REPORT ON ACCIDENT TO
AVRO ARROW 1 25201
AT MALTON

June 11, 1958

71/ENG PUB/9

NOTE

This Report is in two parts. Part I, contains details of the accident and the investigation into the cause. Part II will detail the damage to the aircraft resulting from the accident, and will be issued when the aircraft has been fully stripped and examined.

INDEX

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

1. INTRODUCTION

The accident occurred at Malton Airport at 15.29 on 11 June 1958 when landing at the completion of Flight #11. The accident was due to the left-hand landing gear not being fully extended when it locked down. As a result the wheel bogie was not parallel to the aircraft's line of flight.

The pilot was unaware of the landing gear malfunction during his approach, as the cockpit indicators showed the landing gear DOWN and LOCKED. Observers who were in radio contact with the aircraft were unable to see that the final extension and turning of the leg had not been completed. The Sabre chase plane had returned to base prior to the accident, due to fuel shortage.

2. HISTORY

2.1 Aircraft

Aircraft Type - Arrow 1

Serial No. - 25201

No. of Flights - 11

No. of Flying Hours - 11 hours, 30 minutes

No. of Flying Hours since Last Periodic Inspection - 3 hours, 5 minutes

Nose Wheel Steering - Not fitted

2.2 Landing Gear (Main)

Manufacturer - Dowty Equipment of Canada Limited

Type - Tandem Bogie

No. of Landings Prior to Accident - 10

No. of Landing Gear Functions - 155

Last Ground Function Check - Prior to Flight 11 - Eight Ground Functions of June 9,1958

Last Strip Examination of Landing Gear - Prior to Flight 10

* New Brakes and Pads Fitted Prior to Flight 10

* The brakes were equipped with revised 1 inch thick plates compared with 3/4 inch of the normal brakes, giving a kinetic energy absorption of 7.5×10^6 ft. lb. compared with 5.6×10^6 ft. lb.

3. ACCIDENT DETAILS

3.1 The Landing and Cause of the Accident

The pilot selected landing gear when in the circuit for landing and as stated in section 3.2, the cockpit indicators showed DOWN and LOCKED. The aircraft touched down on the end of runway 32. (Ref. Fig. 1.) Figure 2 shows that the L.H. leg extension and turning had not been completed prior to touchdown. The partial extension can be seen and that the wheels were not in line with the aircraft's longitudinal axis.

Immediately after touch down (Fig. 3), the aircraft's weight caused the left-hand landing gear to turn further and assume the position which it would normally occupy when stowed in the landing gear bay (Ref. para. 3.3). The drag chute was then deployed. Figure 6 shows smoke coming from the left-hand tires, due to their misalignment with the aircraft's path. The aircraft continued to swing towards the left-hand side and corrective brake action had no effect in arresting the swing. The pilot then considered that the drag chute may be causing the swing and jettisoned the chute. Figure 7 shows the aircraft in various positions until it left the runway. When the left-hand wheel struck the soft ground, the aircraft swung violently to the left, causing the landing gear to collapse due to the excessive loads imposed on it. Figures 12 and 13 are aerial photographs taken shortly after the accident. The skid marks shown on Figure 14 are those made by the left-hand landing gear at the touchdown point, and indicates the increase in the spread of the tires, as the bogie is twisted further out of line, due to the increasing weight on the landing gear. Figure 15 indicates the point at which the left-hand tires burst. This occurred at approximately 3/5 of the total distance which the aircraft travelled (approximately 4,000 ft.).

Photographs taken of the left-hand landing gear shortly after the accident are shown in Figures 17, 18 and 19. Figure 17 shows the retracting chain broken off, and protruding from the dust cover.

Instrumentation records have been analyzed, and show that the touchdown speed was 170 knots TAS and the rate of descent was five to six feet per second. The drag chute was streamed at 150 knots TAS.

3.2 Pilot's Statement

On June 11, 1958, at the end of Flight No. 11, I selected landing gear DOWN on downwind leg at a speed of approximately 210 knots I.A.S. Landing gear operation was normal and the indicator was showing down and locked. The approach was carried out at approximately 170 knots I.A.S. At touchdown, slight change of direction to the left was noticeable and nose wheel went down sharply. The drag chute was streamed immediately because a short landing run was intended, but with the decrease of speed the aircraft was turning slowly to the left, and full opposite brake was not enough to maintain a straight run.

Suspecting strong cross-wind or faulty drag chute, jettison of chute was carried out at approximately 50 knots. This action had no apparent effect, and the aircraft left the runway at approximately 30 knots. When the left-hand wheel struck soft, muddy ground, the aircraft swung violently to the left and the landing gear collapsed.

3.3 Details of Landing Gear Design

The landing gear consists of a main leg which is braced by a rear drag strut and a telescopic down lock strut (Ref. Figure 20). In order to permit adequate fuselage ground clearance on landing, the length of the main landing gear is such that in its fully extended position the leg would not fit in the wheel well, on retraction. A mechanism has therefore been incorporated in the main leg, which during retraction, draws the shock absorber into the main landing gear strut, thus reducing the leg length approximately 8 inches. At the same time the wheel bogie is turned through approximately 40° so that the wheels will lie flush with the wing contour when retracted, since the wings are set at 4-1/2° incidence to the static ground line. During the extension cycle the landing gear is lengthened and the bogie rotated so that the wheels will be parallel with the aircraft's longitudinal axis.

Turning is accomplished by means of two cam tracks on the main leg barrel and two rollers on the extending unit. The main oleo is attached to the shortening gear, therefore, the oleo is active whether the extension is up or down. Figure 21 shows the main leg details and Figure 22 shows the shortening mechanism details lock. The dust cover is shown on Figure 23.

When the main gear is released from the wheel well by the up lock, the spring (Figure 22) starts extending gear and at the same time the helical cam track turns the bogie.

