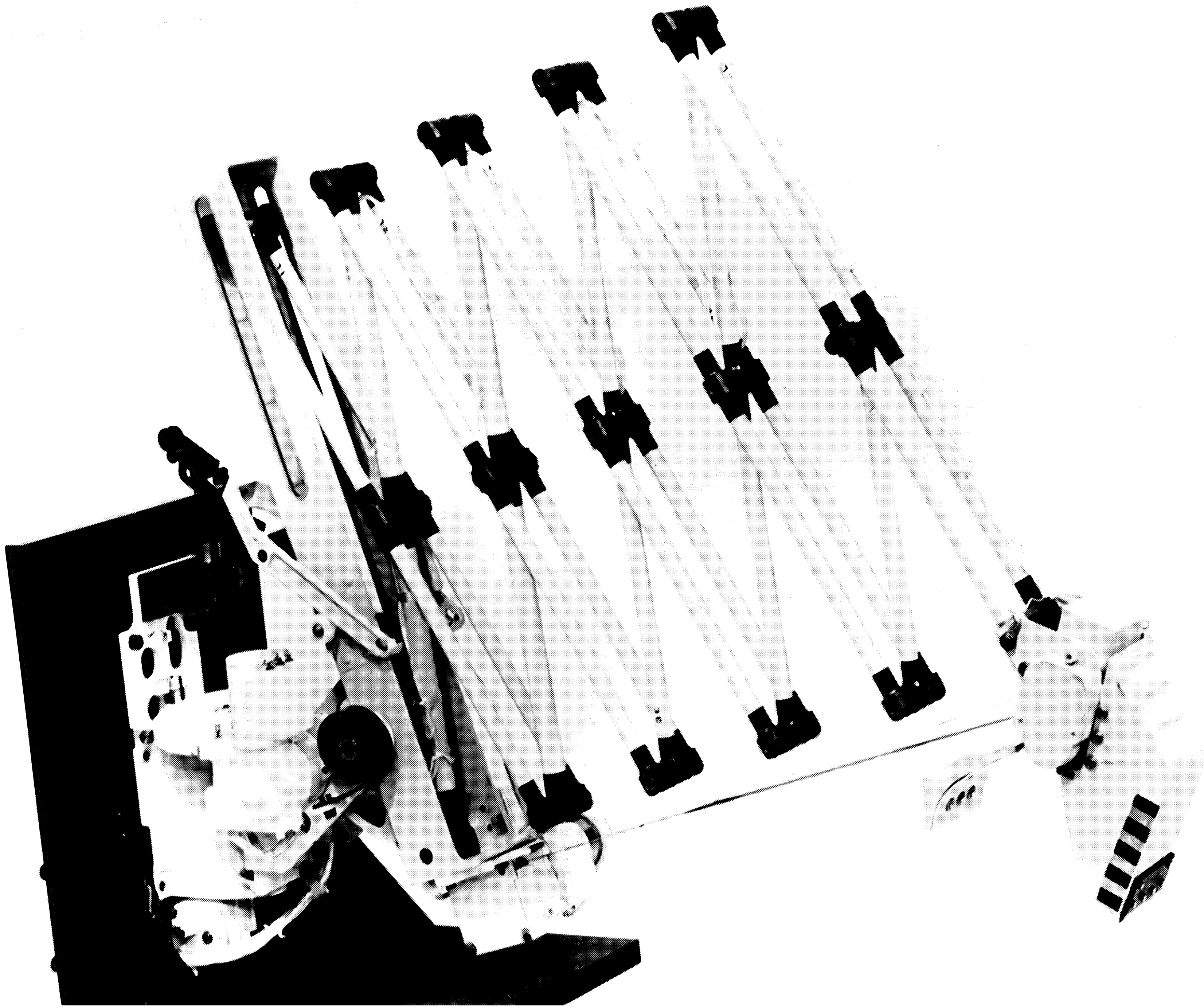

Fig.1

Fig. 2

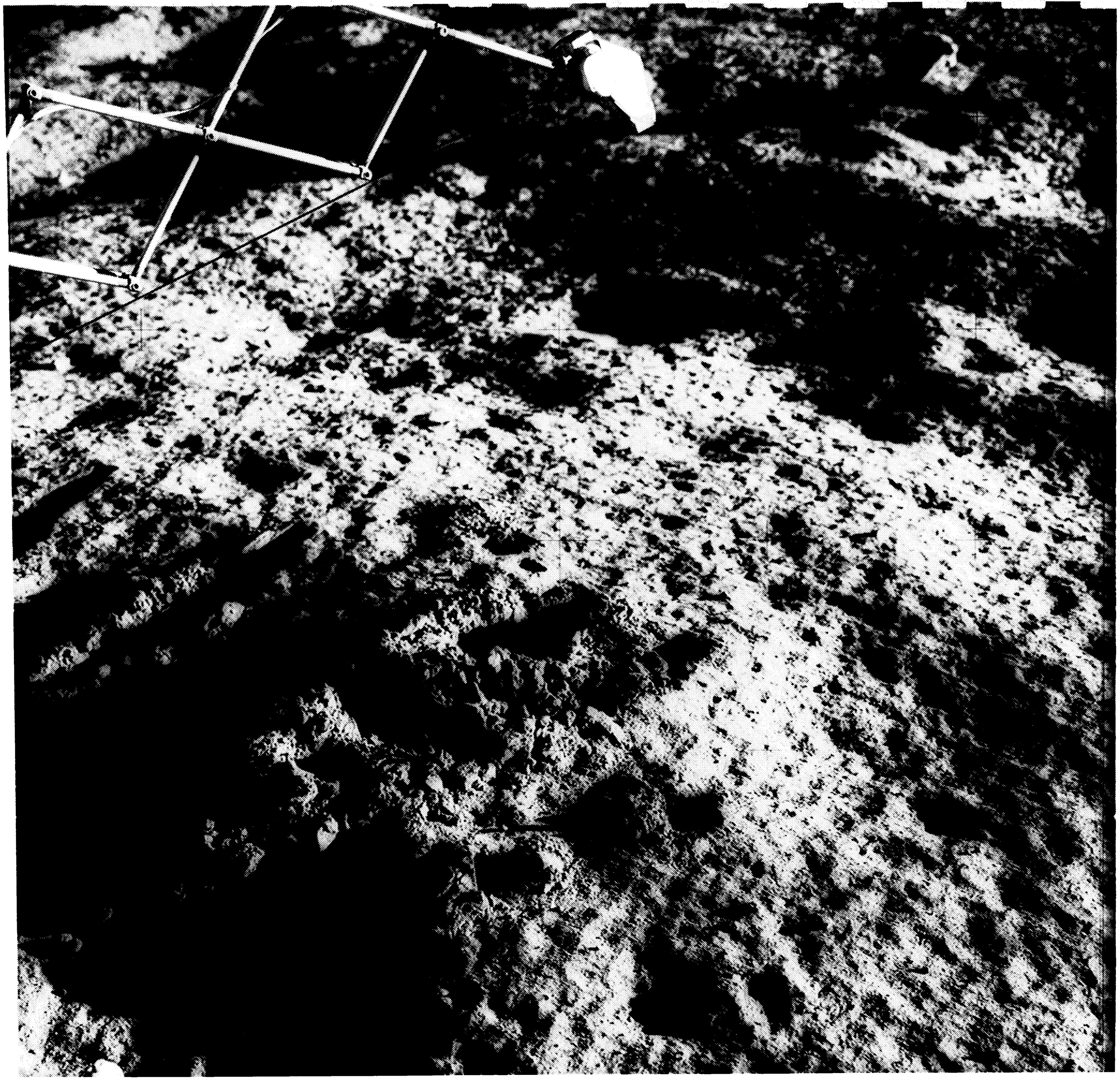

Fig. 3

