

648 NAT. ADV. ...
~~CONFIDENTIAL~~
UNCLASSIFIED

REPORT ON ACCIDENT

TO

AVRO ARROW I 25201

ON

Classification cancelled/changed to.....

by authority of..... (date).....

Signature *[Signature]* Rank *[Rank]*

June 11, 1958

at

MALTON

UNCLASSIFIED



170520

COMPILED BY:

[Signature]
P. Martin
Project Engineering - Arrow I

APPROVED BY:

[Signature]
F.P. Mitchell
Project Designer - Arrow I

~~RESTRICTED~~
~~CONFIDENTIAL~~

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.

~~RESTRICTED~~

INDEX

~~CONFIDENTIAL~~

1. INTRODUCTION
2. HISTORY
 - 2.1 Aircraft
 - 2.2 Landing Gear
3. ACCIDENT DETAILS
 - 3.1 The Landing and Cause of the Accident
 - 3.2 Pilot's Statement
 - 3.3 Details of Landing Gear Design
 - 3.4 Strip Examination of the L.H. Landing Gear Leg
 - 3.5 Electrical Check on the Aircraft
 - 3.6 Examination of R.H. Landing Gear Leg
4. DISCUSSION
 - 4.1 Possible Causes of L.H. Landing Gear Malfunction
 - 4.2 Tests Conducted at Dowty Equipment of Canada Limited
5. CONCLUSIONS

RESTRICTED

CONFIDENTIAL

LIST OF FIGURES

1. Malton Airport Showing Location of Accident
2. Photograph of Aircraft just Prior to Touchdown
3. Photograph of Aircraft after Touchdown
4. Photograph of Aircraft During Landing Run
5. Photograph of Aircraft Landing Run
6. Photograph of Aircraft with Chute Deployed
7. Photograph of Aircraft with Chute Deployed
8. Photograph of Aircraft with Parachute Jettisoned Leaving Runway
9. Photograph of Aircraft Leaving Runway
10. Aircraft with Gear Collapsing
11. Final Position of Aircraft
12. Aerial Photograph of Accident
13. Aerial Photograph of Accident
14. Tire Marks at Touchdown Point
15. Tire Marks showing Burst Point
16. Tire Marks and General View of Aircraft
17. Top of L.H. Leg Showing Chain
18. L.H. Landing Gear
19. L.H. Landing Gear showing Collapsed Extension
20. G.A. of Main Landing Gear
21. Section Through Main Landing Gear
22. Shortening Mechanism
23. Top End Fitting of Leg Showing Dust Excluder
24. Radiograph of Locking Mechanism
25. Radiograph of Cam Track Section of Leg
26. Photograph of Top of Leg Taken in the Field

LIST OF FIGURES (Cont'd)

~~RESTRICTED~~
CONFIDENTIAL

27. Chain with Dust Excluder Removed
28. Chain with Dust Excluder Removed
29. Chain with Dust Excluder Removed
30. Shortening Mechanism Stripped
31. Dust Excluder Parts
32. Dust Excluder Parts
33. Dust Excluder Parts
34. Cam Track and Broken Rollers
35. Locking Band and Barrel
36. General View of Shortening Mechanism being Withdrawn from Leg
37. L.H. Landing Gear Microswitch
38. L.H. Tires
39. Schematic of Cockpit Indicator Electrical System
40. Photograph of Chain Jammed in Dowty Tests
41. General Arrangement of Leg in Dowty Tests
42. R.H. Tire
43. R.H. Brakes
44. Detail of Shortening Mechanism

RECORDED

JUN 1958

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.

~~RESTRICTED~~
~~CONFIDENTIAL~~

- 2 -

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.

CONFIDENTIAL

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.

~~CONFIDENTIAL~~

~~RESTRICTED~~

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 was normal and the indicator was showing ~~locked~~ **UNCLASSIFIED**. 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.

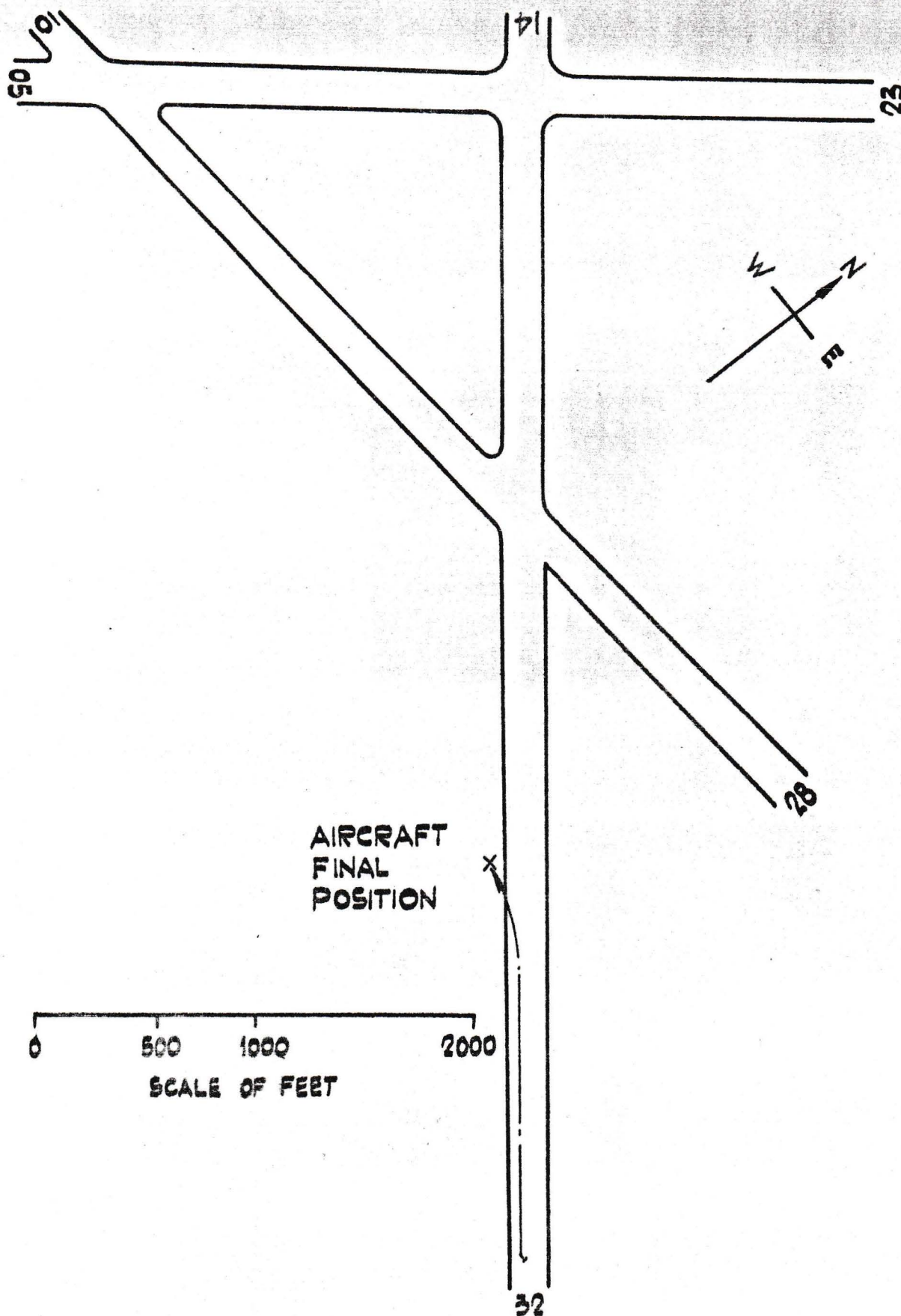
When the main gear is released from the wheel well by the up lock, the spring (Figure 22) starts extending gear and at the same time the helical cam track turns the bogie.