FIG. 5

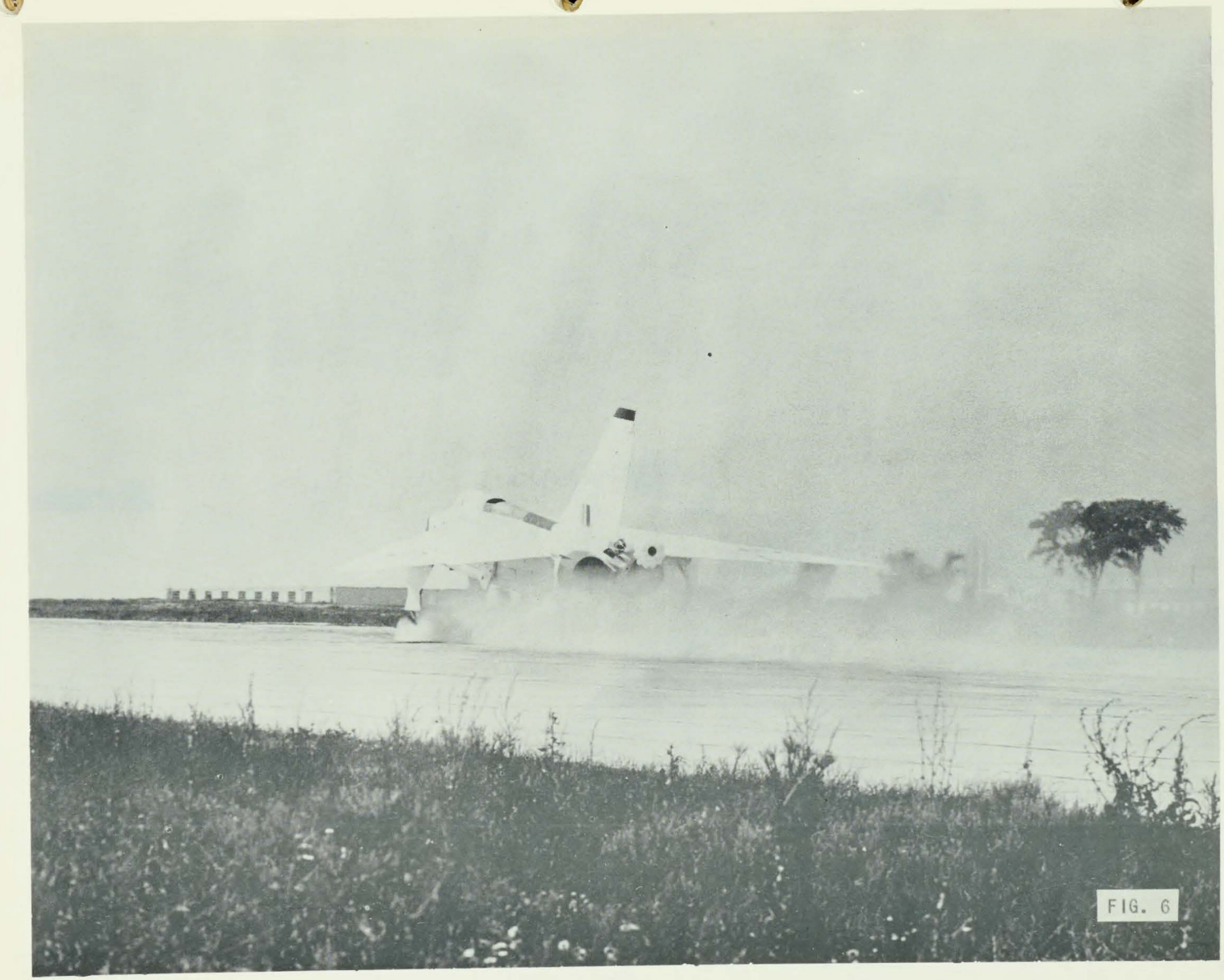

FIG. 6

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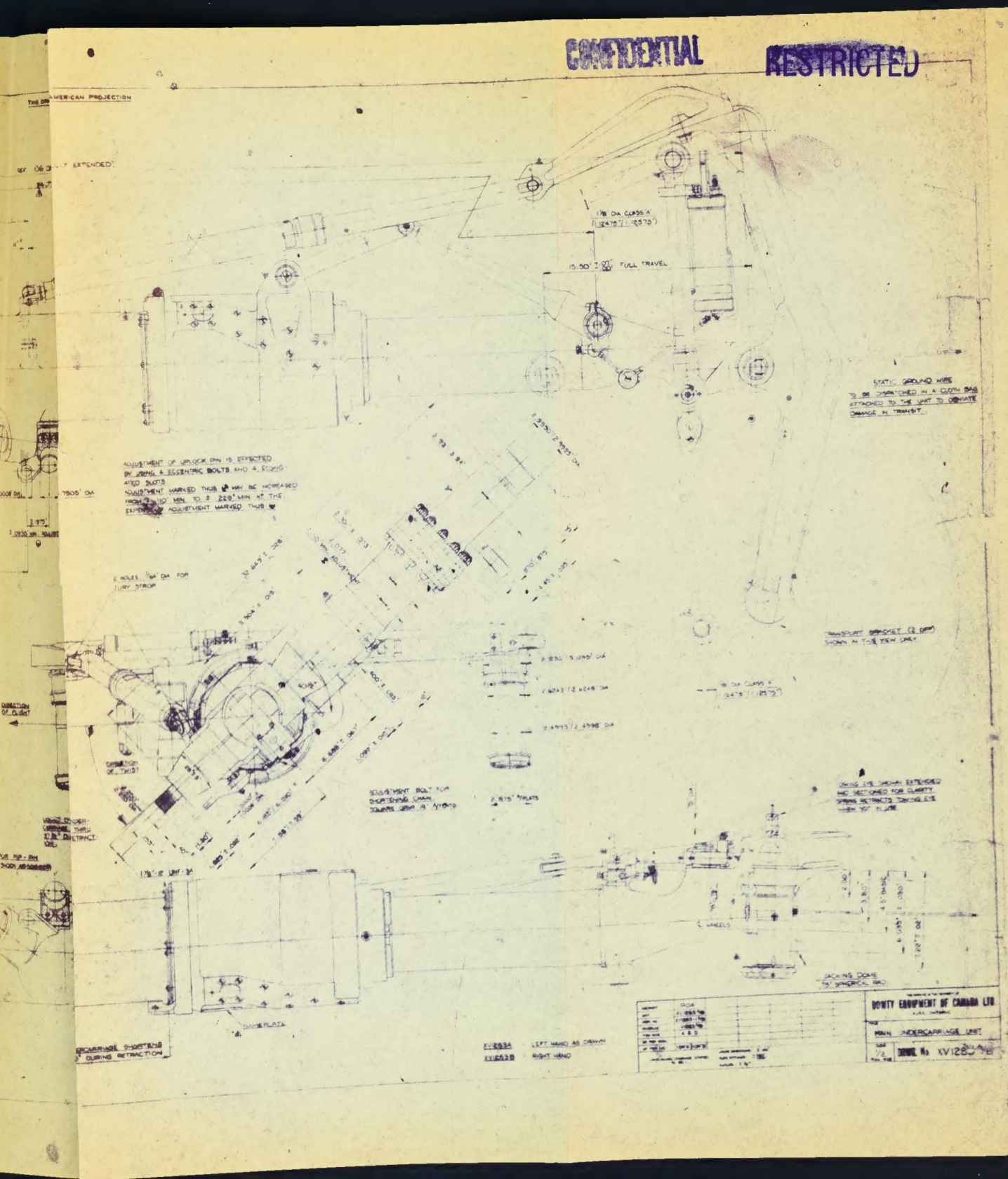

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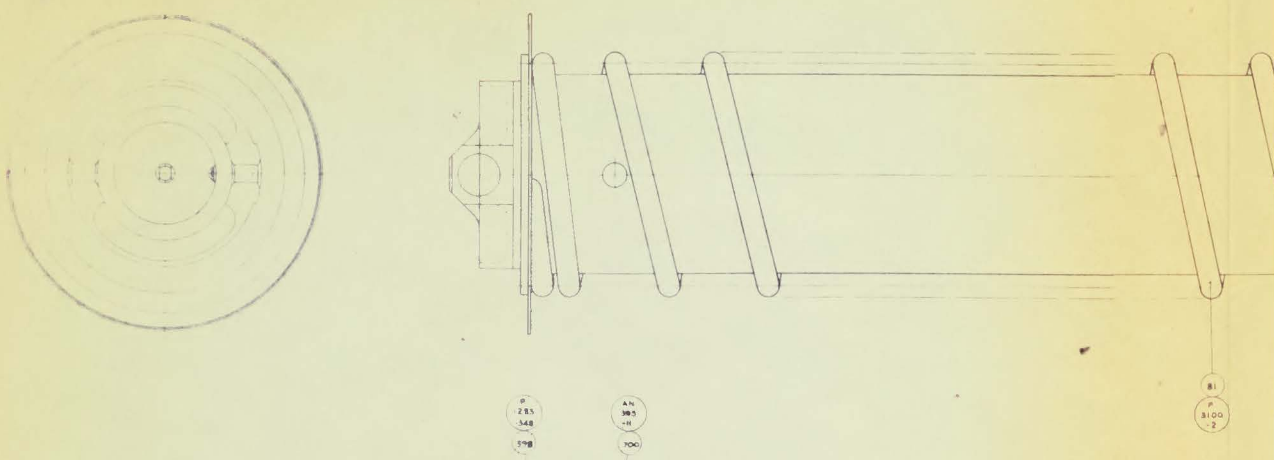
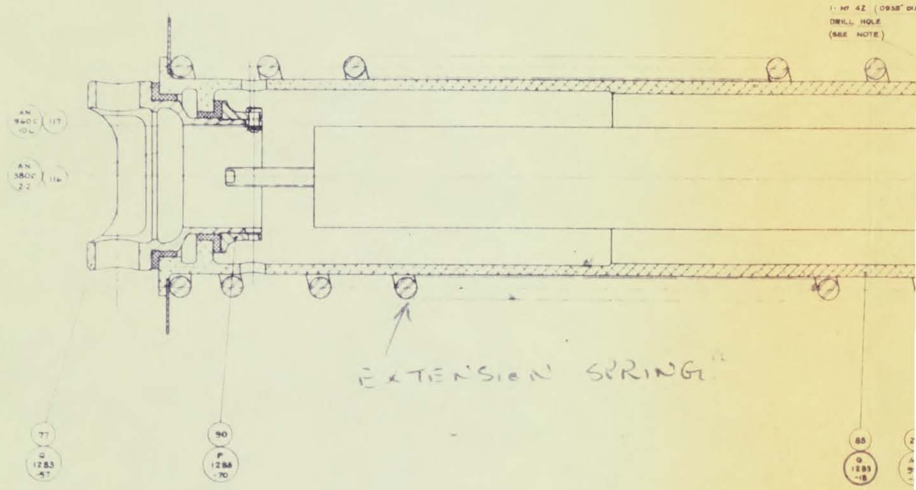




WHEN DRILLING LOCK RING HOLE THROUGH SLOT IN SPHERICAL BEARING HOUSING (ITEM 982), CARE SHOULD BE TAKEN TO ENSURE HOUSING IS SCREWED HARD HOME ON SHORTENING SLEEVE BEFORE DRILLING LOCKING HOLE ON THE CORRECT SIDE OF SLOT

BEFORE DRILLING Nº 60 (.098) HOLE FOR LOCK RING P 1283-74 CARE SHOULD BE TAKEN TO ENSURE DOWNLOCK PLUNGER Q 1283-67 MOVES FREELY UP AND DOWN IN DOWNLOCK BODY WITH NO BACKLASH AGAINST THE EXTENSION STOP