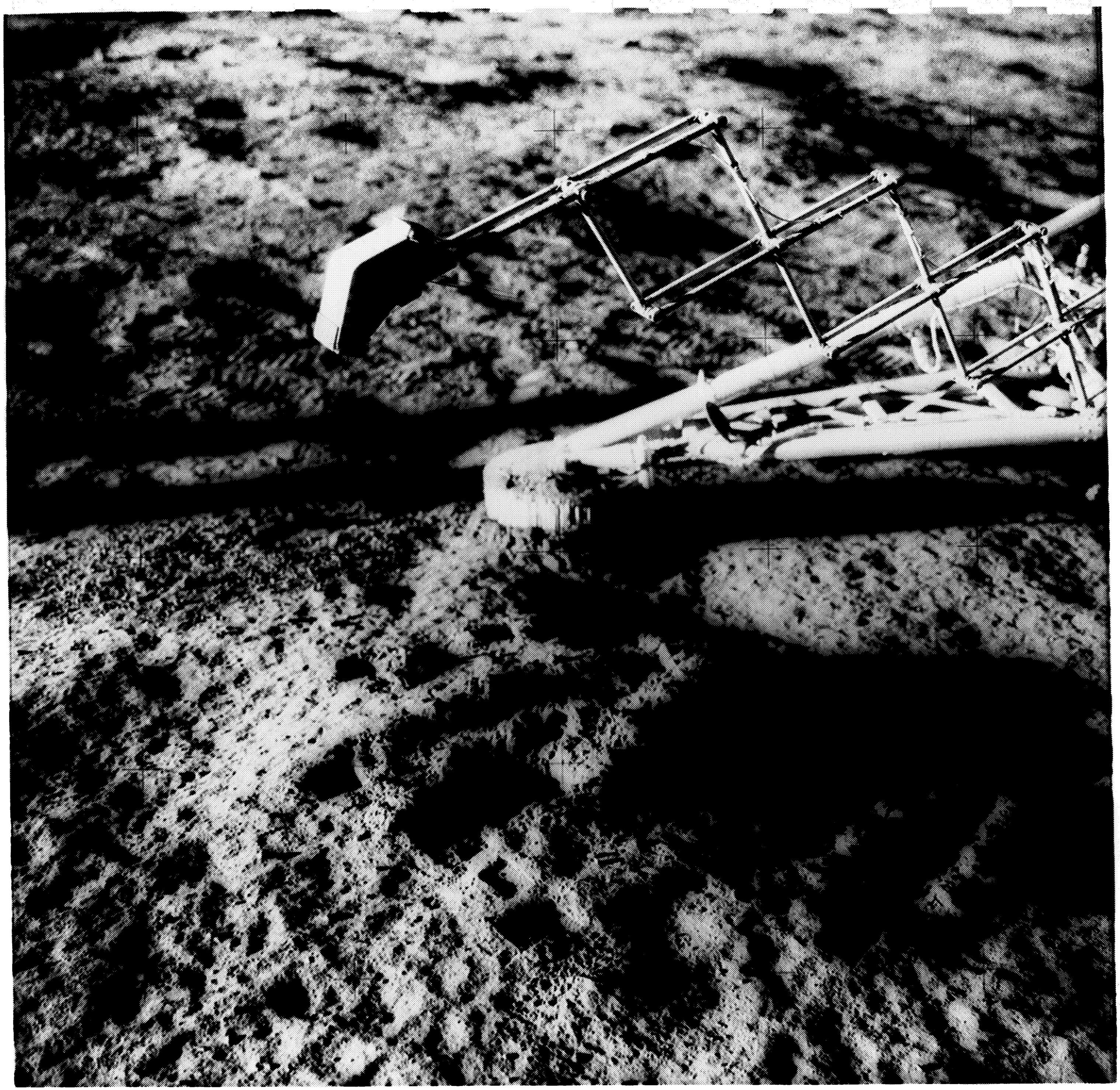

Fig. 4

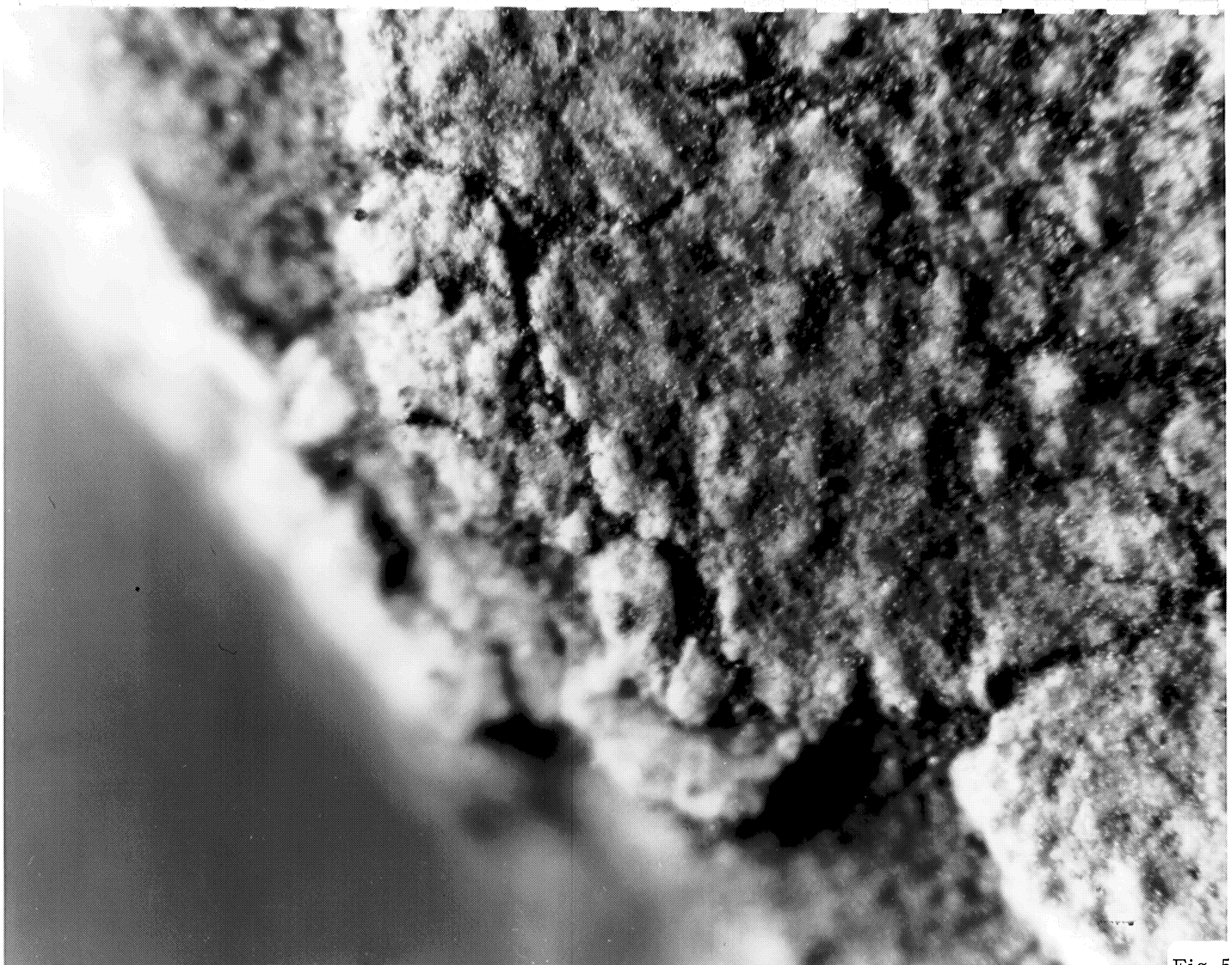

Fig. 5

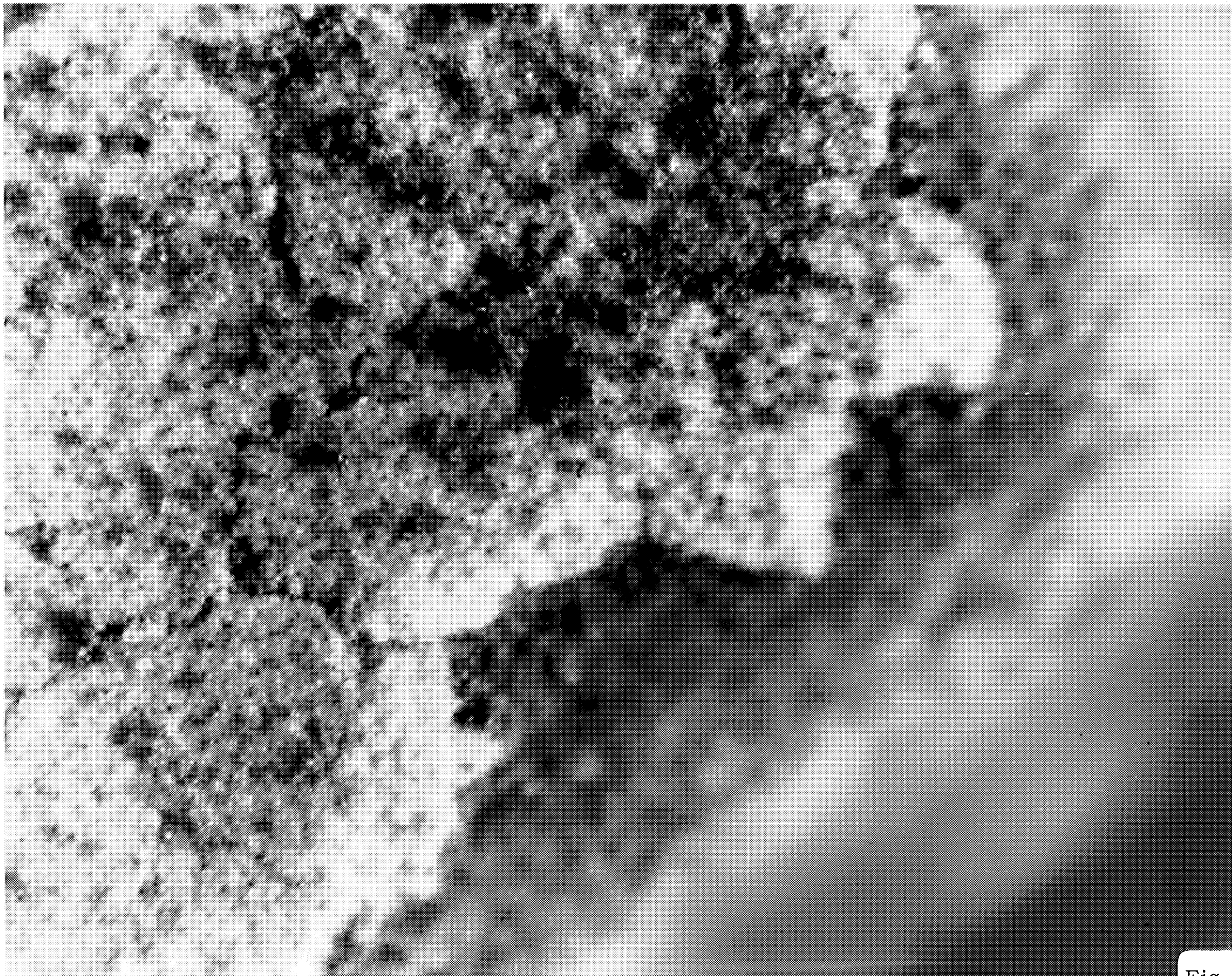