~~CONFIDENTIAL~~

~~RESTRICTED~~

FIG. 1

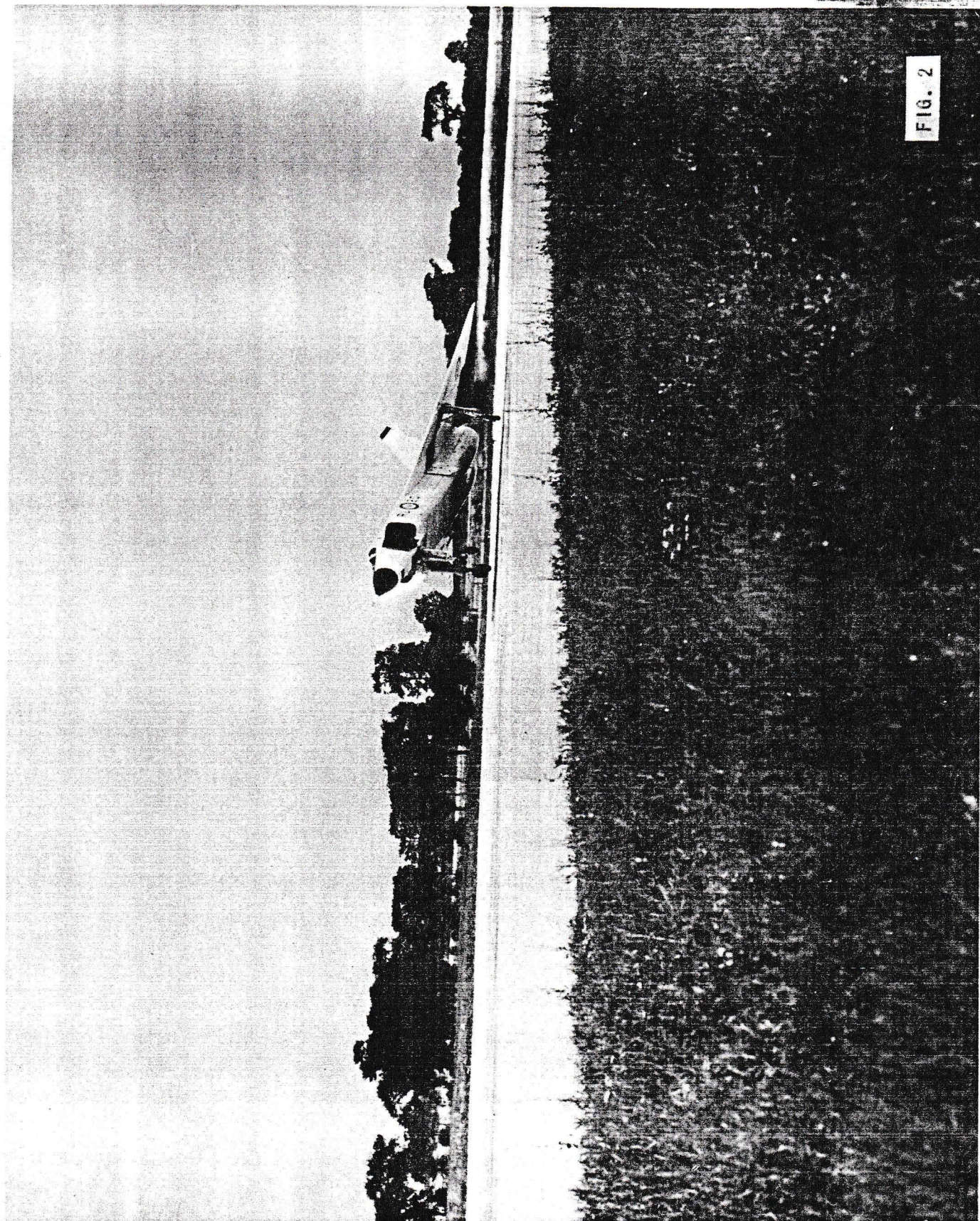
MALTON AIRPORT SHOWING LOCATION OF ACCIDENT



CONFIDENTIAL

RESTRICTED

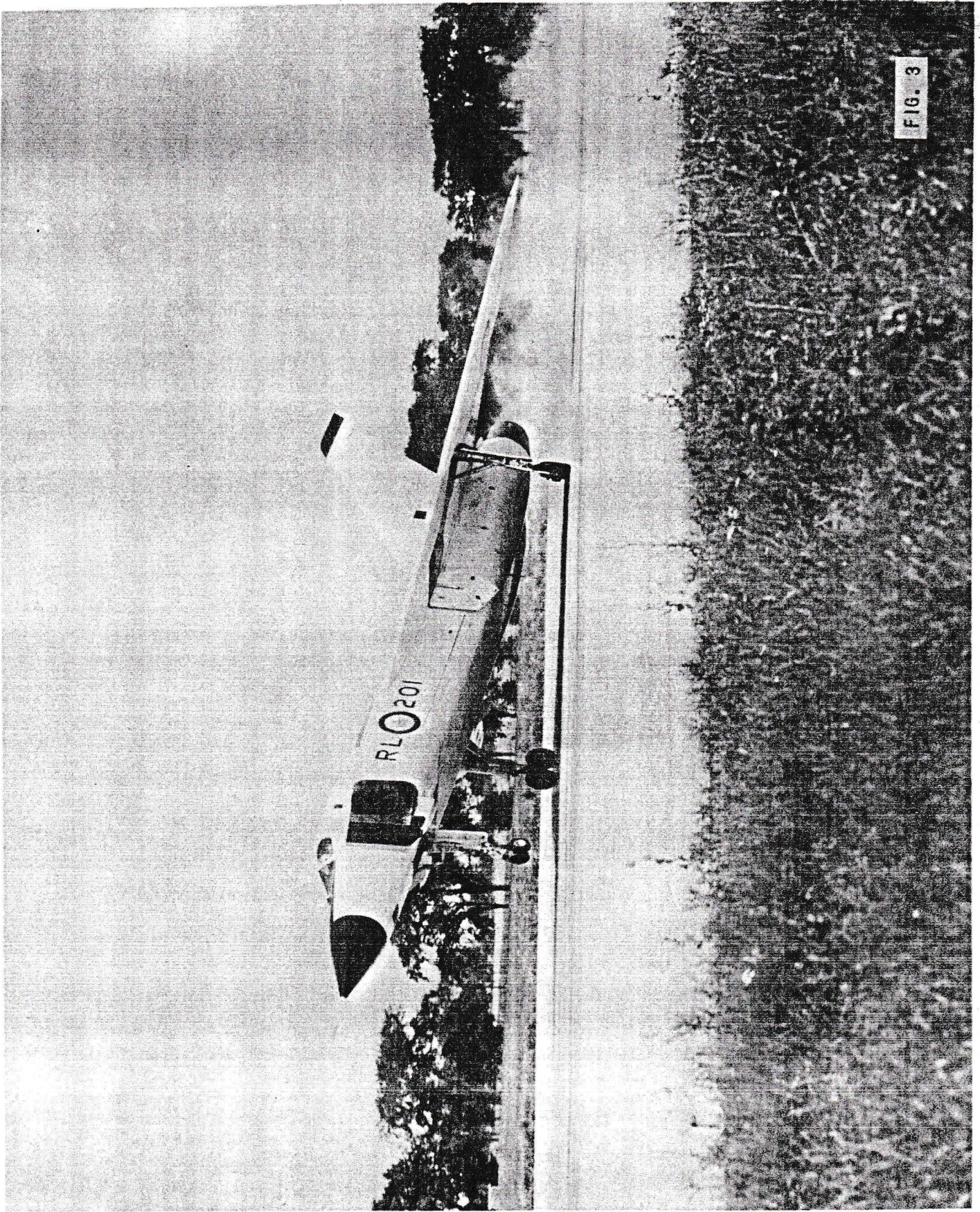