AFTER DRILLING LOCK RING AND COTTER PIN HOLES DISMANTLE PARTS AND REMOVE ALL SWARF

ALL LOCKING HOLES DRILLED IN ALUM ALLOY ARE TO RECEIVE LOCAL TREATMENT TO PROCESS INST Nº 3

COAT SURFACES OF DISSIMILAR METALS WITH MIL-P-6889 (ZINC CHROMATE PRIMER) AND ASSEMBLE WHILE WET

COAT MOVING PARTS WITH MIL-G-3278 GREASE (ITEM 39) DURING ASSEMBLY. ALSO CAVITY MARKED THUS - ✱

△ TEST AT THIS STAGE TO TEST INSTRUCTIONS L 1283-40

SECTIONED VIEW SHOWN
IN LOCKED DOWN

IF IN DOUBT ASK

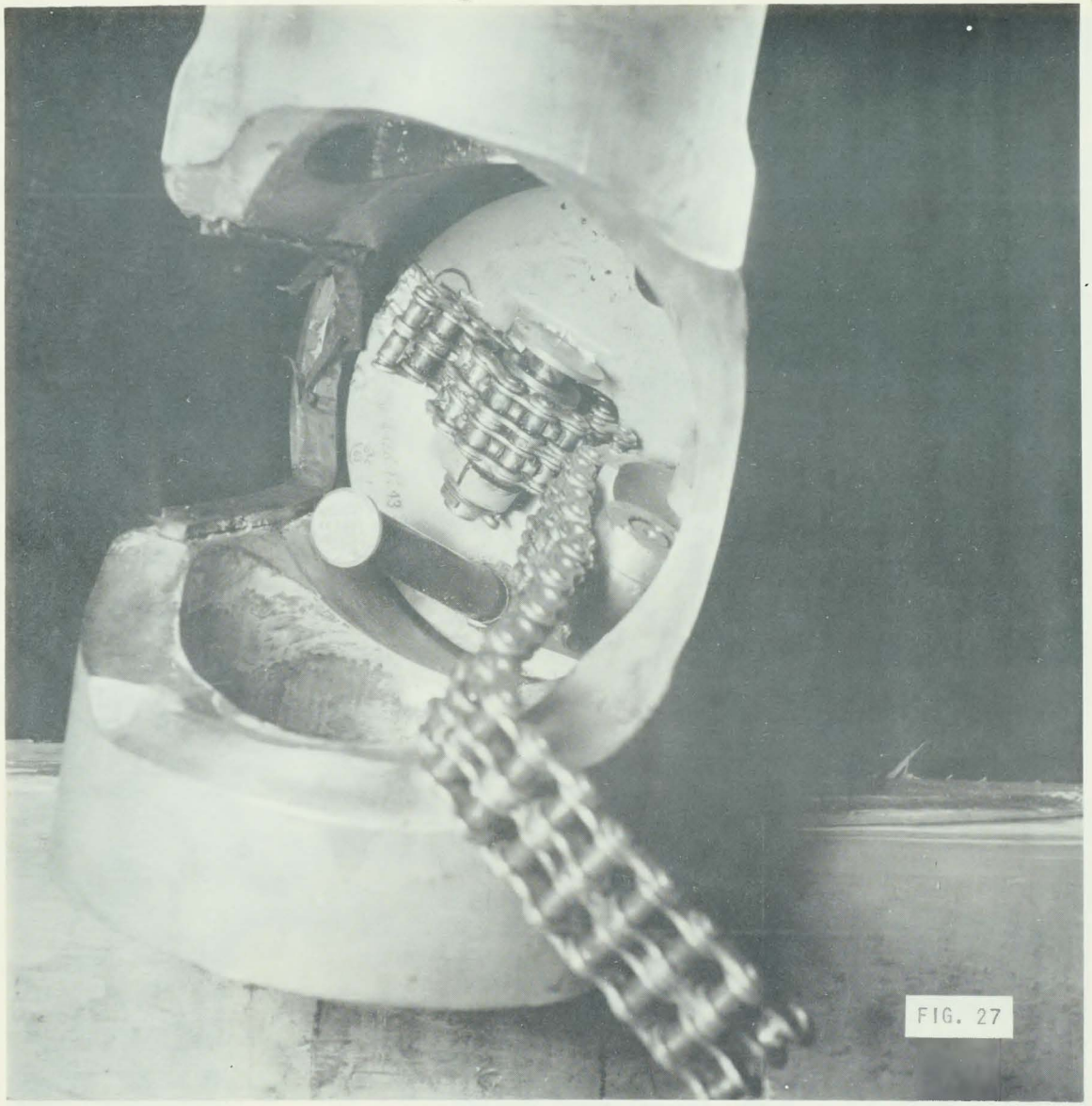


FIG. 27

FIG. 28