Fig. 6

Fig.7

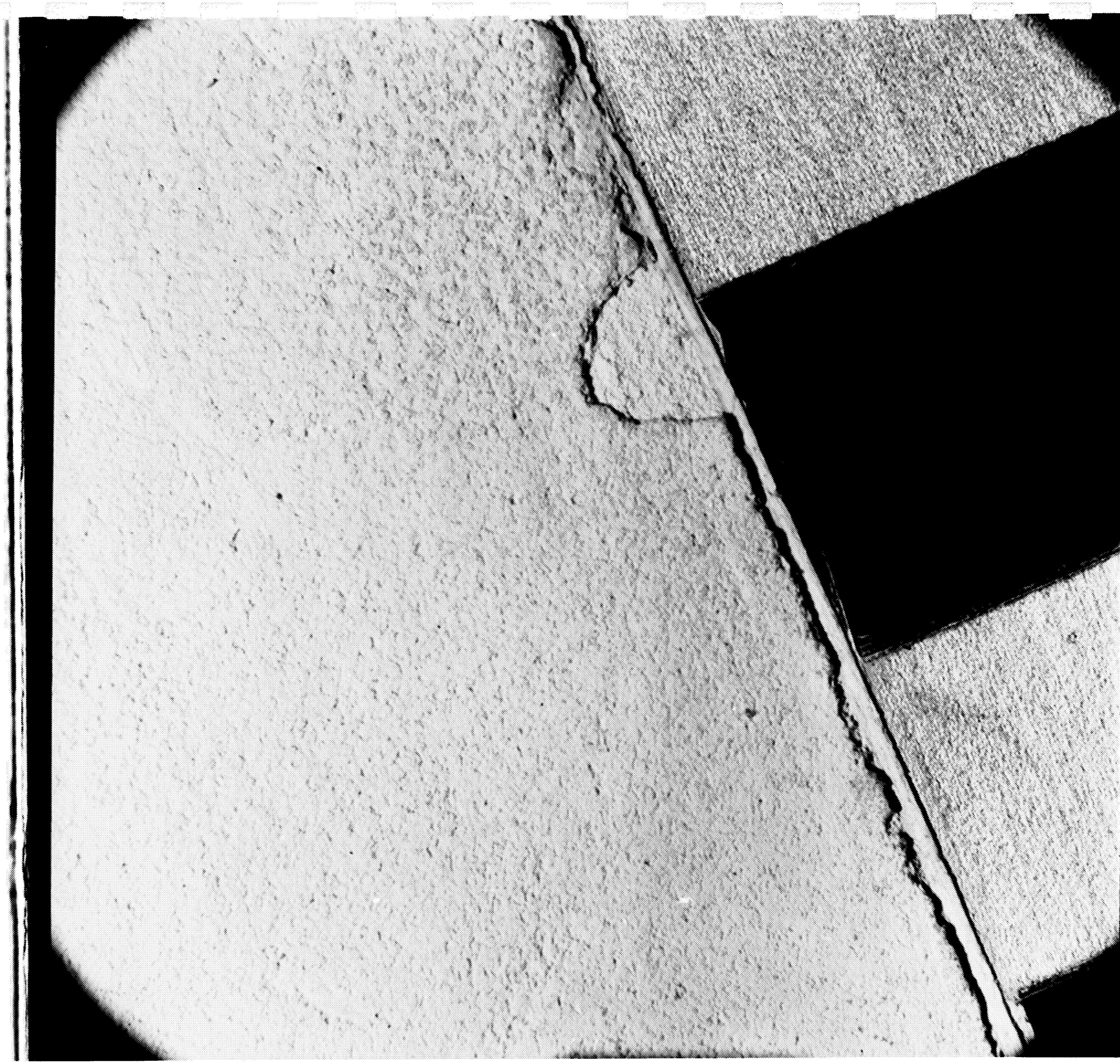

Fig.8

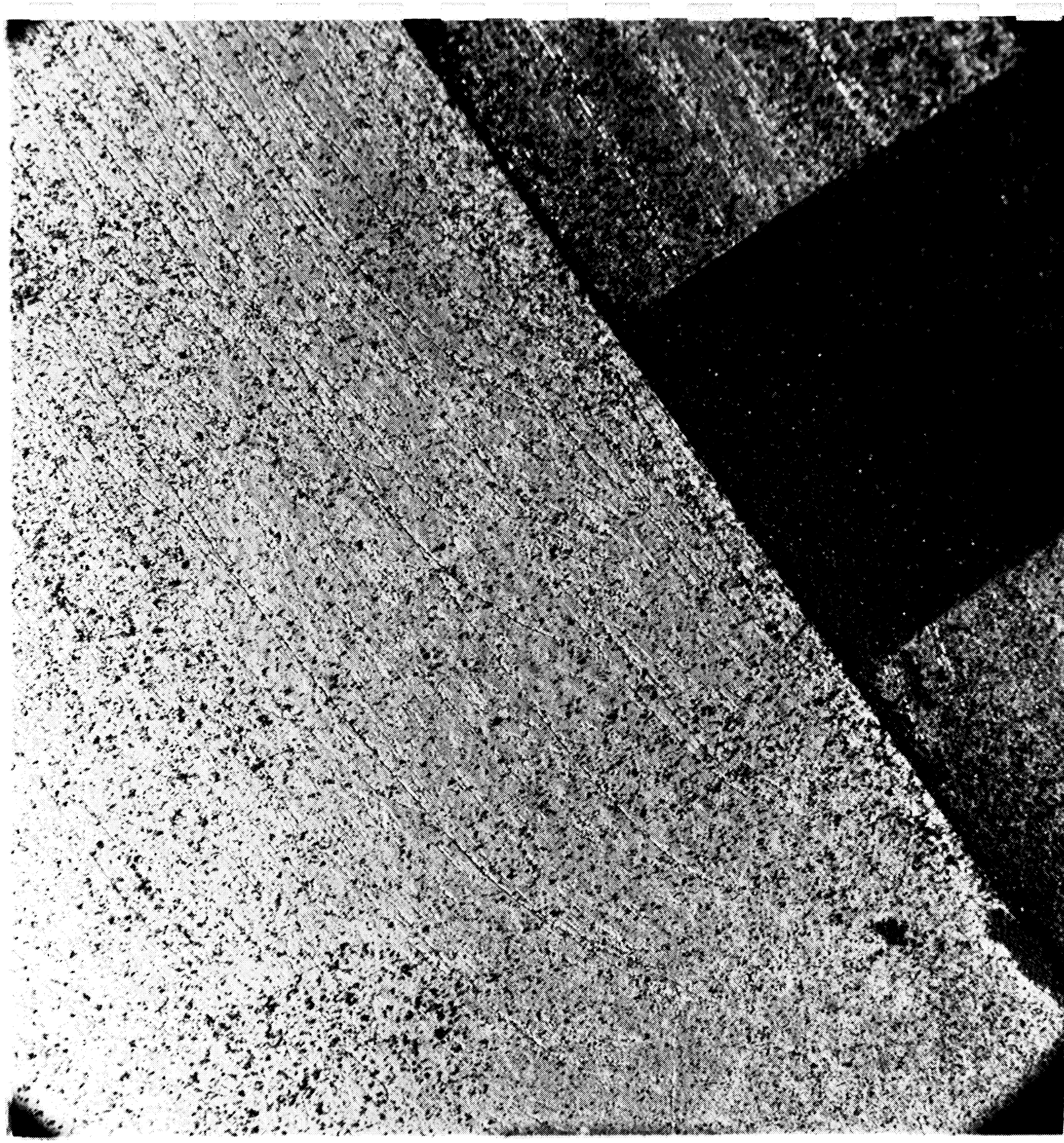

Fig.9

Fig. 10