FIG. 2



CONFIDENTIAL

CONFIDENTIAL

FIG. 3



CONFIDENTIAL

RESTRICTED

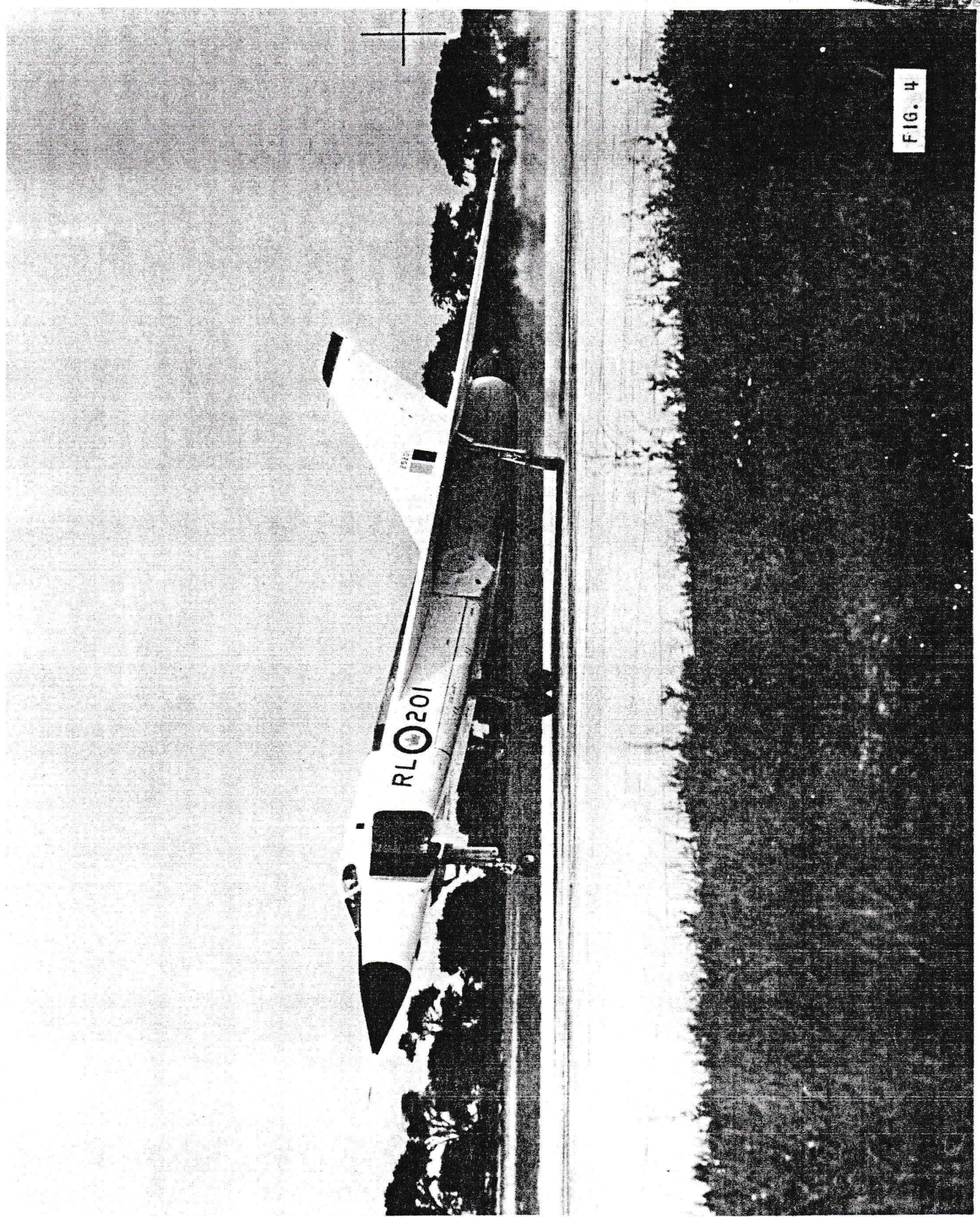
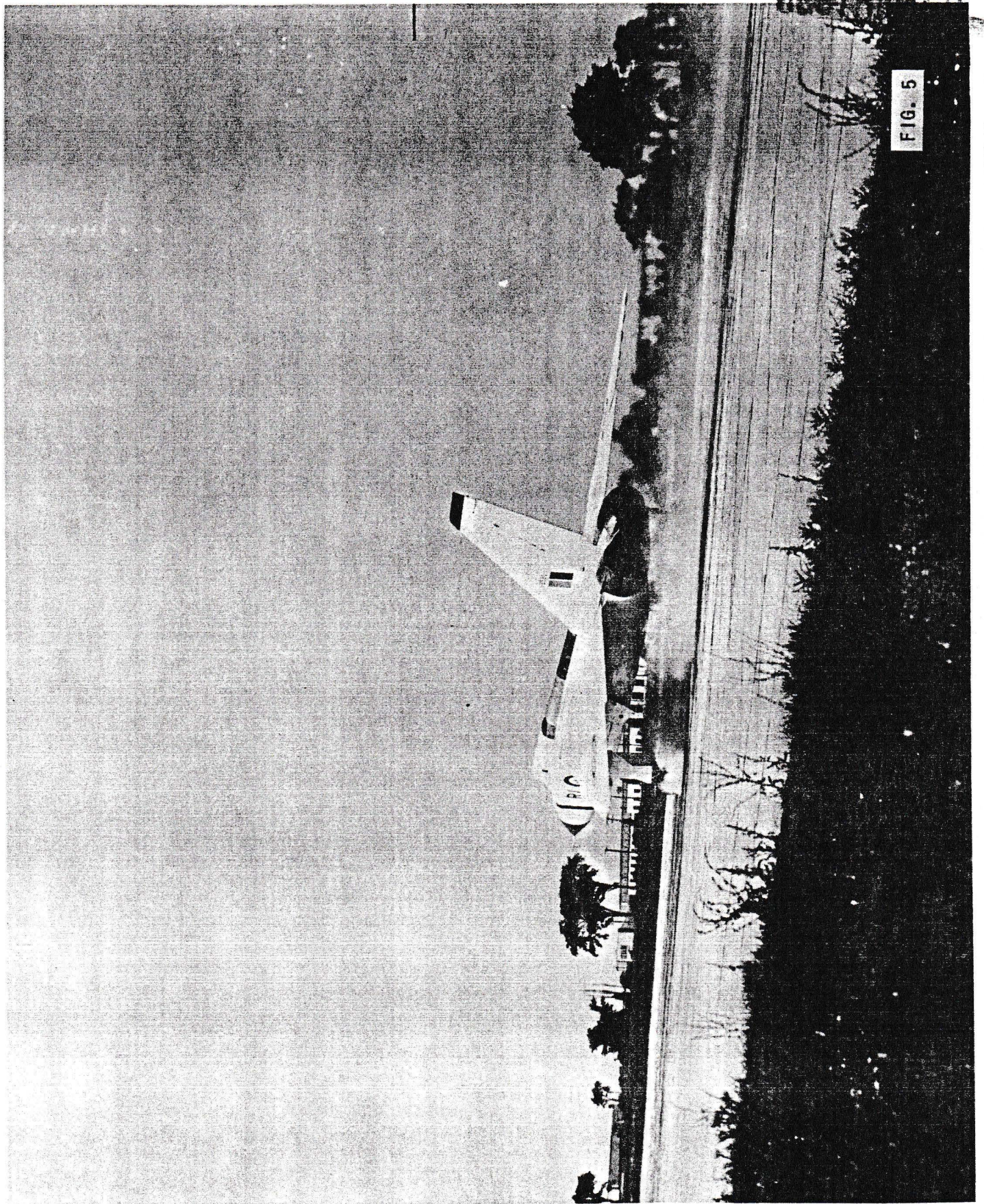