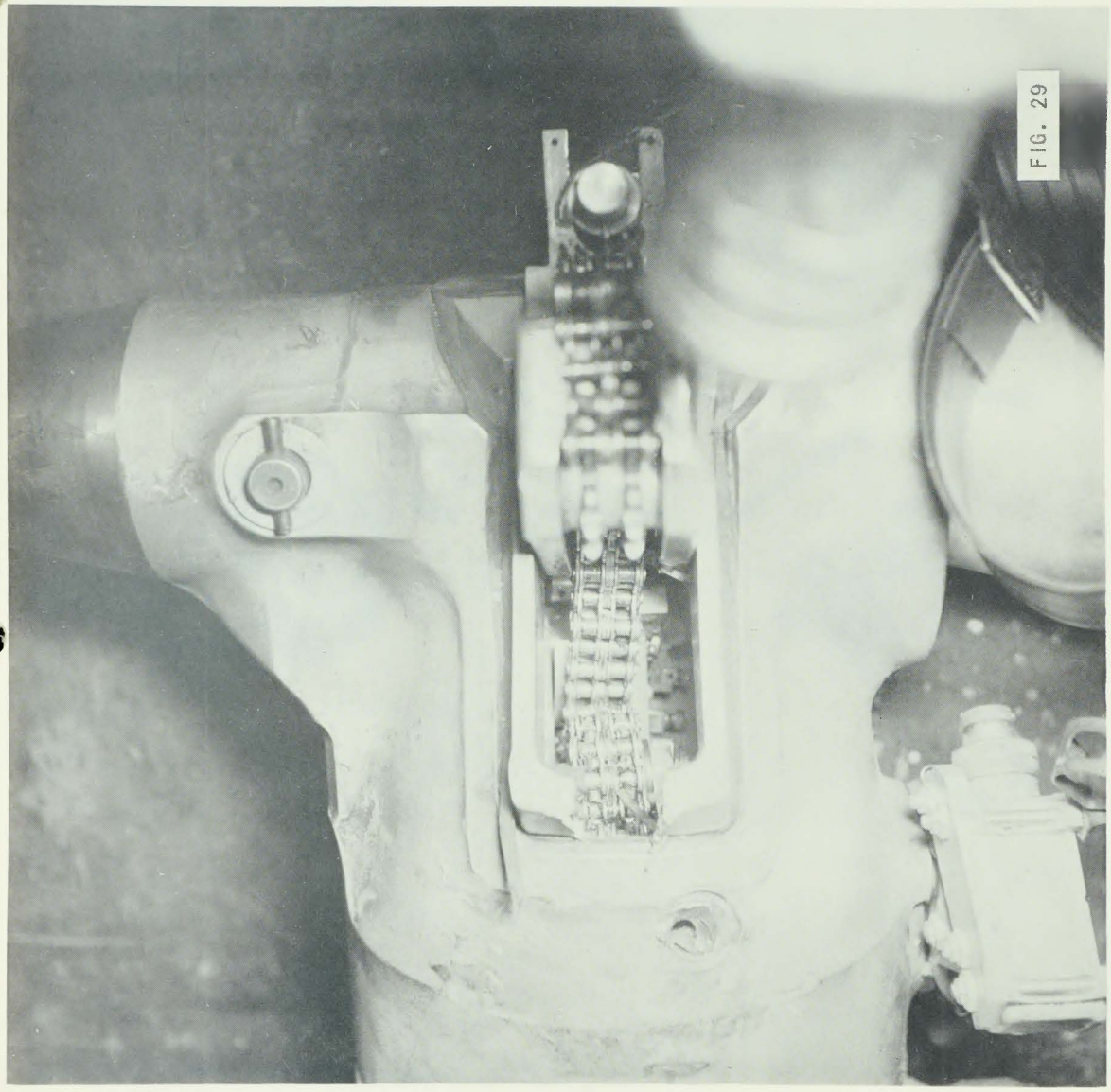


FIG. 29

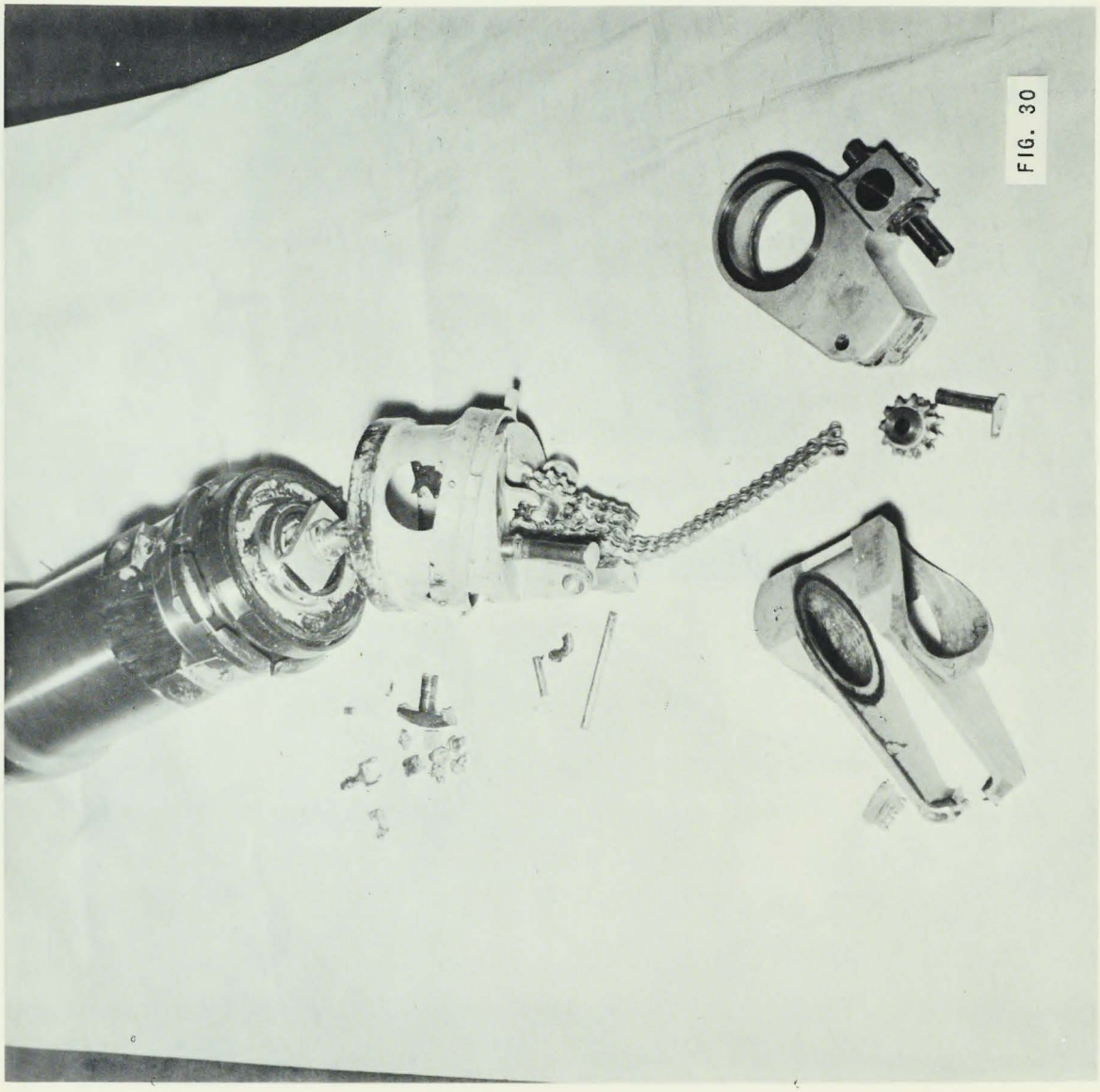


FIG. 30

FIG. 31

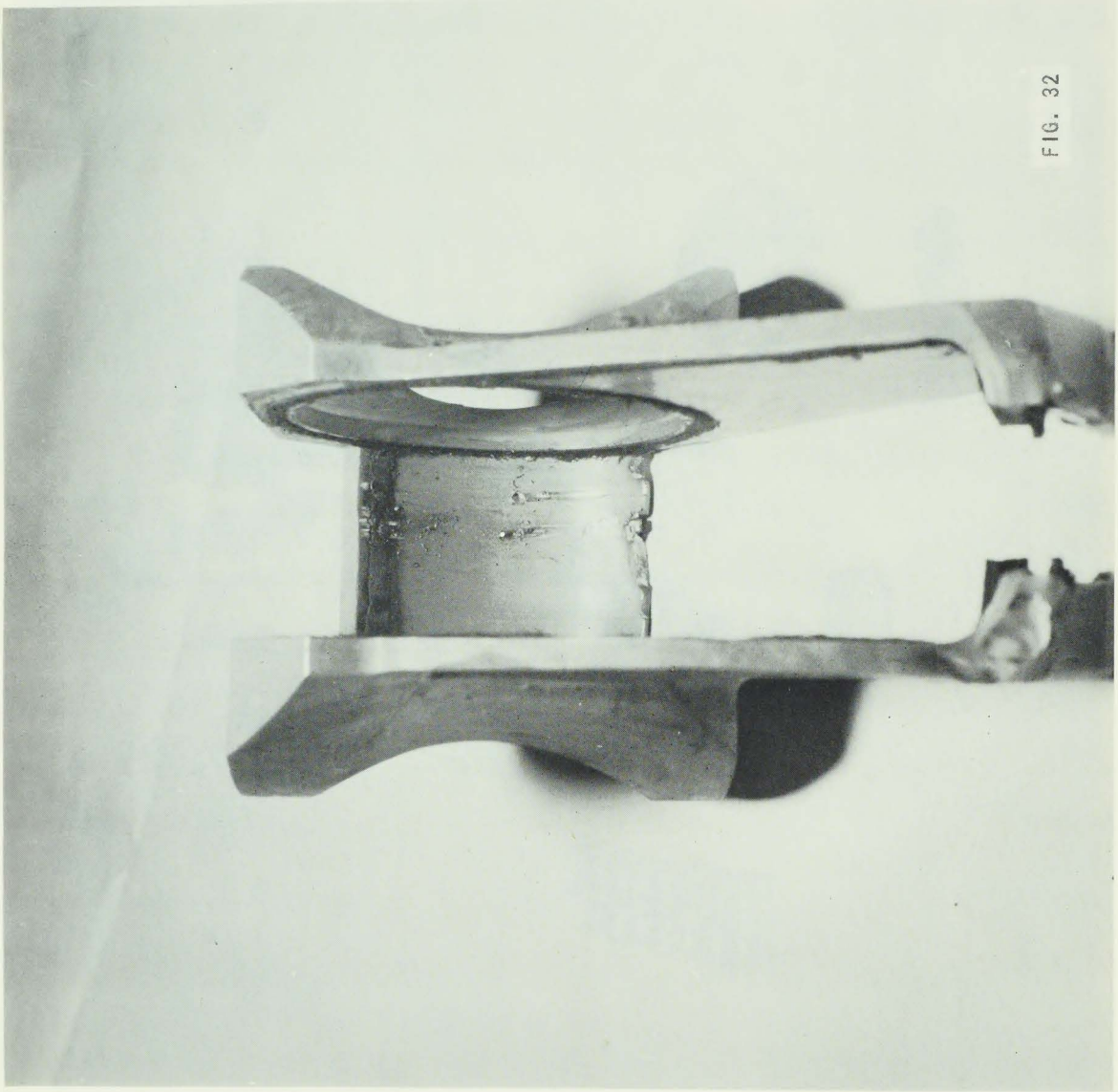


FIG. 32

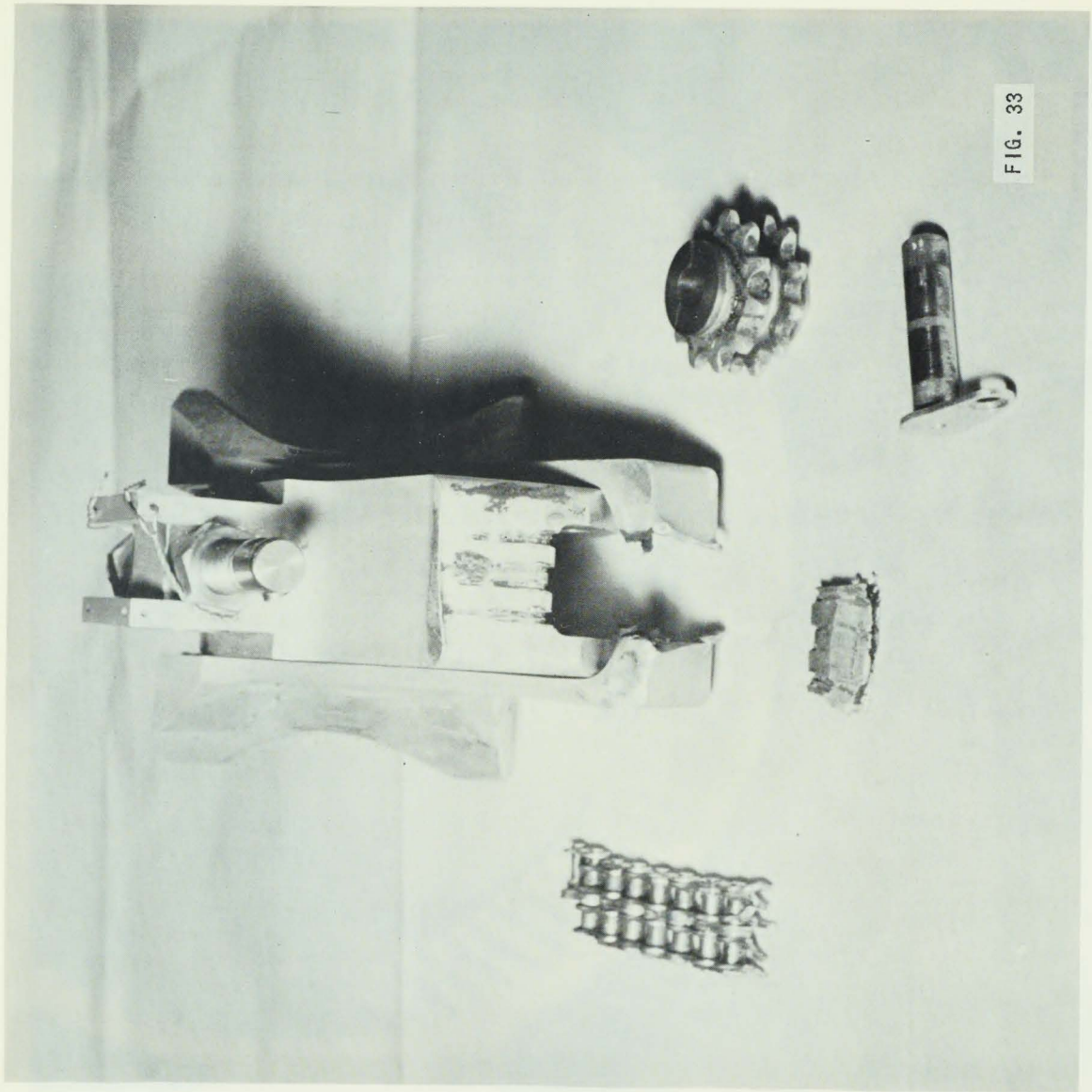


FIG. 33

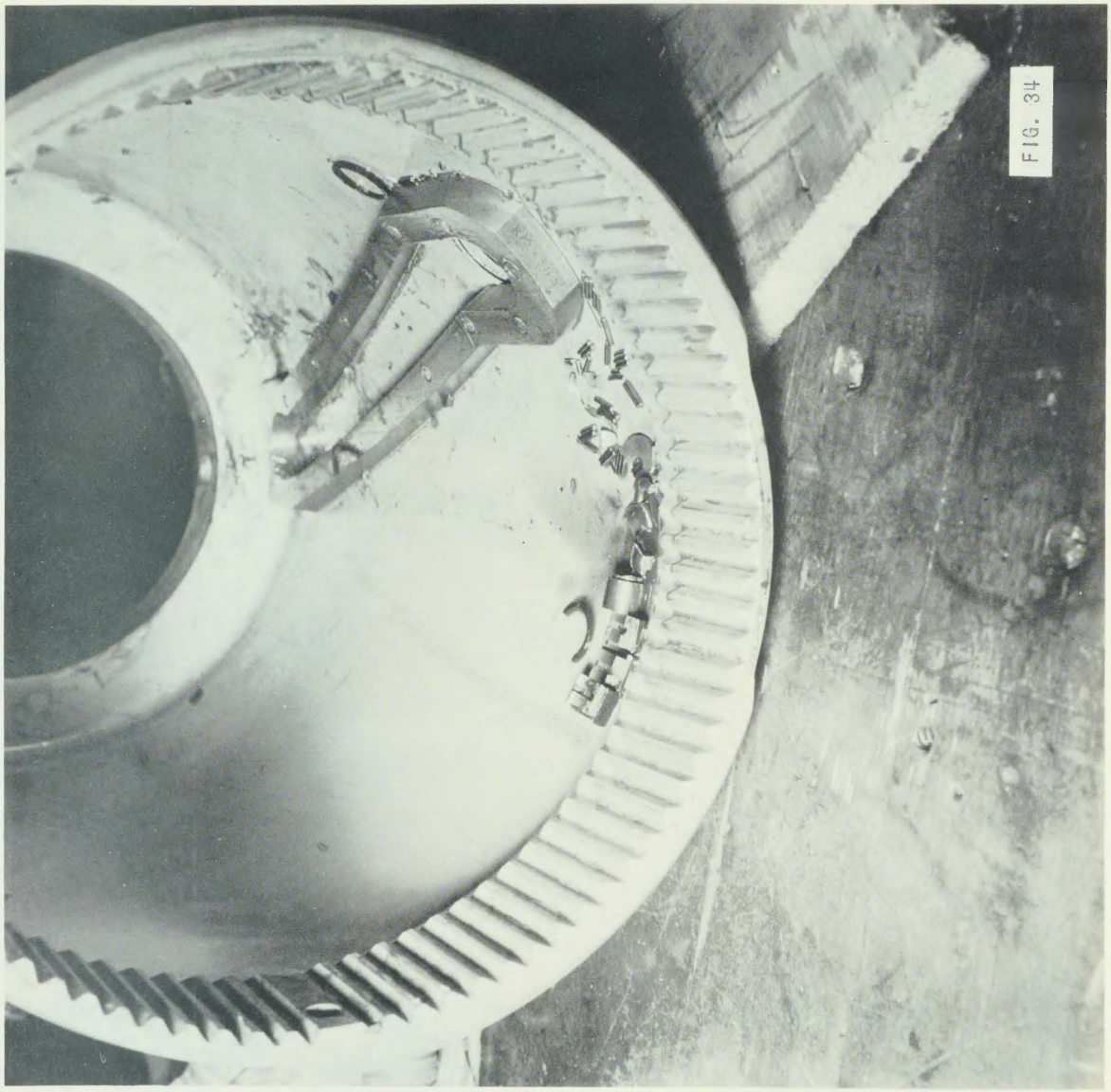
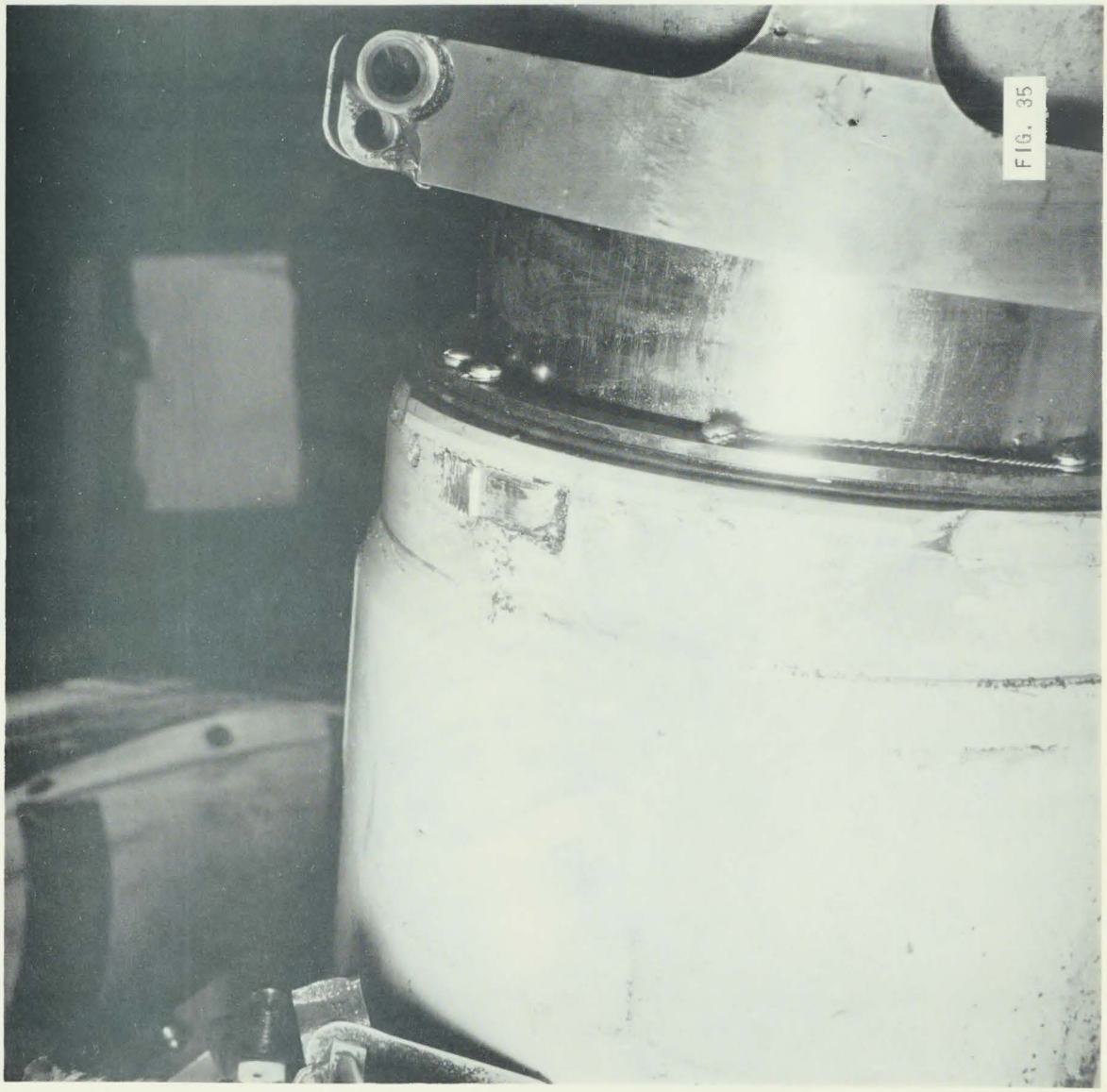