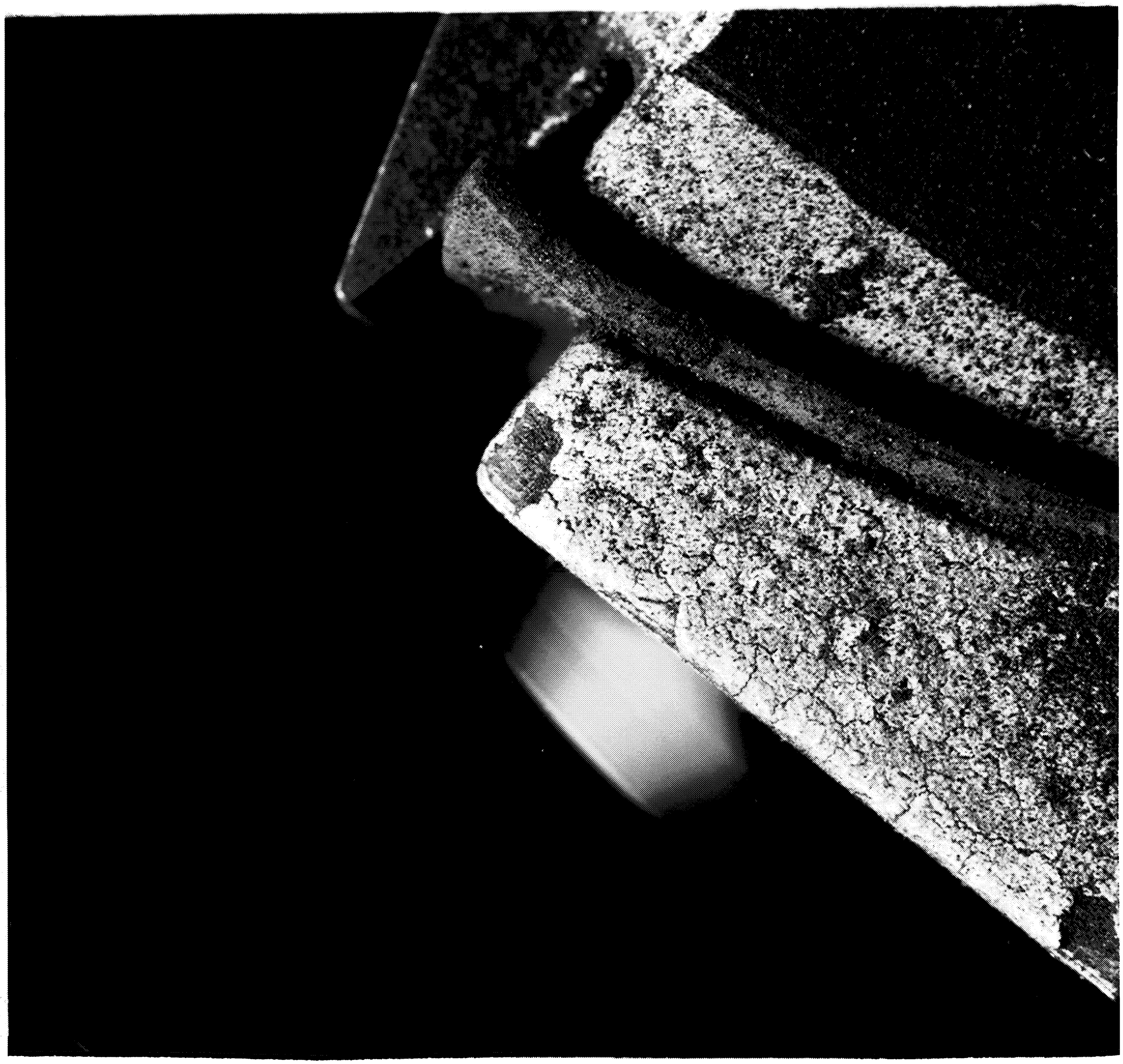

Fig. 11

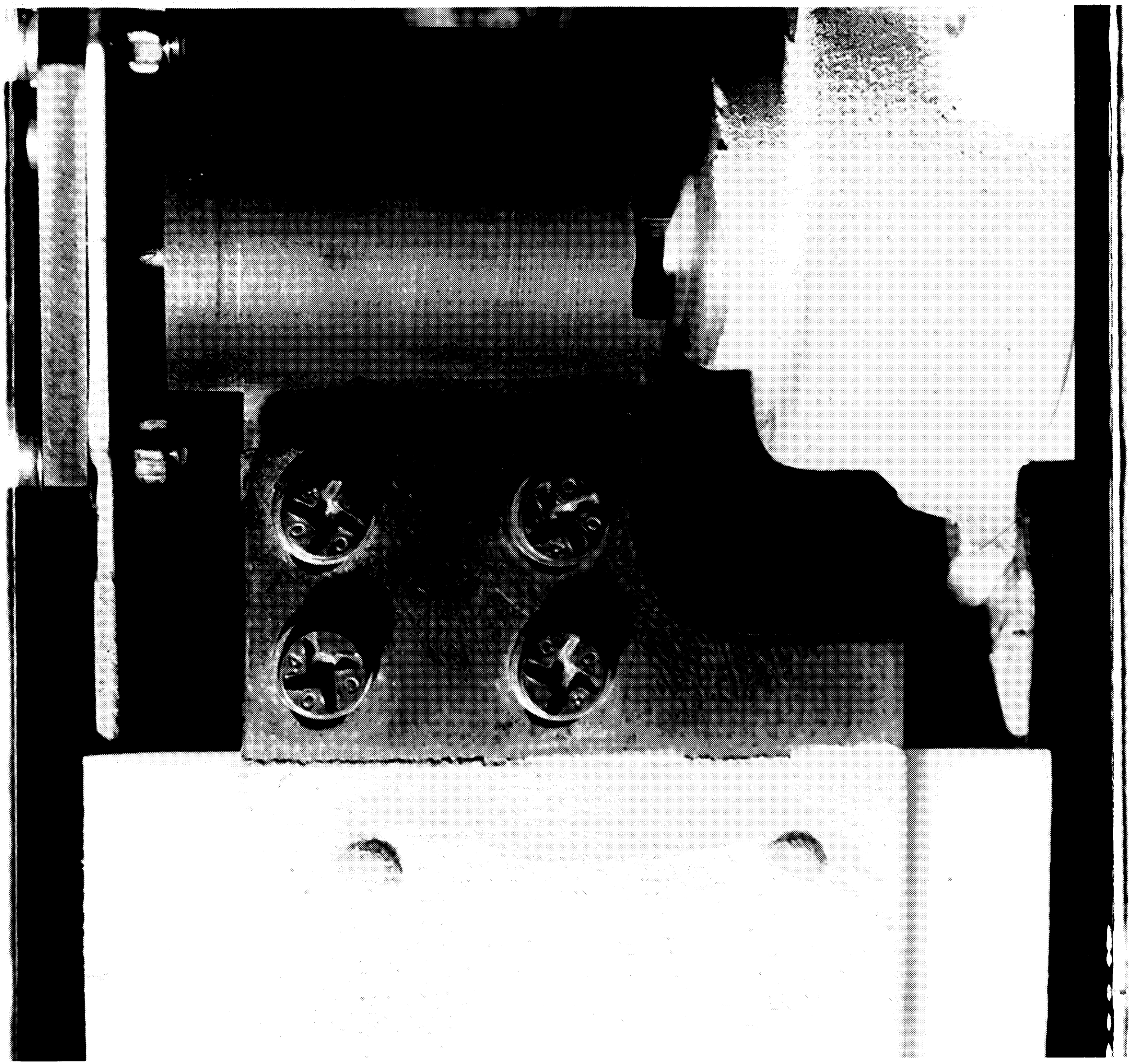

Fig. 12