FIG. 4

RESTRICTED

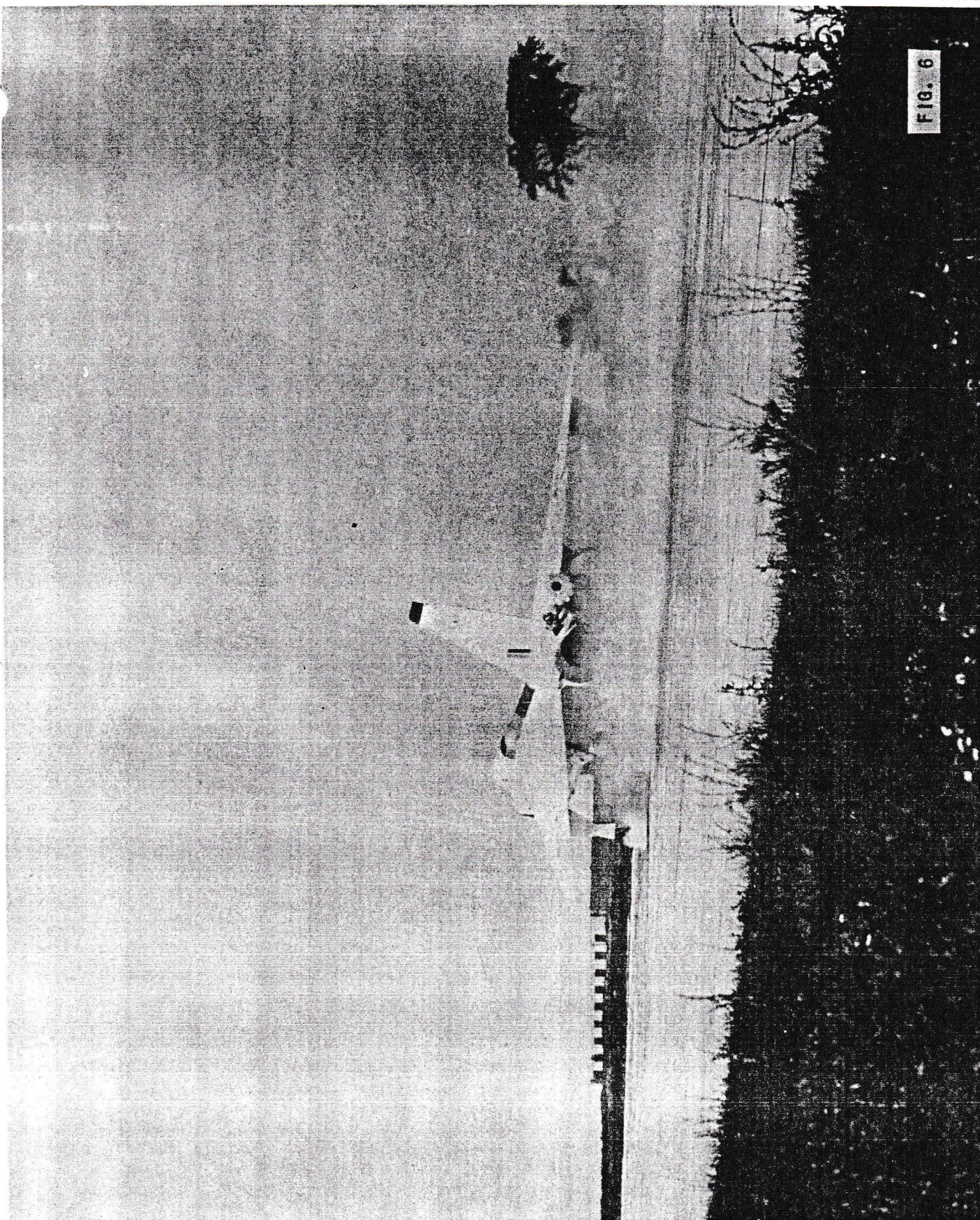
FIG. 5



CONFIDENTIAL

RESTRICTED

FIG. 6



CONFIDENTIAL

RESTRICTED

FIG. 7

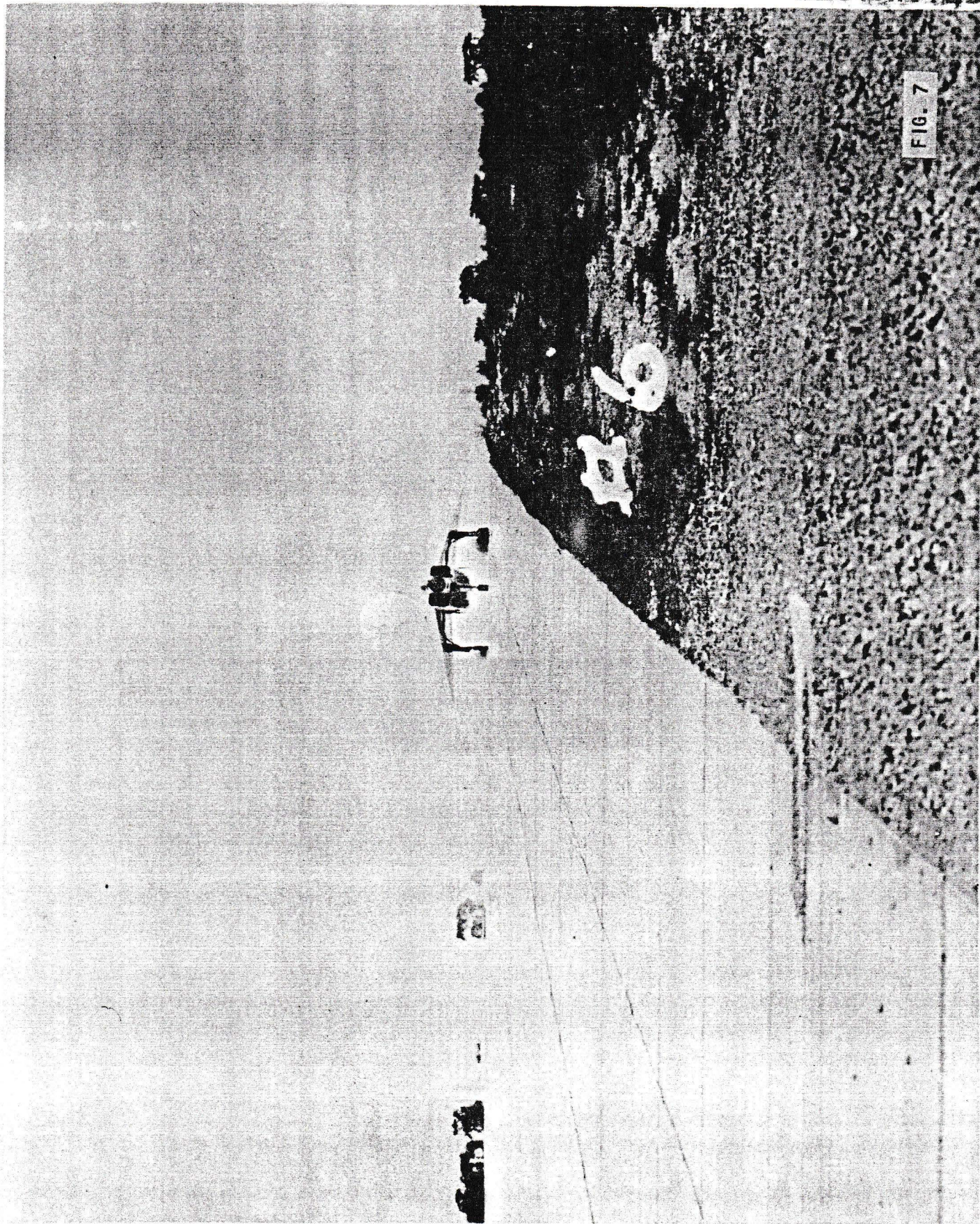
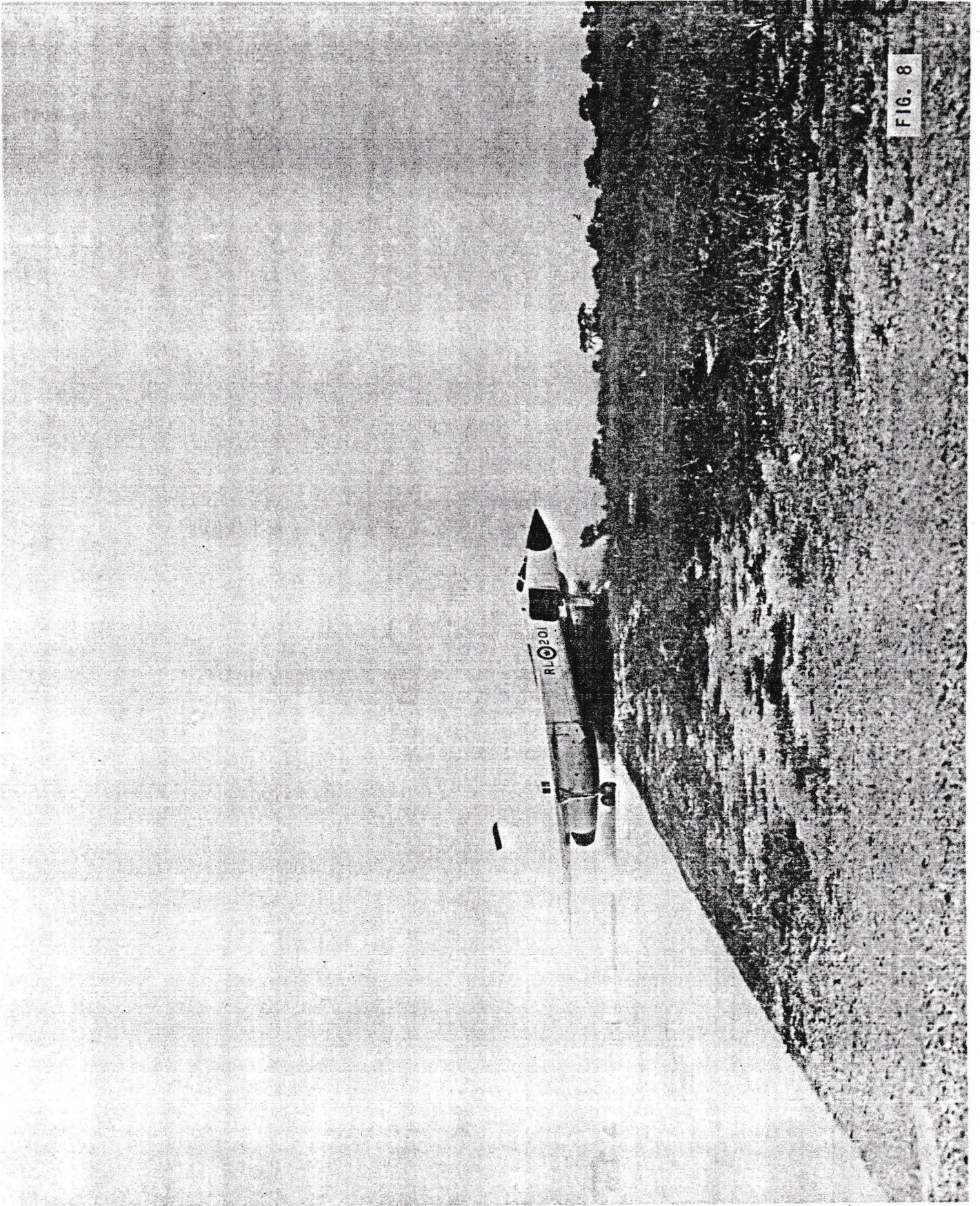