FIG. 34



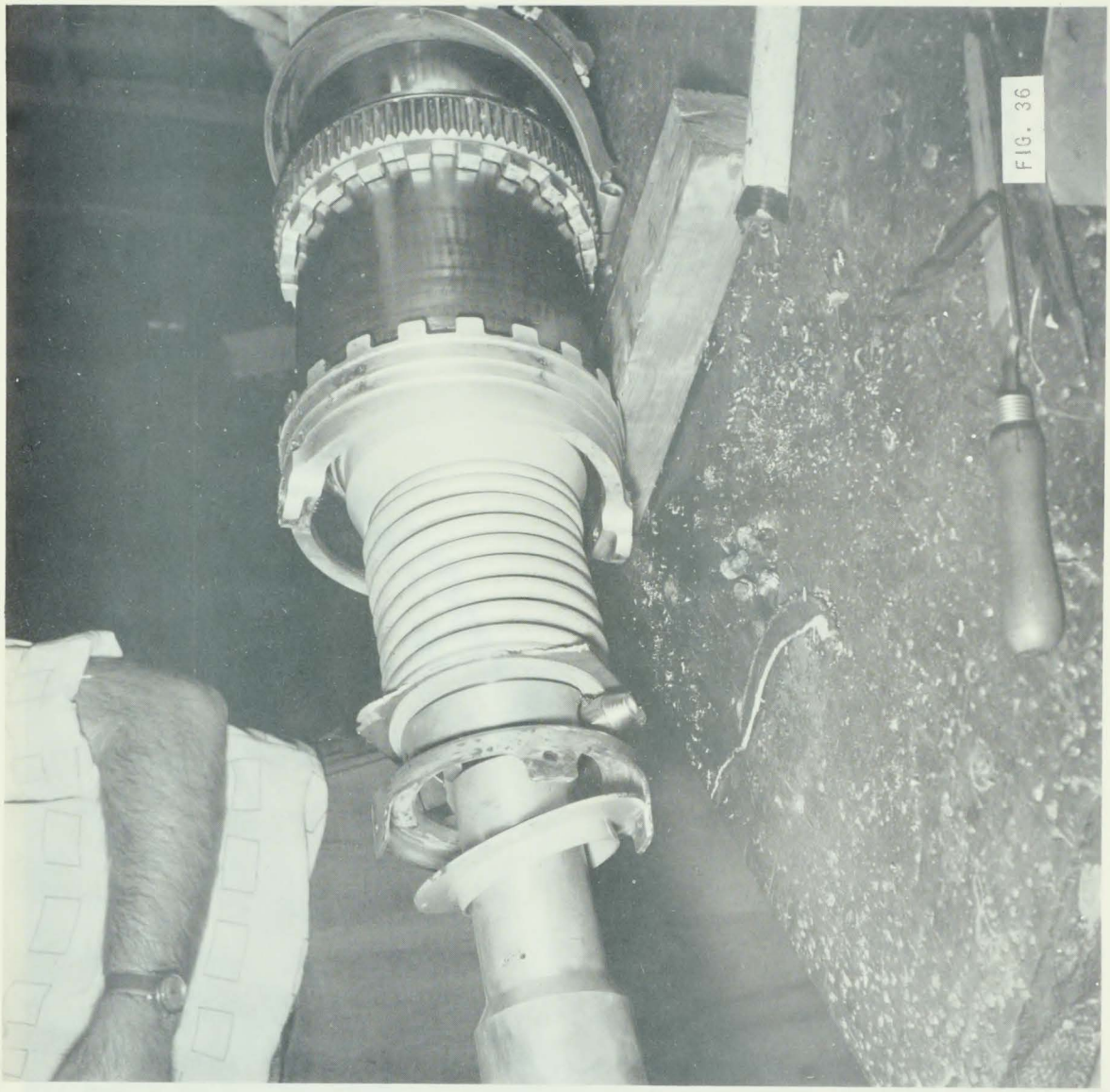


FIG. 36

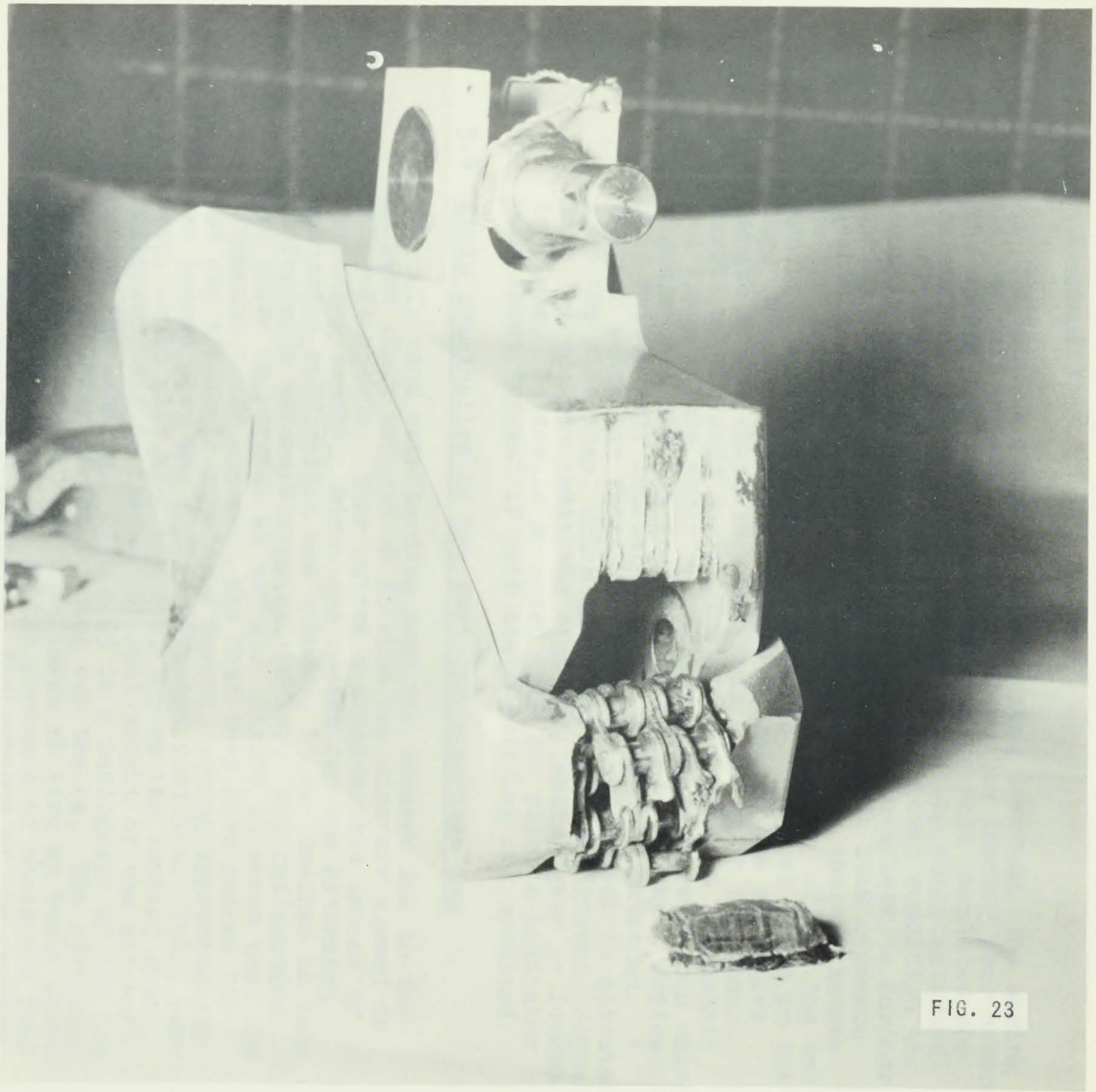


FIG. 23

3.3 (Continued)

In the initial stage of landing gear lowering, the spring is the main extending force; but as the landing gear extends, the spring load decreases and gravity pull completes the extension. The load on the spring in the fully extended condition is 10 lb. and in the fully closed condition the load is 600 lb. When the extension is complete, a further spring (Figure 22) pressing against eight lock segments pushes them into a groove in the lock. A chain attached to the locking barrel passes up to the top of the leg and around a sprocket which is fastened to a dust cover on the leg. When the landing gear is retracted, the effective length of the chain shortens, thus pulling up the inner barrel of the main leg against the spring. A telescopic rod fixed to the inner barrel actuates a micro-switch which signals that the leg is fully down to the cockpit indicator. This switch only indicates that the leg has extended. A further switch is fitted to the side stay which is actuated when the side stay, which is telescopic, has locked, signalling the cockpit indicator that the landing gear is locked in place. It should be noted that the pilot's indicator only shows "green" if both micro-switches are actuated.