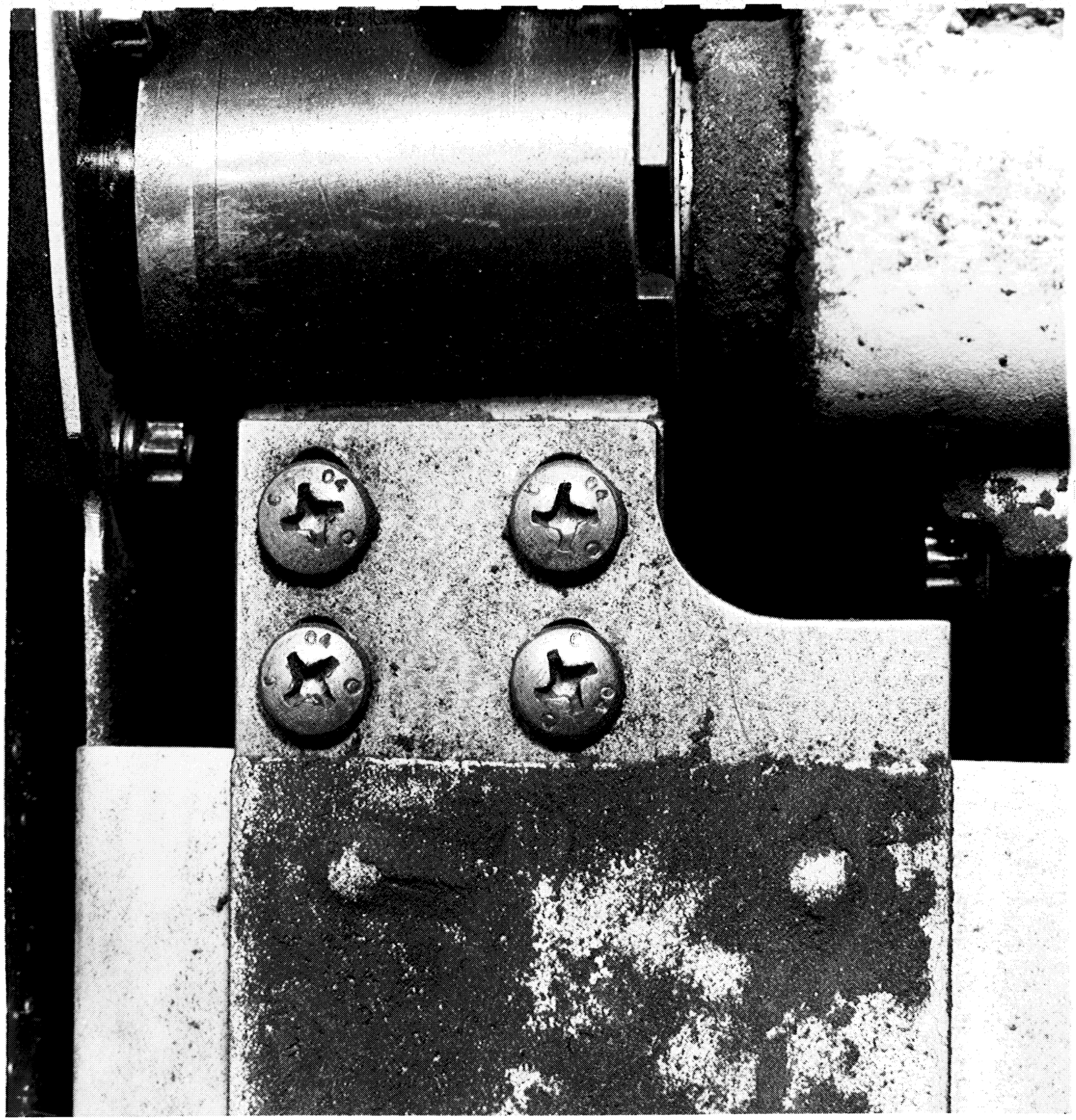

Fig. 13

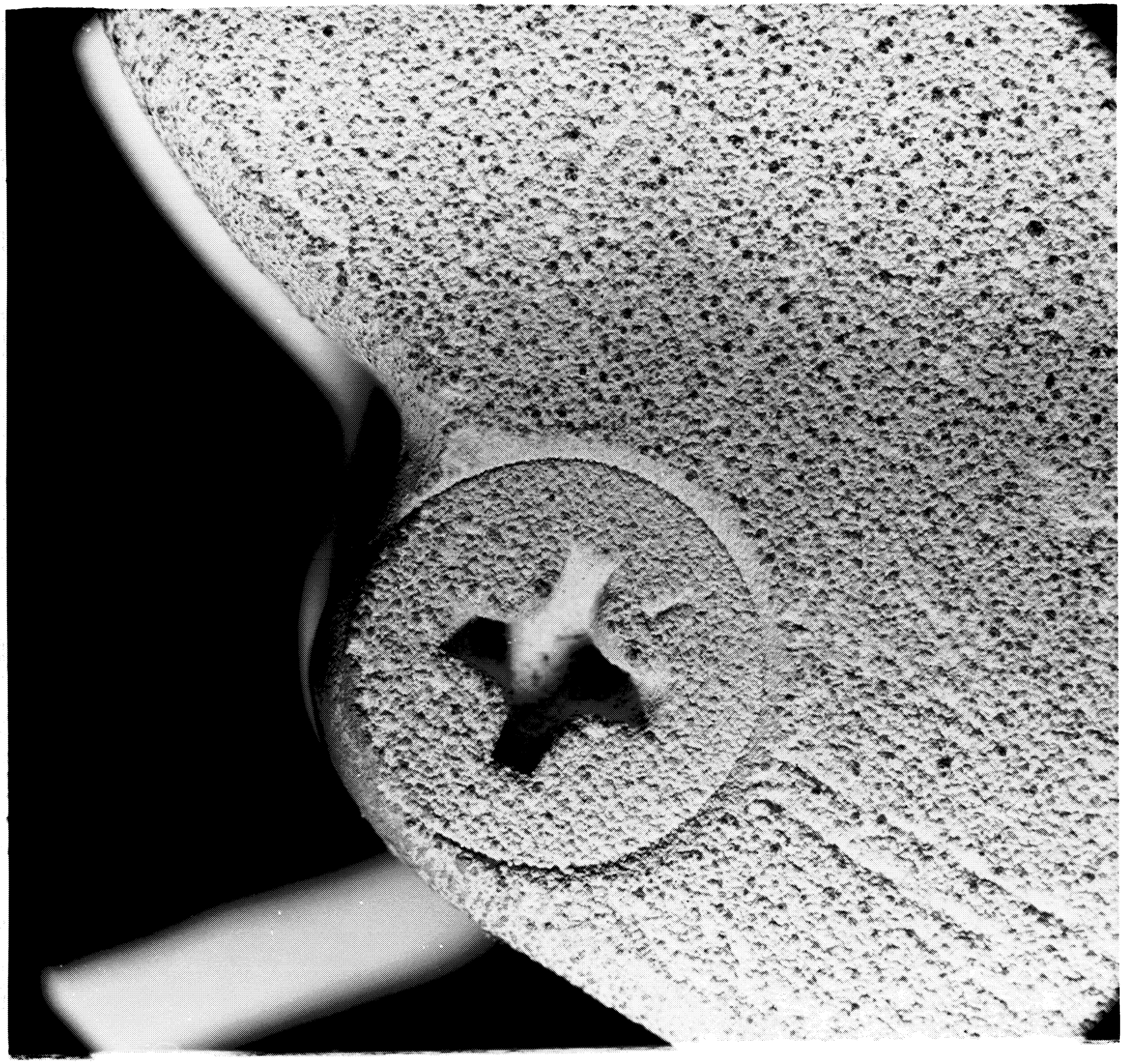

Fig. 14

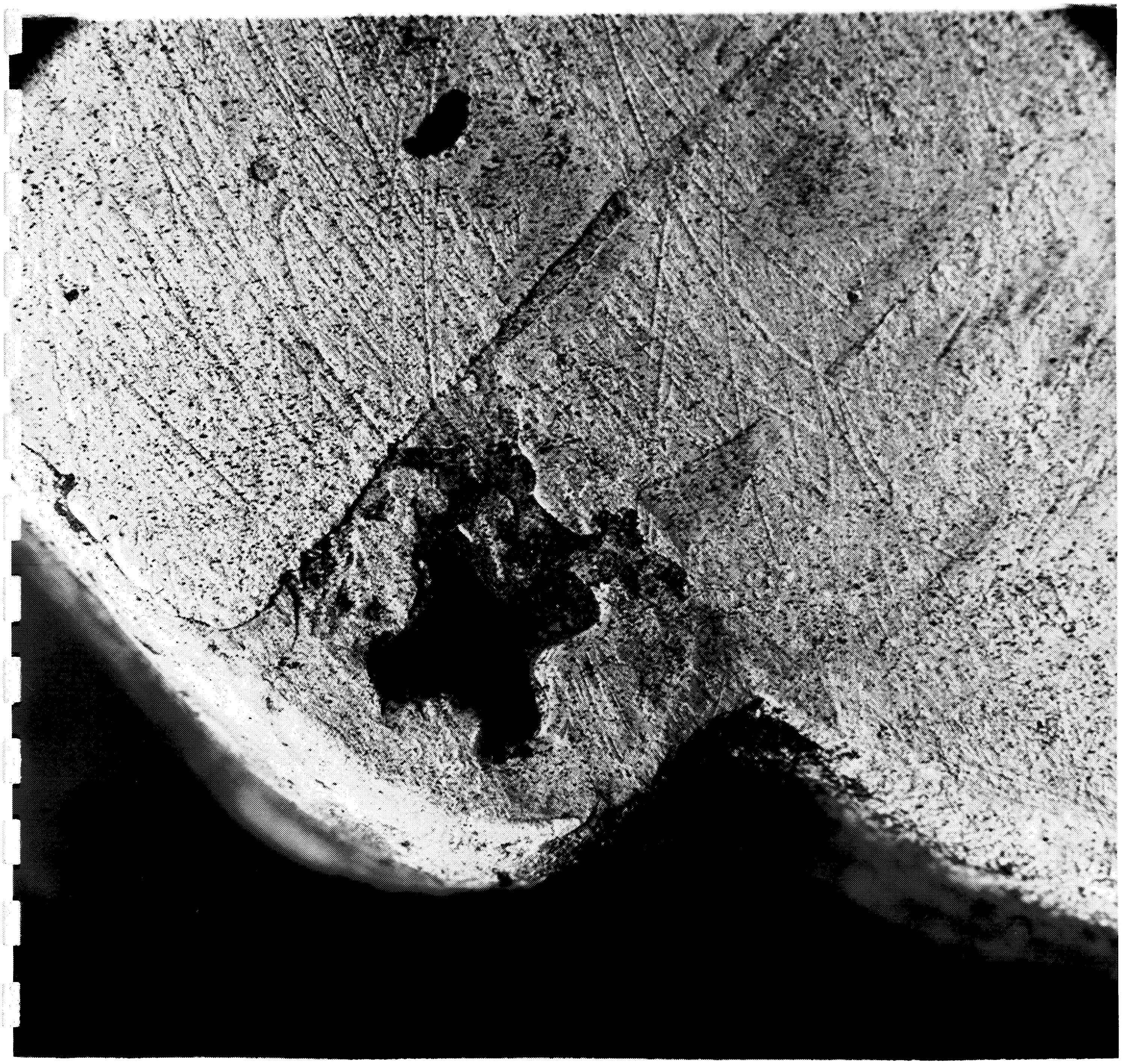