FIG. 8



CONFIDENTIAL

RESTRICTED

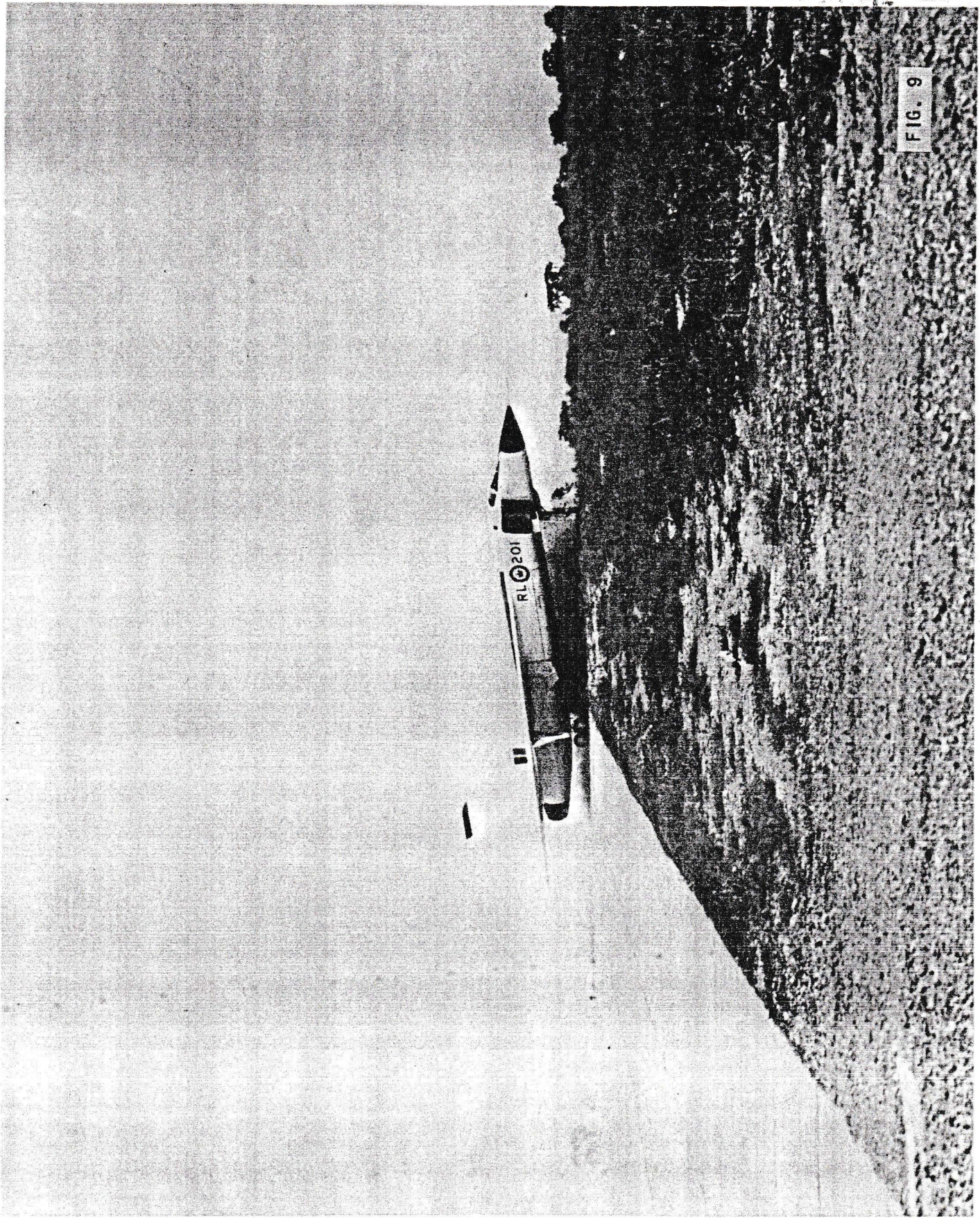
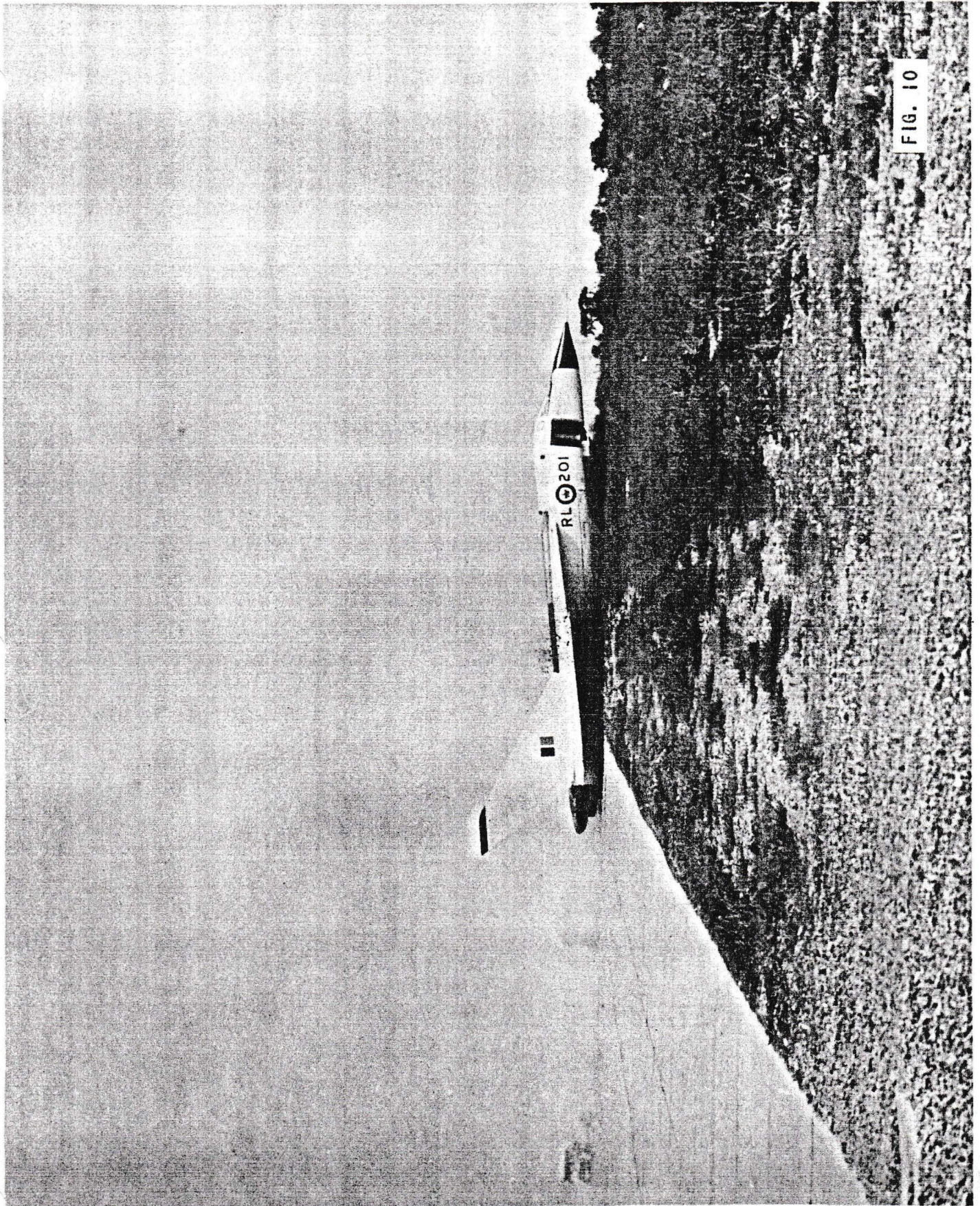