3.4 Strip Examination of the Port Undercarriage Leg

The left-hand main landing gear was sheared due to the extreme loads imposed on it when the aircraft slewed in the soft ground. This caused a considerable amount of secondary damage. Since the reason for the extension mechanism malfunction was unknown, it was decided to take radiographs before stripping the leg. The radiographs are shown in Figures 24 and 25. Figure 24 shows that the extension locks are out, but that they have pushed the end cap off their retaining barrel, moving approximately two inches past the fully retracted position. This, however, could also have occurred before the landing gear collapsed, due to taking the full weight of the aircraft during the landing. Figure 25 is a radiograph of the leg in the vicinity of the turning cam tracks. The stripping of the landing gear was undertaken at Avro by Dowty Equipment of Canada Limited, in the presence of observers from Avro Engineering Department. Photographs of the various stages of strip and details of individual parts were taken. Figure 26 is a view of the top of the leg and shows the retraction chain outside the moveable dust cover. The marks on the dust cover indicate that the chain may have been trapped between the dust cover and the top of the main leg forging. The gear was stripped, therefore, to determine if anything could have caused the chain to slacken, loose its tension so that a fold in the chain became jammed. If this occurred, it could stop the leg

3.4 (Continued)

from fully extending against the partially extended spring and the weight of the gear.

Figure 27 shows the end of the leg with the dust cover removed, revealing the chain and idler sprocket. In addition, this photograph shows that a section of chain is jammed between the sprocket and the end cap, and the sprocket mounting lugs have also failed. However, the jammed chain could also have been caused by secondary damage due to the extension mechanism being pushed two inches past the fully retracted position.

Figure 30 shows the dust cover, chain and top of the extending gear after they had been withdrawn from the leg forging. Figure 30 shows the fixed portion of the dust cover along with a part of the forging which was torn out by the chain being looped between its moveable piece at the left top corner. Figure 31 shows the chain marks on the dust cover. Figure 32 is a close-up photograph of the fixed part of the dust cover showing part of the forging broken out at the extreme right-hand side. Figure 33 shows the piece of chain which had been broken off and damaged the dust cover. It should be noted that the chain breakage could have been caused when the landing gear was sheared in the final stages of the accident.

Figure 34 shows one of the two cam tracks; the rollers in the bottom are broken. This is secondary damage, due to the extending portion of the leg being driven beyond the fully retracted position.

Figure 35 shows the bearing retaining clamp and the barrel. The marks on the barrel indicate that the band had rotated, and the dowel had scored the barrel. The torque to release the bolts was in the order of 350 lb. in. However, some of this high loading could be attributed to twisting during the final breakage of the leg.

Figure 36 shows the shortening mechanism extension spring, which is almost coil bound. This is due to the locks passing beyond the normal retracted position, forcing off the end cap and then forcing the locking segments out at the top of the cylinder. A metallurgical check on the spring showed that it was according to specification, although it had a permanent set of about 1-1/2 in.

Figure 37 shows the left-hand landing gear extension microswitch and Figure 38 shows the left-hand tires.

3.5 Possible Electrical Malfunctions

The electrical system was examined to determine what malfunctions could cause false indications.

The landing gear position indicator is wired in series through both the leg extension and the side stay switches to ground. The warning light in landing gear selector lever is wired by positive supply through both switches in parallel. If a short had occurred between the cockpit indicator and the leg extension switch, the indicator would only have shown DOWN, and would not have shown the neutral and up positions.

If there had been a short between the UP extension switch and the side stay switch, the indicator would have shown DOWN, with only the down lock switch actuated. However, an unactuated side stay switch would have given a warning signal to the selector handle light. Therefore, if no signal had been given to the selector handle warning light, it would indicate that the positive supply through the unactuated position of the side stay switches, had also failed.

If the cockpit indicator had been wired incorrectly so that it bypassed the extension switch and was wired to ground, when only the side stay switch was actuated, the extension switch would have given a warning signal if unlocked. This would occur unless there was also a fault in the positive supply line to the selector lever light. Failure of the selector lever light circuit breaker, or of the filament would have to occur at the time of down lock, otherwise the absence of the light during the down actuation period would probably have been noticed. If the selector lever light had been wired to the actuated side of either micro-switch, the light would have been on, prior to takeoff.

The foregoing circumstance would appear to reduce the possibility of wiring faults being the cause of false indication. However, if the leg extension switch operating mechanism could be adjusted to actuate the switch at all times, or if the mechanism should join in the actuated position, regardless of gear position, the side stay would be the controlling feature for both down lock indication and lever warning light; from the indication aspect, the landing gear would appear to be operating satisfactorily.

3.6 Electrical Check on the Aircraft

Figure 39 shows the schematics of the cockpit indicator for the main landing gear. It will be noted that both micro-switches must be actuated in order to indicate GEAR DOWN - LOCKED. The working drawings were checked to ensure that the system had been correctly converted into the aircraft wiring drawings. The drawings were found to be correct. The harness from the left-hand landing gear was then re-fitted to the aircraft and circuit checks were made. The side stay micro-switch was found to be unserviceable, and a new switch was installed for the check. It is considered that the failure of this switch was due to the secondary damage, since the pilot's indicator showed the gear to be locked down. This indication would be given if both side stay and extension micro-switches are actuated and serviceable. (Ref. Figure 39.)

The bulb in the cockpit undercarriage selector handle was tested for continuity and found to be serviceable. The following checks were then conducted:

1) UP was selected and all the micro-switches set to the UP position. The indicator shows UP and the light in the handle flashed when the throttles were closed.

2) DOWN was selected and the light in the selector handle changed to a continuous ON.

3) The nose door uplock switch was placed in the unlocked position, the nose indicator showed unlocked.

4) The nose door switch was operated for the fully open position, no change was noted in the position indicator.

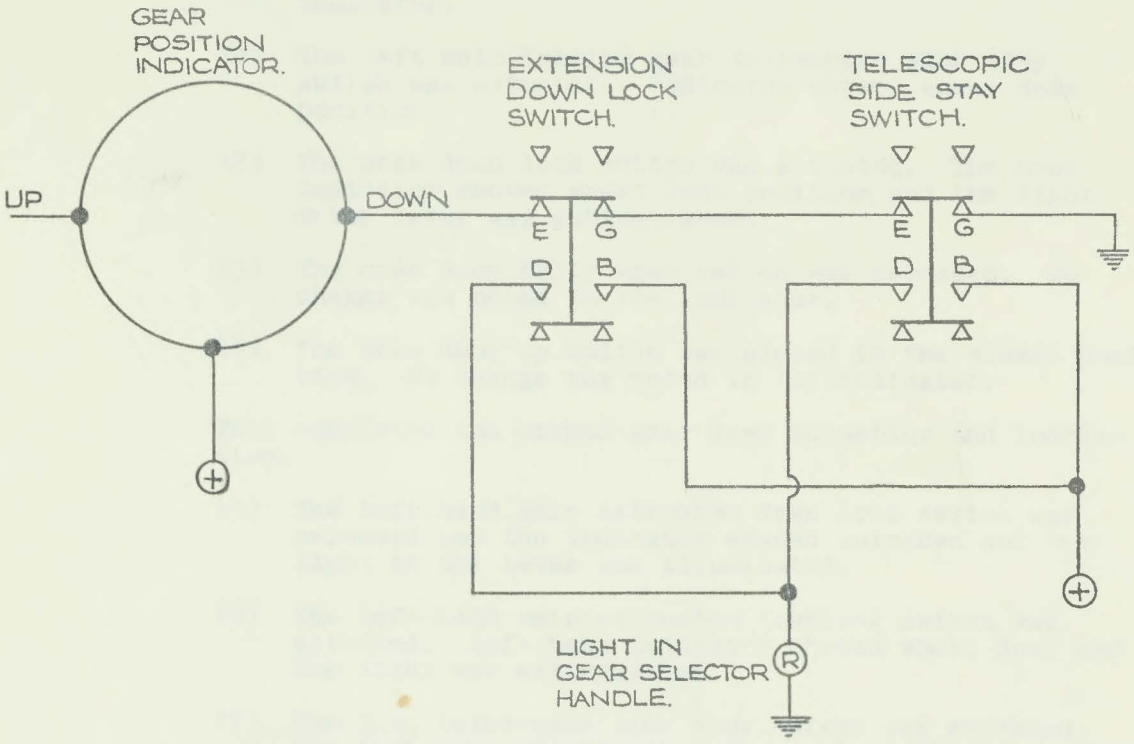
5) The nose gear uplock switch was released, no change was noted in the indicator.