Fig. 15

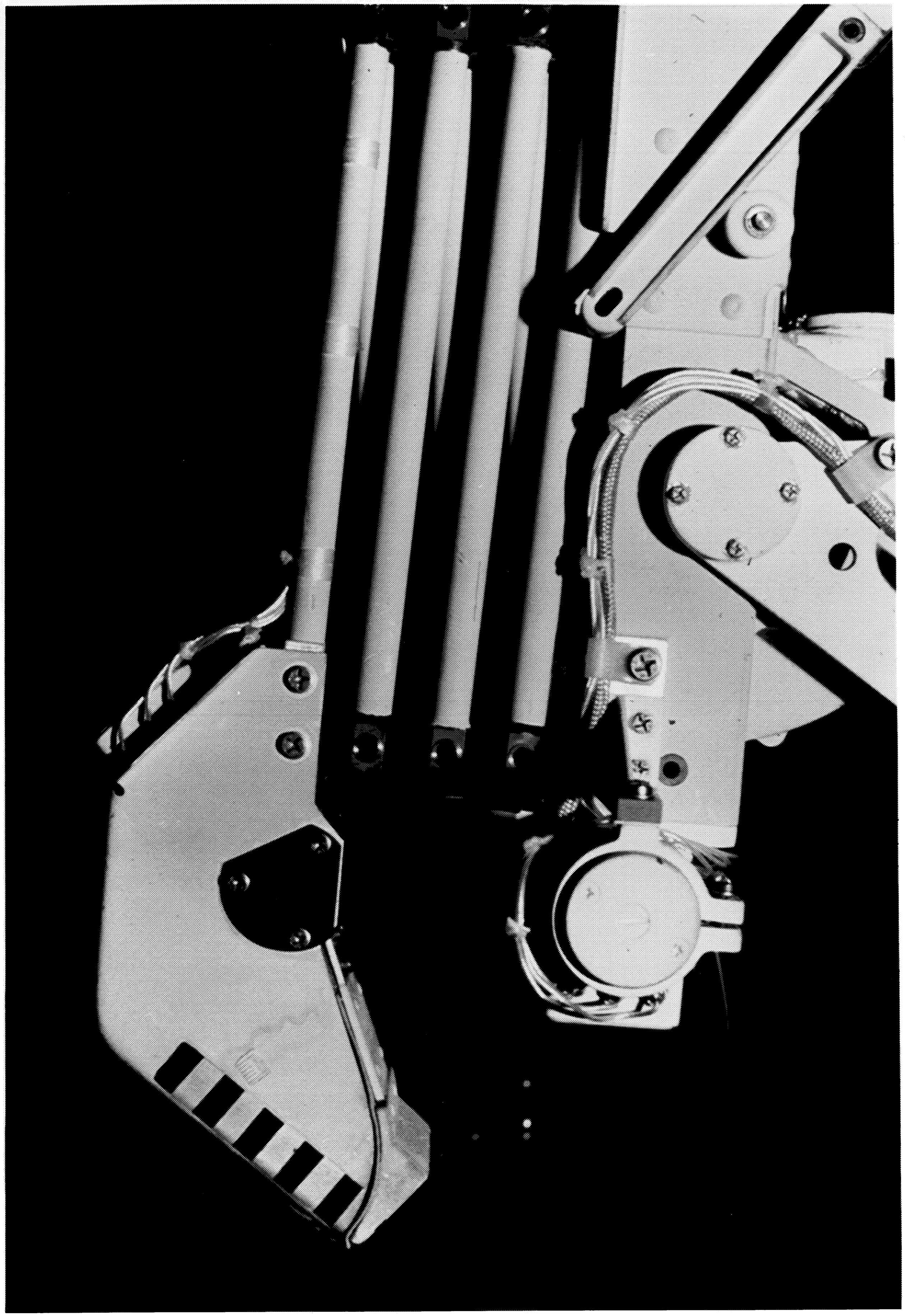

Fig. 16

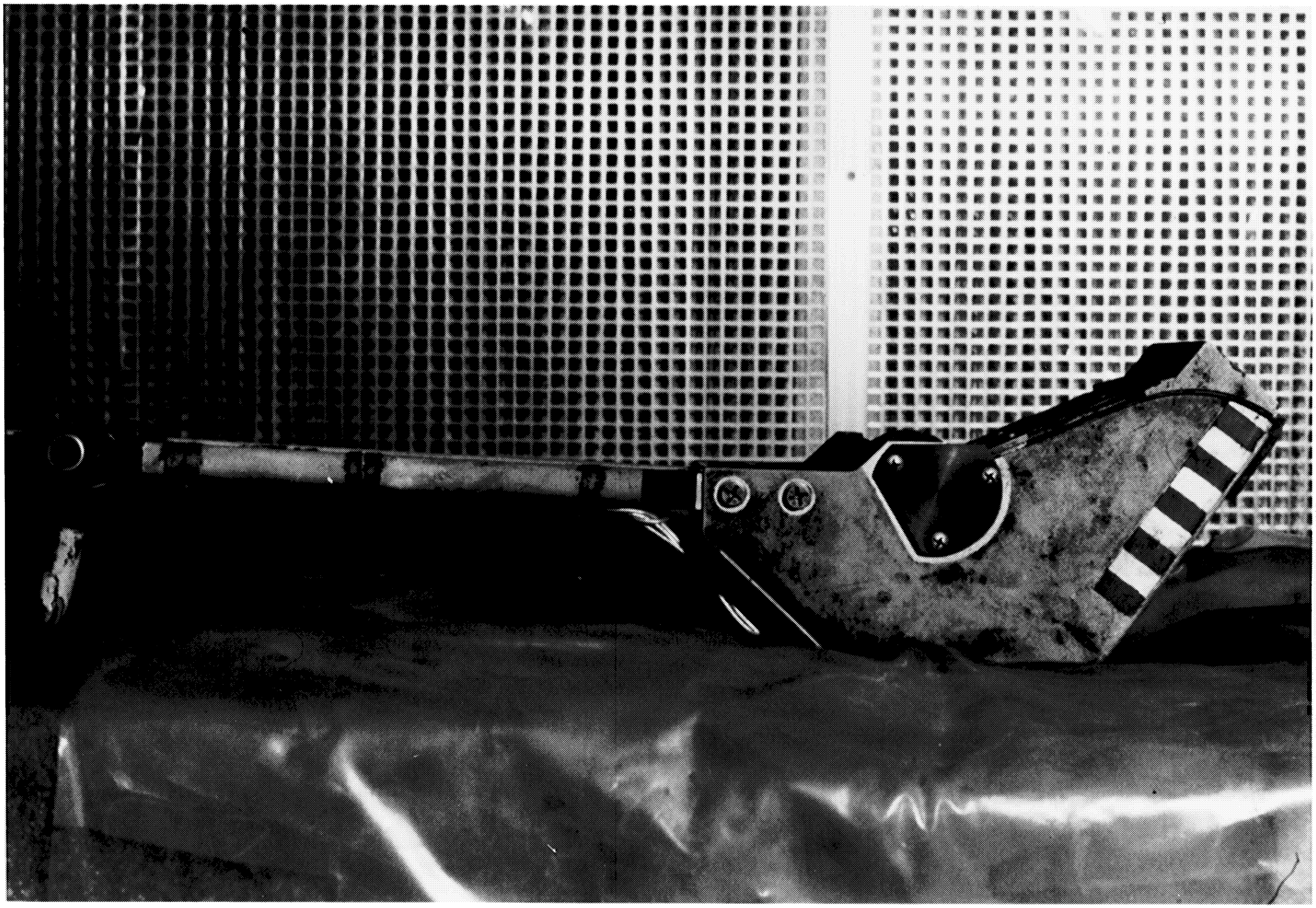

Fig. 17

Fig. 18