FIG. 9

CONFIDENTIAL

RESTRICTED

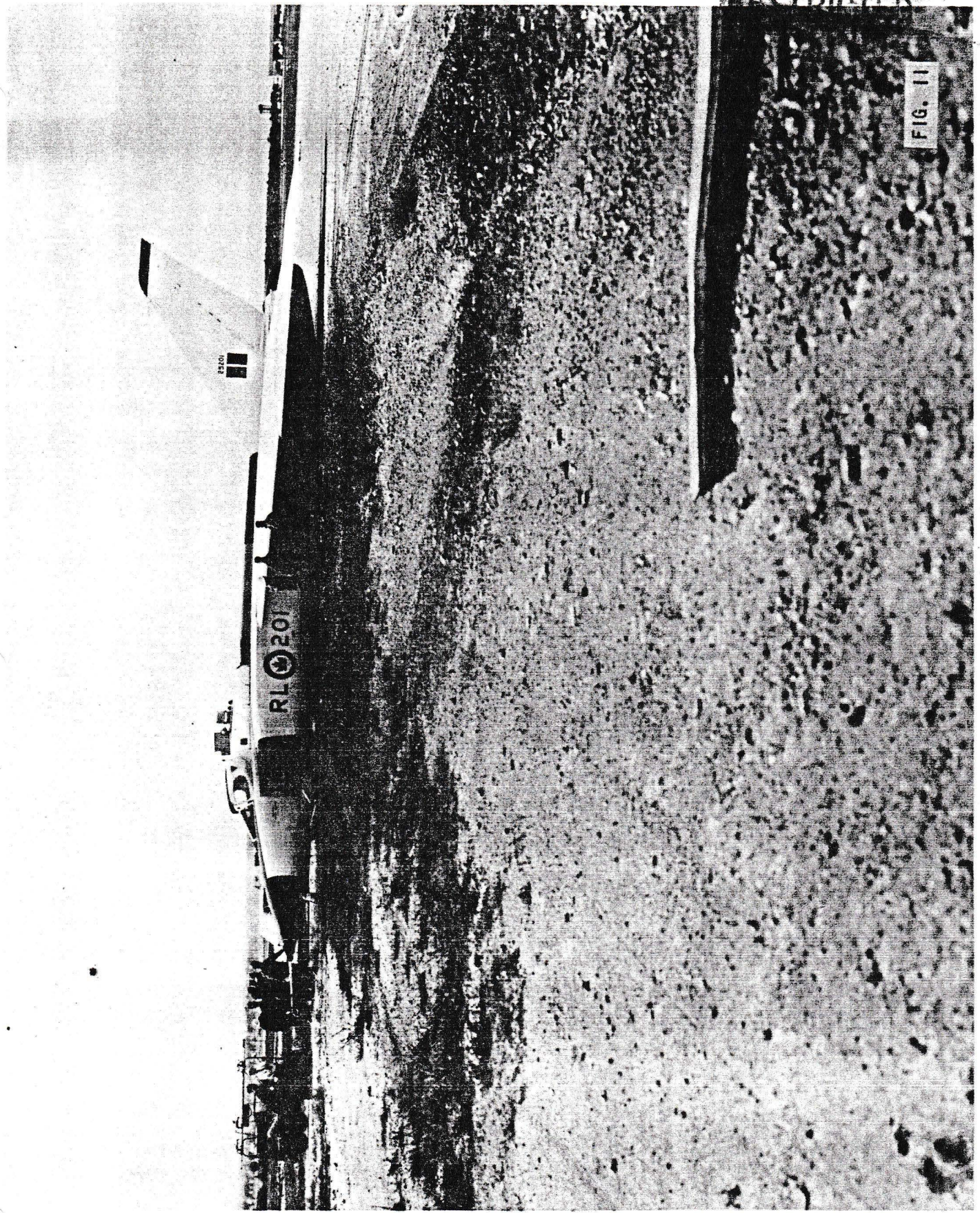
FIG. 10



RESTRICTED

RESTRICTED

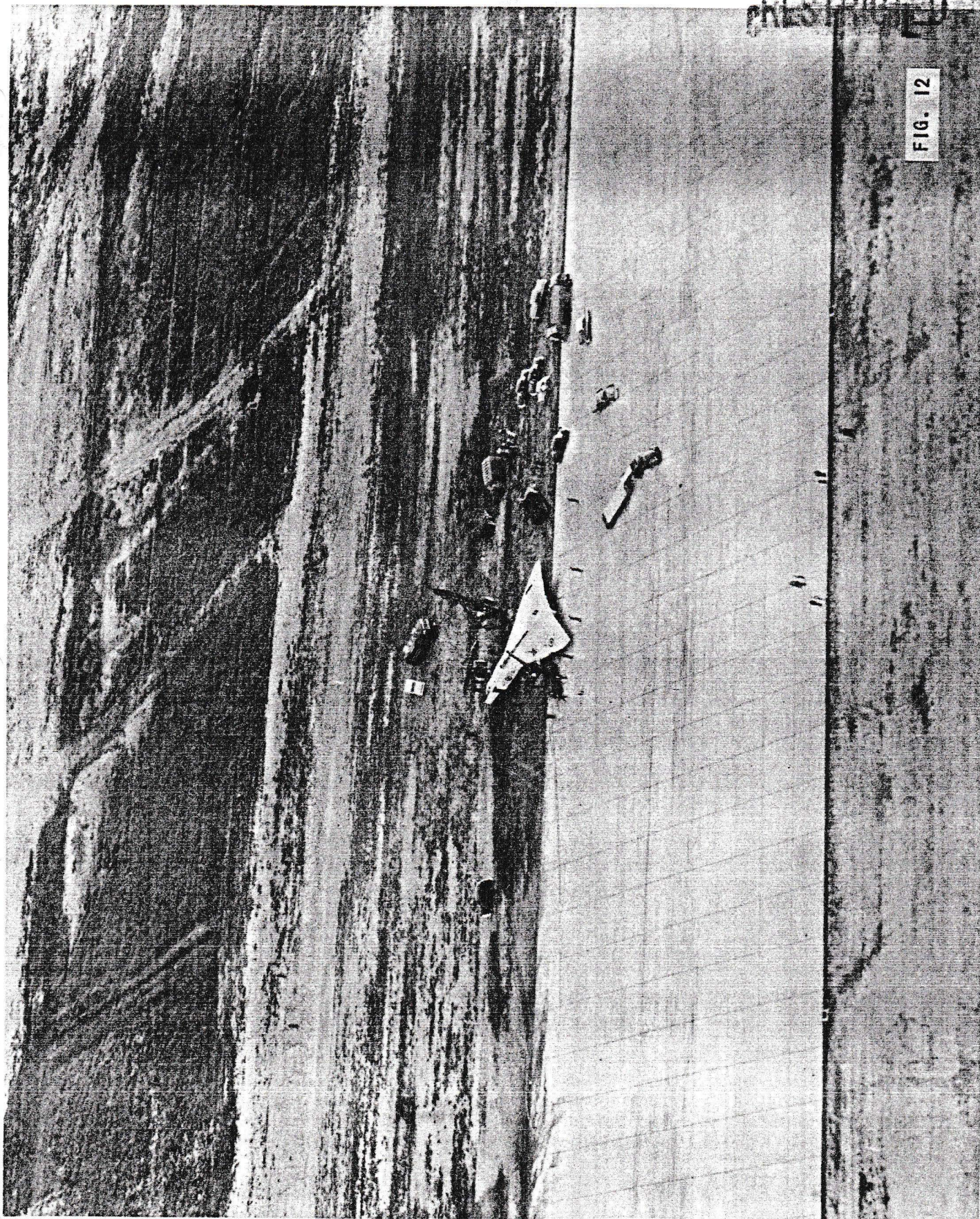
FIG. 11



CONFIDENTIAL

RESTRICTED