6) Right-hand main landing gear uplock switch was released. The right-hand indicator showed unlocked.

7) Left-hand landing gear main uplock released. Indicator showed unlocked.

8) Right-hand main landing gear leg extension switch was actuated. No change was noted in the indicator.

9) The right-hand main landing gear telescopic side stay switch was actuated. Indicator showed wheel down position.



SCHEMATIC OF MAIN LANDING GEAR
ELECTRICAL SYSTEM- COCKPIT INDICATOR.

FIG. 39

3.6 (Continued)

10) The left main landing gear leg extension switch was actuated. No change was noted in the left-hand indicator.

11) The left main landing gear telescopic side stay switch was actuated. Indicator showed wheel down position.

12) The nose down lock switch was actuated. The nose indicator showed wheel down position and the light in the lever was extinguished.

13) The nose door fully open switch was released. No change was noted in the indicator.

14) The nose door up switch was placed in the closed position. No change was noted in the indicator.

This completed the normal gear down actuation and indication.

15) The left-hand main extension down lock switch was released and the indicator showed unlocked and the light in the lever was illuminated.

16) The left-hand main extension downlock switch was actuated. Left-hand indicator showed wheel down and the light was extinguished.

17) The L.H. telescopic side stay switch was released. The indicator showed unlocked and the light was illuminated.

18) The left-hand [illegible] telescopic side stay was actuated. The indicator showed wheel down and the light in the selector lever was extinguished.

The above tests proved that the aircraft wiring was correct and the false indication must have been caused by micro-switch maladjustment or jamming in the wheels down position. If this switch was permanently in the actuated condition, the indication would be in order i.e. "wheels down" when the side stay was actuated and "wheels up" when the gear was retracted and the side stay micro-switch released.

It should be noted that the assembly of the harness in the aircraft was not performed by the same crew who originally wired the aircraft, and that all the idents were checked by Engineering staff.

3.7 Examination of the Right-Hand Landing Gear Leg

The right-hand landing gear leg was removed from the aircraft and examined for any signs of trapping of the retracting chain between the dust excluder and the main leg fitting. No evidence of trapping was found.

4. DISCUSSION

4.1 Possible Reasons for Left-Hand Landing Gear Malfunction

Test functions of gear in the aircraft and in the test rig at AVRO have not taken into account airloads on the gear. Air loads at a speed of 250 knots E.A.S. (which is the design limitation for landing gear down) can cause bending and friction in the extension gear. A restriction in the extension, before the full weight of the gear helps it lock down, can cause a release in the retracting chain tension loop thus formed,&if caught in the gap between the dust cover and the main leg fitting could prevent the leg fully extending and locking down.

The portion of the landing gear leg barrels on which the extension bearing moves, were chrome-plated to size on both aircraft 25201 and on the test rig. During landing gear function tests on 25201 prior to first flight, the right-hand gear was found to be jerky during extension. This leg was returned to Dowty and thebarrel was ground. The left-hand leg, however, was not ground, and it is possible that the tolerances were on the high side. Consequently, ground functions, without air loads were satisfactory, whereas during flight 11, the margin may have been exceeded, and the chain jammed, restricting the leg extension.

Dowty has stated that the bearing on the main barrel of the leg near the turning cam can cause high friction if the locking band is too tight. The band is secured by two opposed bolts which are torqued to a valve of 50 in. lbs. and this figure is critical to the gear extension. During the gear strip Dowty confirmed that the locking of the bolts in question was the original performed when the gear was assembled. However, it could be possible that persons stepping on the locking band when standing on the gear for maintenance purposes could have tilted the band and increased the loading and consequently the friction. The ratio of the base to diameter is very low (1-1/2 inches to 9 inches approximately).

4.2 Tests Carried Out at Dowty Equipment of Canada Limited

Tests were conducted at Dowty on a rig in which the friction at the extension bearing was increased. The locking band bolts were torqued to 410 lbs. ins. instead of 50 lbs. ins. The gear was then lowered, and it was found that the retraction chain looped and jammed in the dust cover, as it closed; the length of chain jamming being about 5 links. The tests were stopped before the gear was fully down in order to prevent damage to the gear. However, on one occasion, when it was thought that the chain was clear, the gear was let go and damage was caused to the dust cover similar to that shown in Figure 30.

5. CONCLUSIONS

The main landing gear failed to extend properly. The first malfunction occurred when a "hang up" kept the extension mechanism from lowering, causing an excess amount of chain at the upper end of the gear. (See Fig. 44.)

This "hang up" cleared itself during extension, but the excess amount of chain had jammed, making proper extension impossible. Detail design of the chain mechanism is such as to make jamming almost certain if there is excess chain.

The reason for the "hang up" is not positively known at this time, (see para. 4.1), however, the two most probable reasons are as follows:

(1) There is no confirmation that the 600 lb. extension spring is sufficient to overcome friction within the full flight envelope, considering speeds, attitude and 'g' forces.

(2) The gear that failed did not have the chrome plating honed to fight tolerance. This is the only gear in this state. Grinding in the early stages was not considered satisfactory in conjunction with the very high heat treat steels (260,000 psi - 280,000 psi).

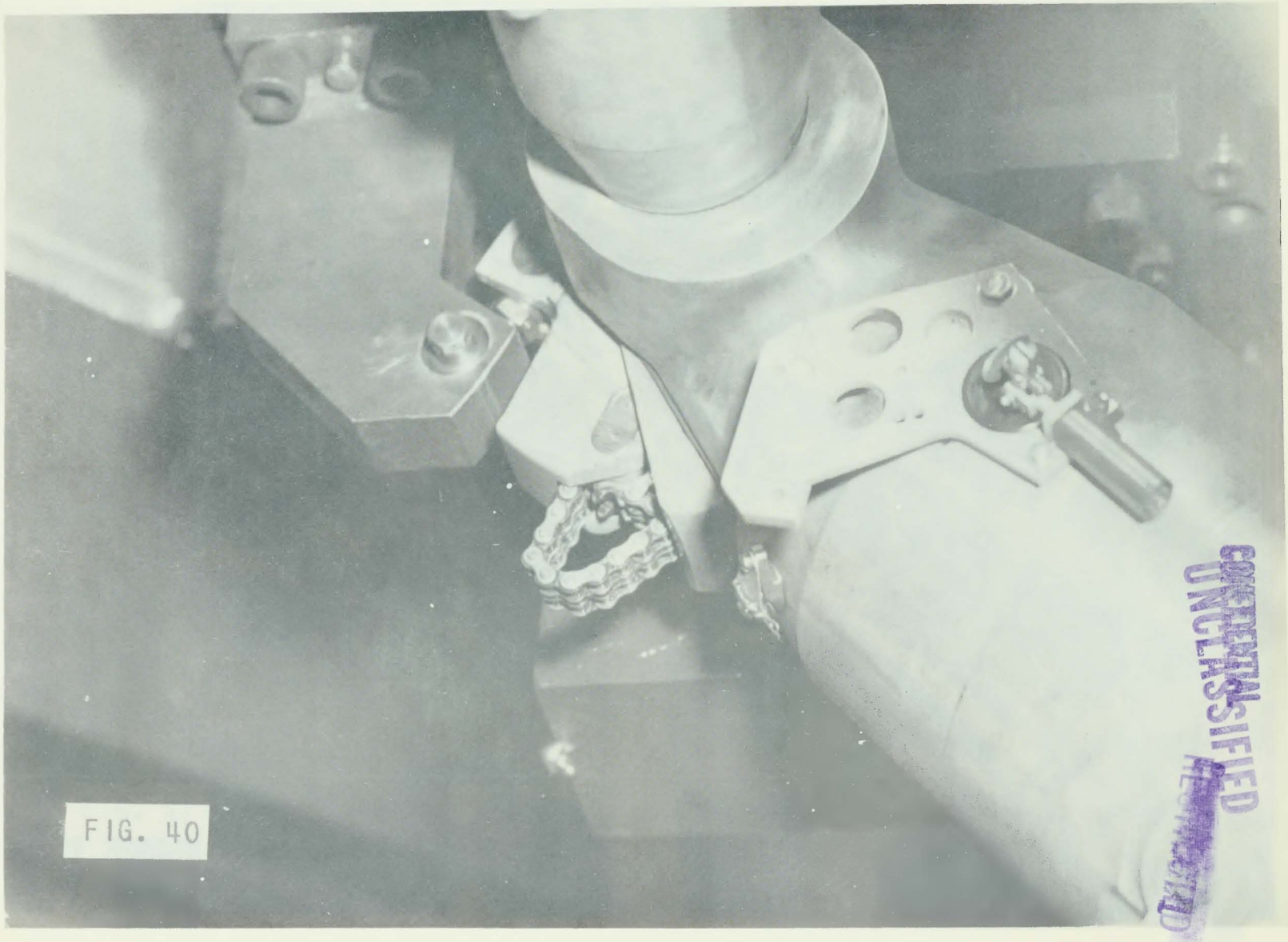


FIG. 40