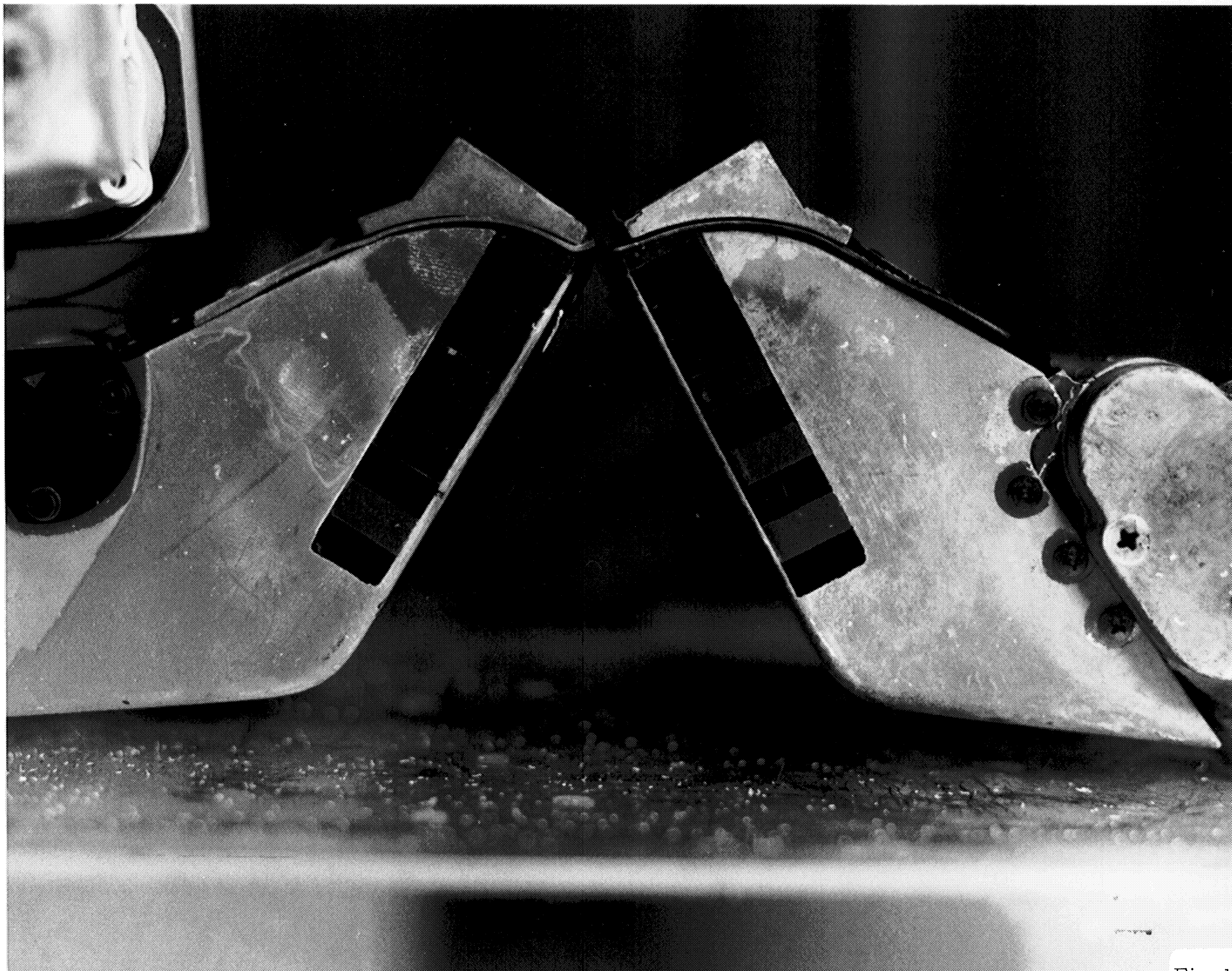

Fig. 19

Fig. 20

Fig. 21

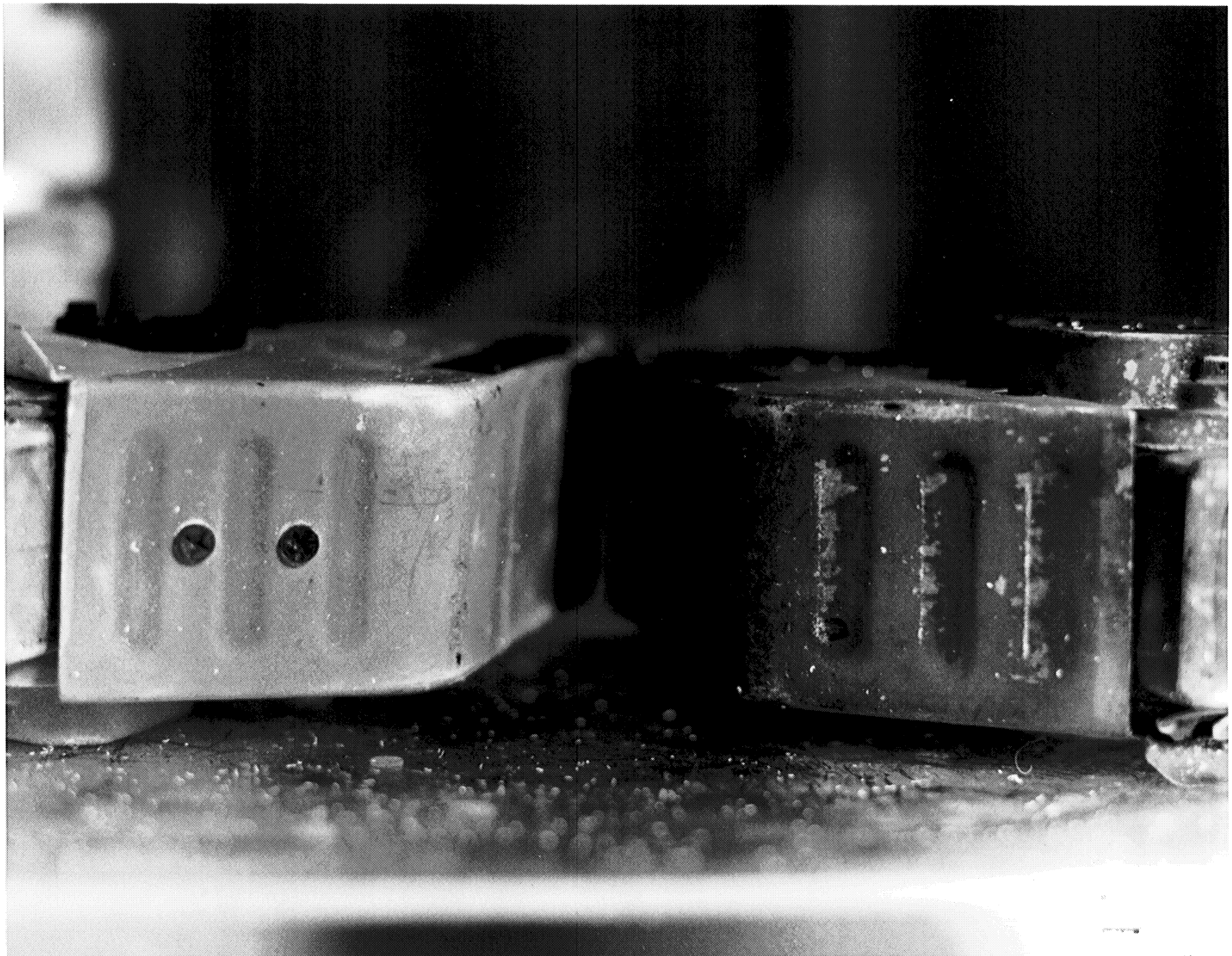

Fig. 22