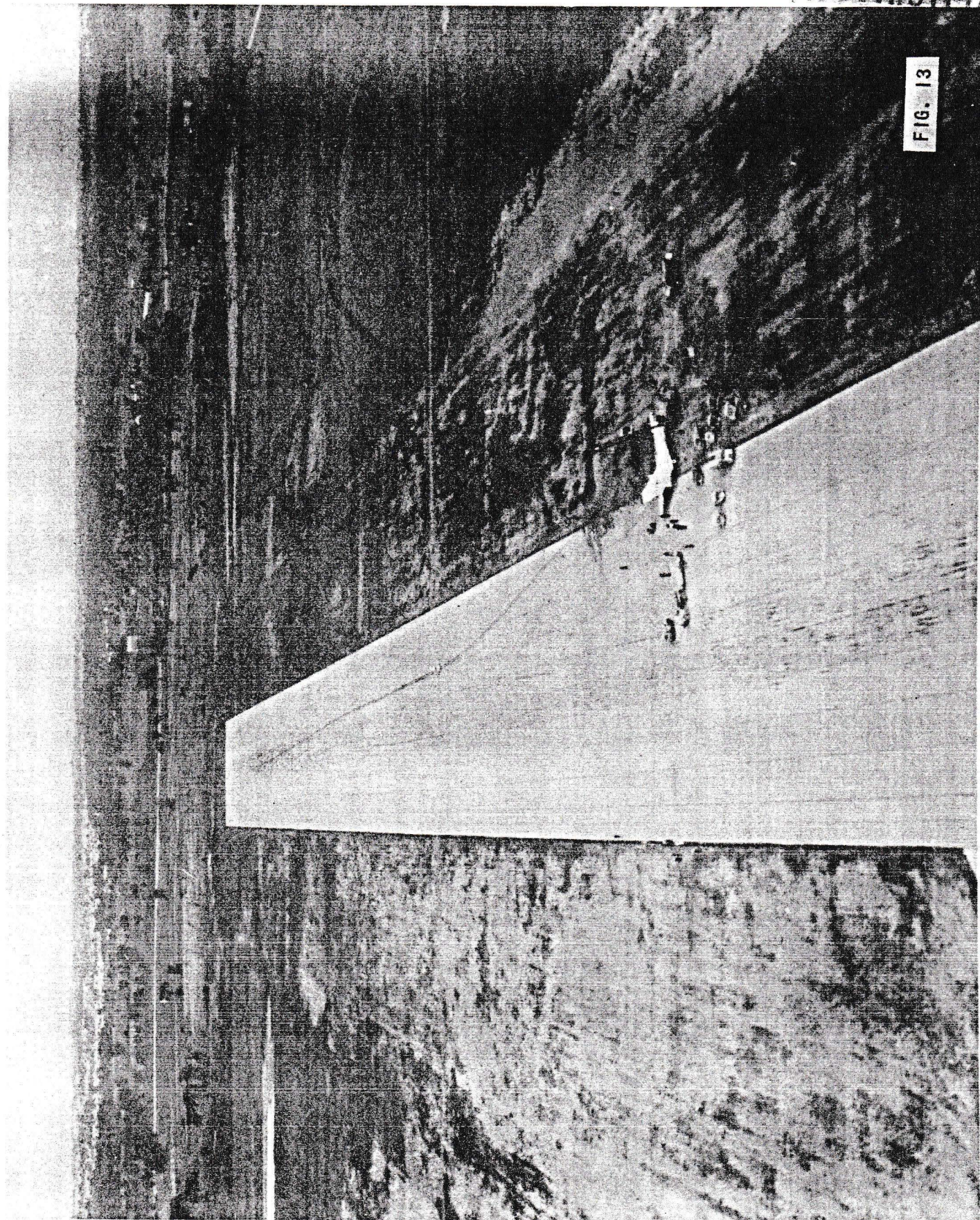
FIG. 12



CONFIDENTIAL

RESTRICTED

FIG. 13



CONFIDENTIAL

RESTRICTED

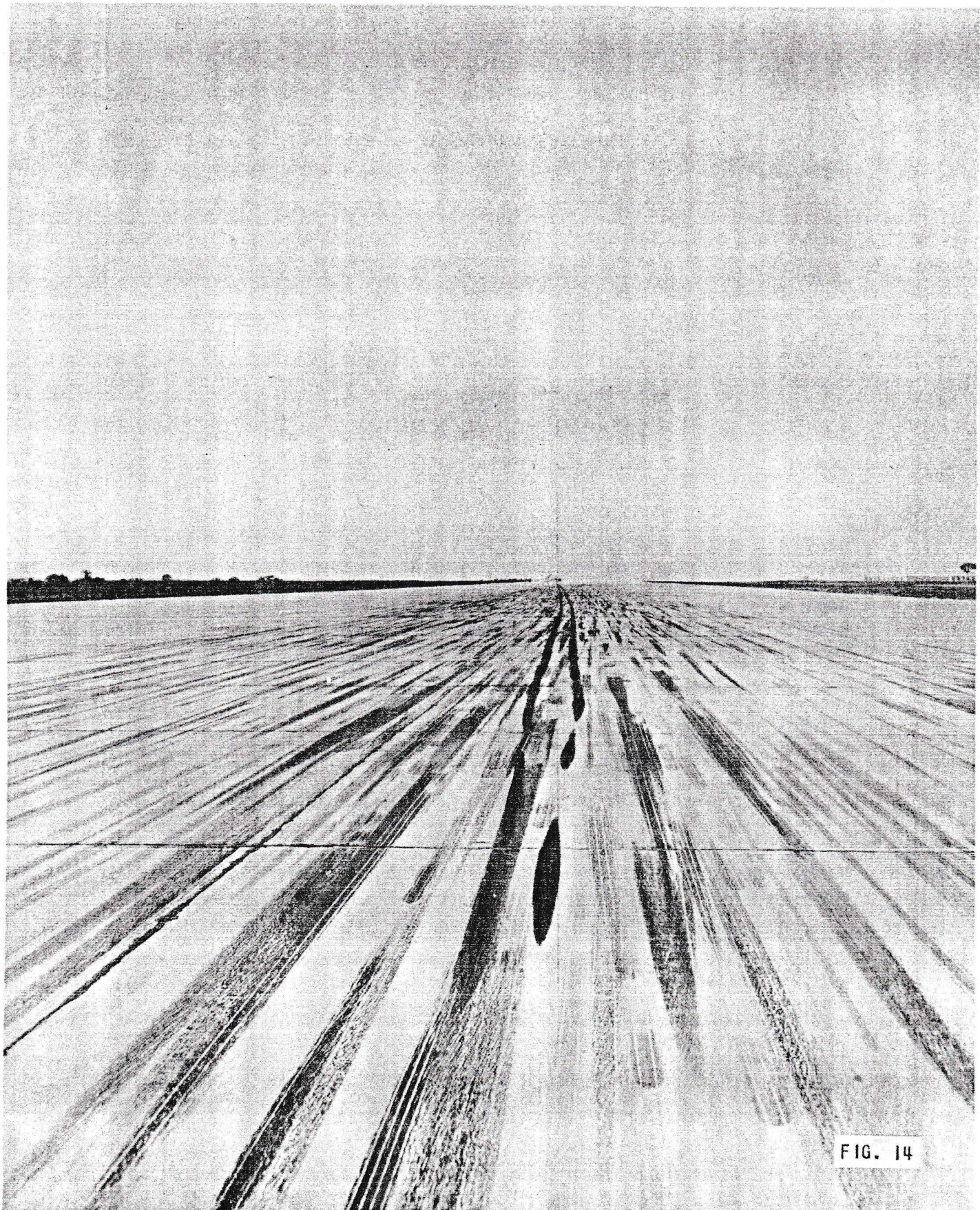
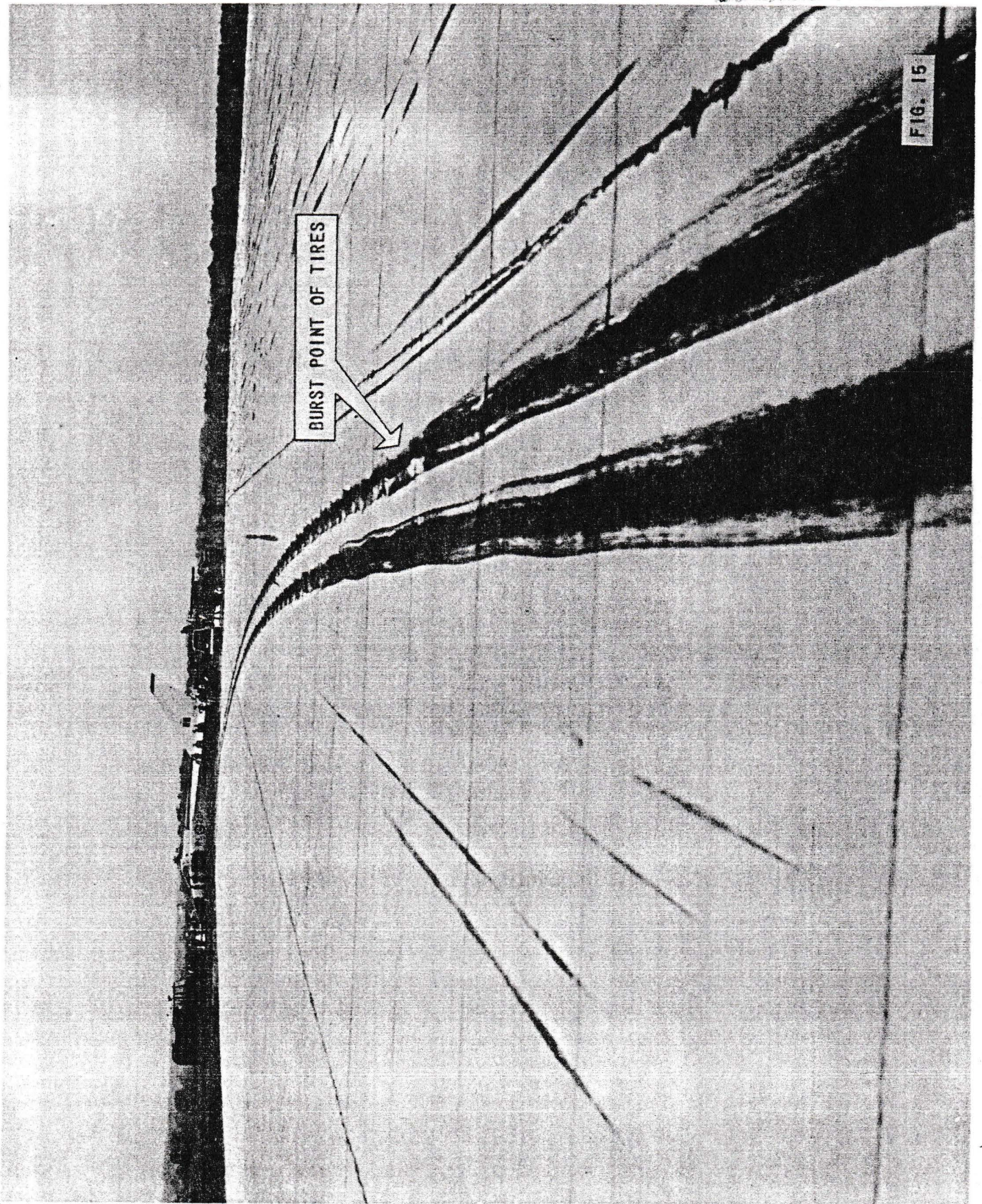