Fig. 23

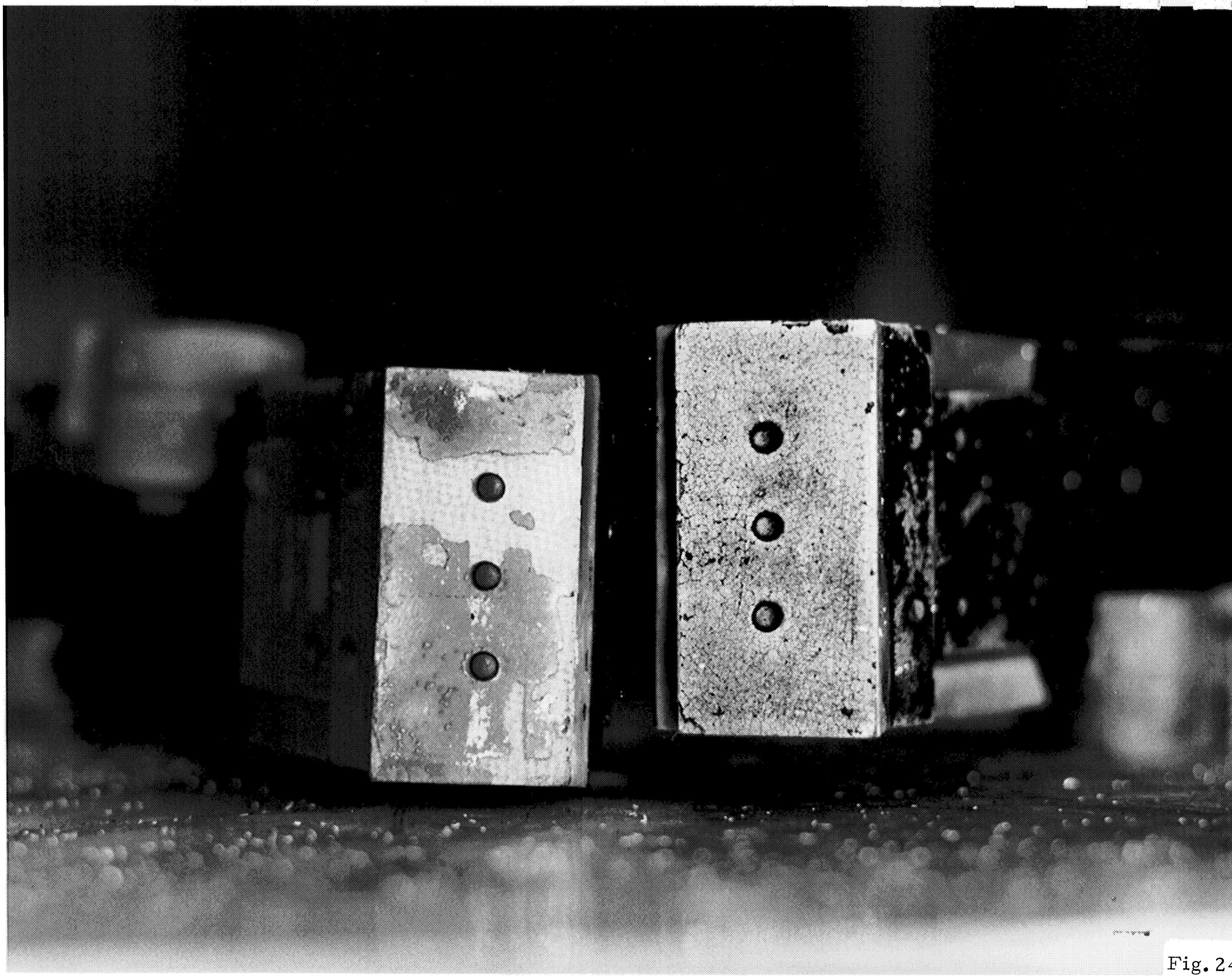

Fig. 24

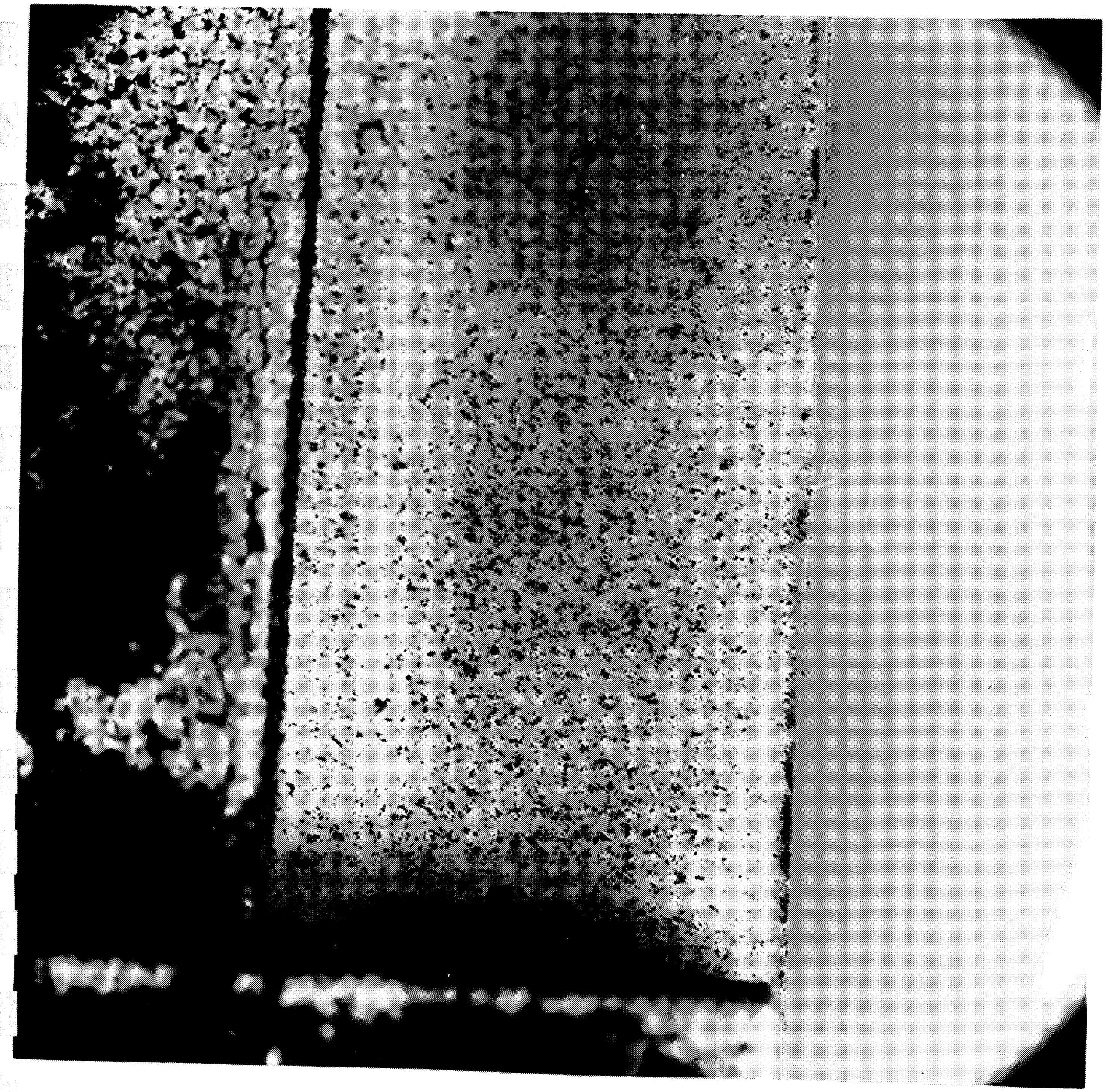

Fig. 25

Fig. 26

Fig. 27