FIG. 14

CONFIDENTIAL

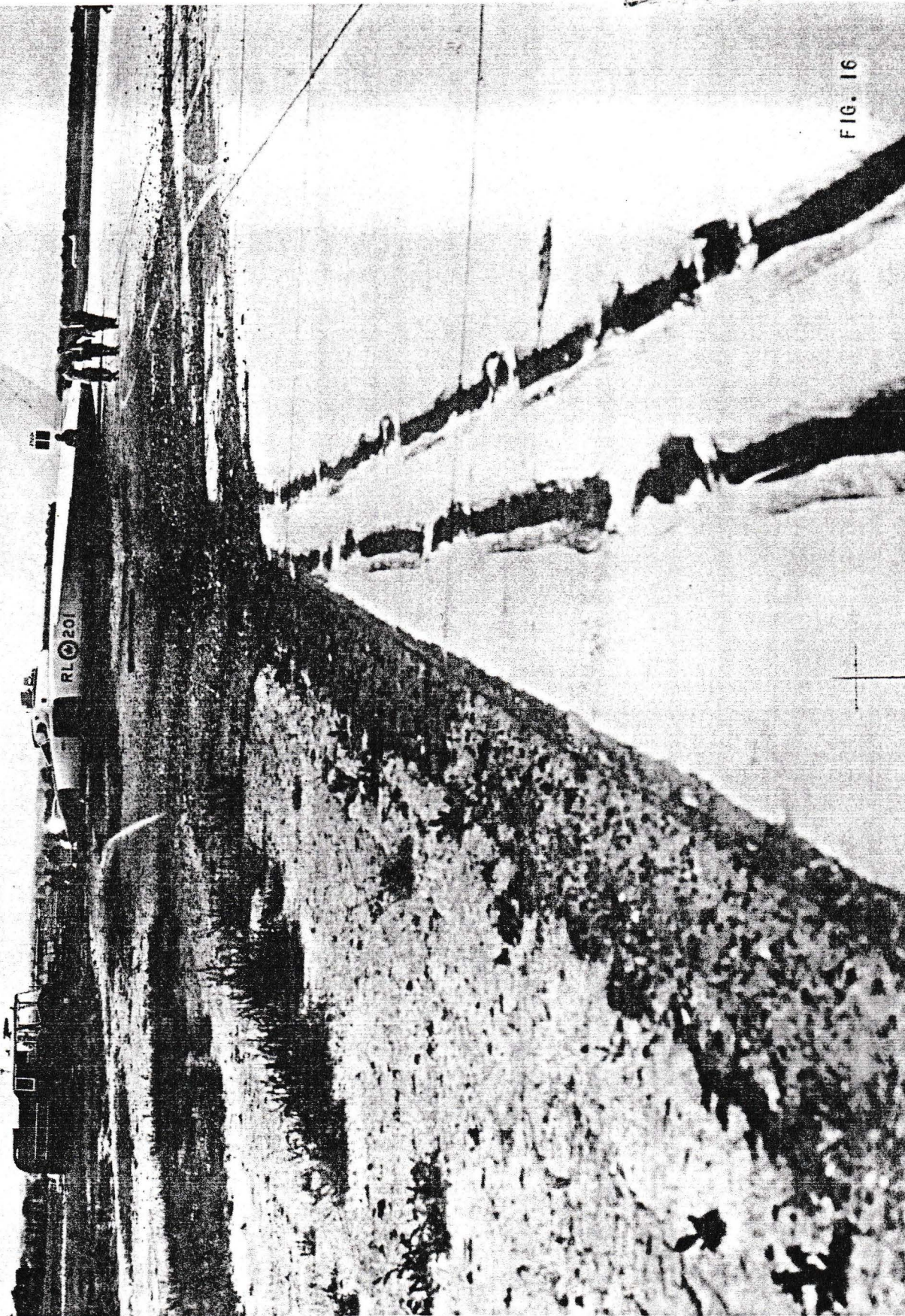
RESTRICTED



CONFIDENTIAL

RESTRICTED

FIG. 16



CONFIDENTIAL

RESTRICTED

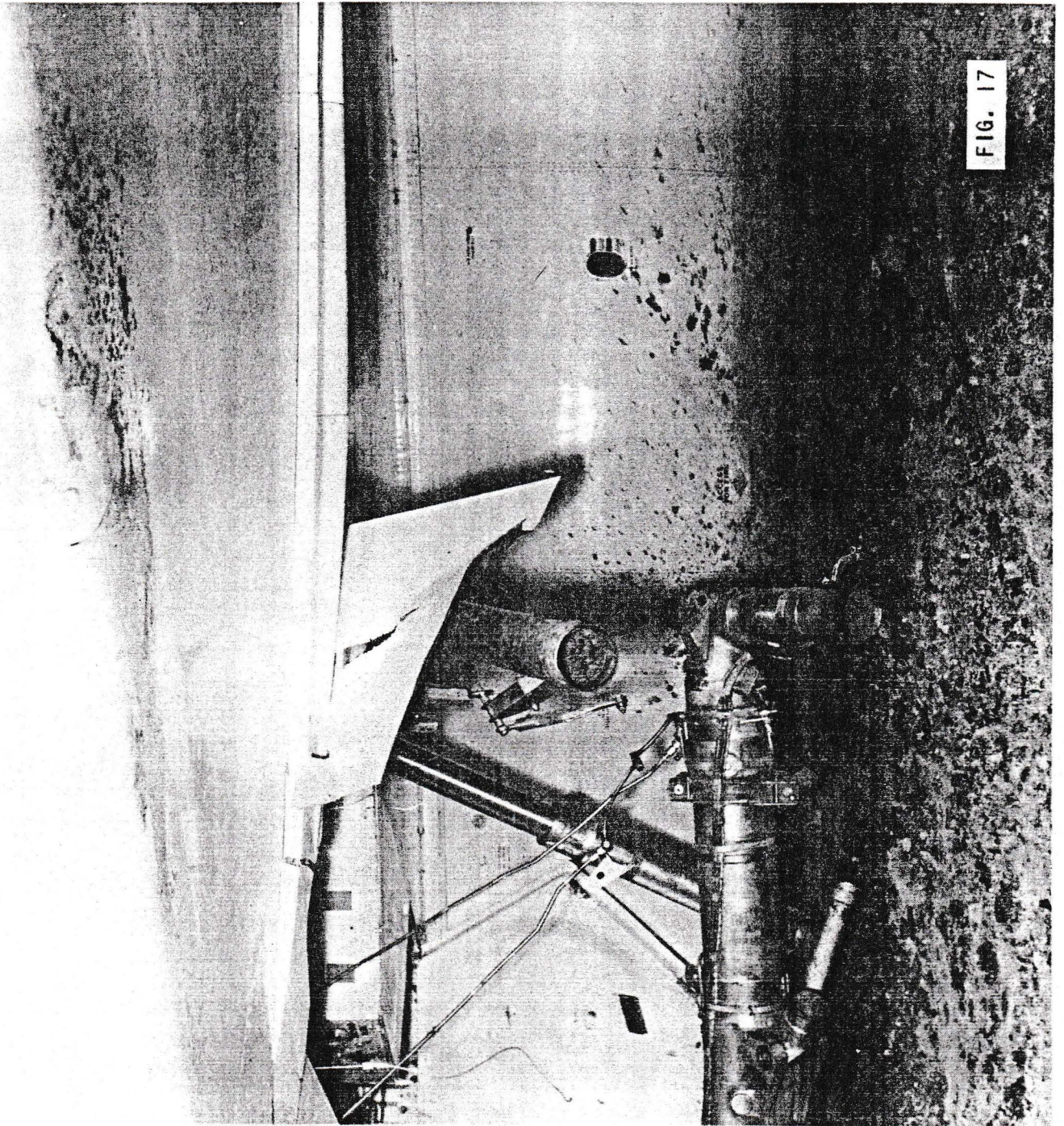
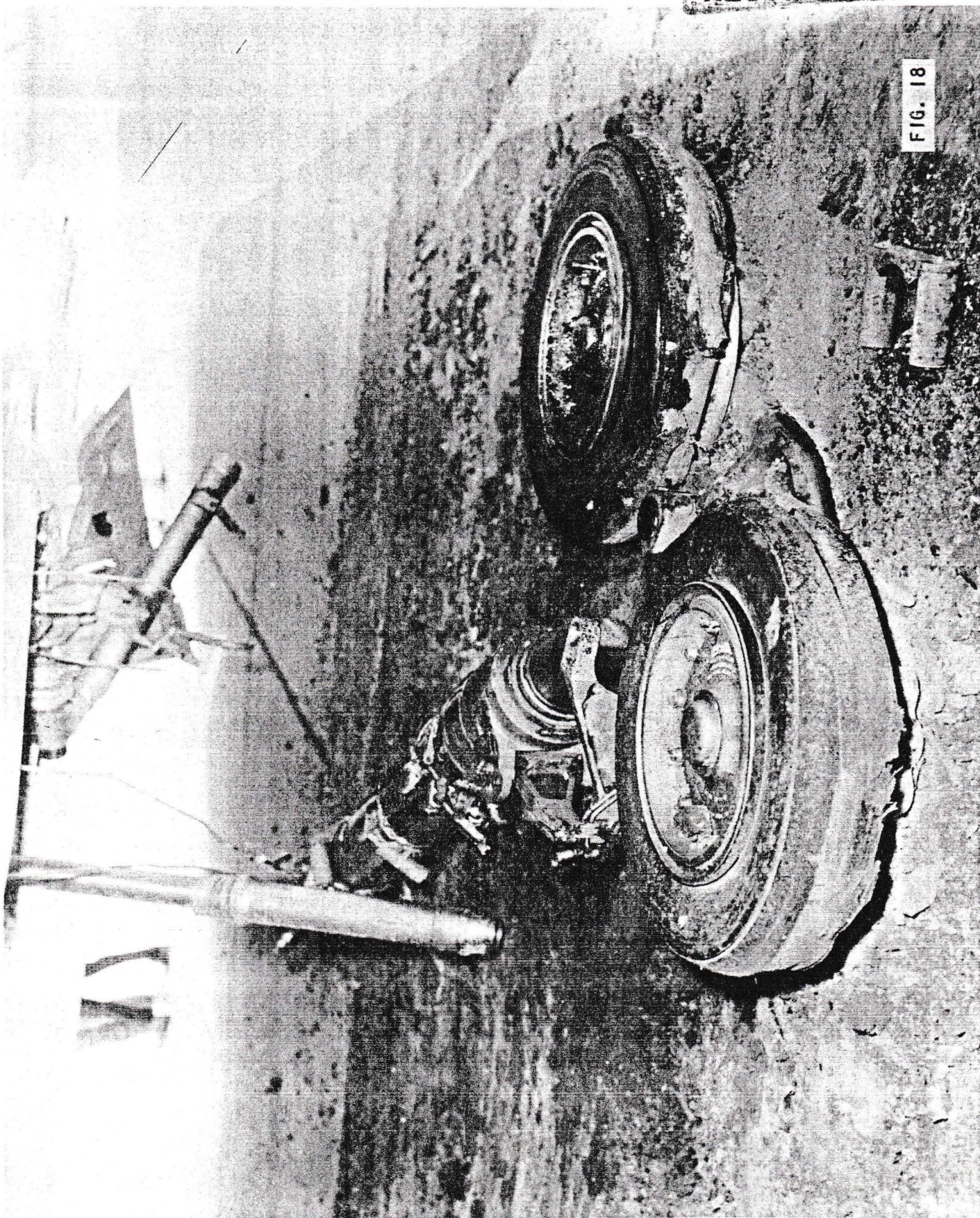


FIG. 17

CONFIDENTIAL

RESTRICTED

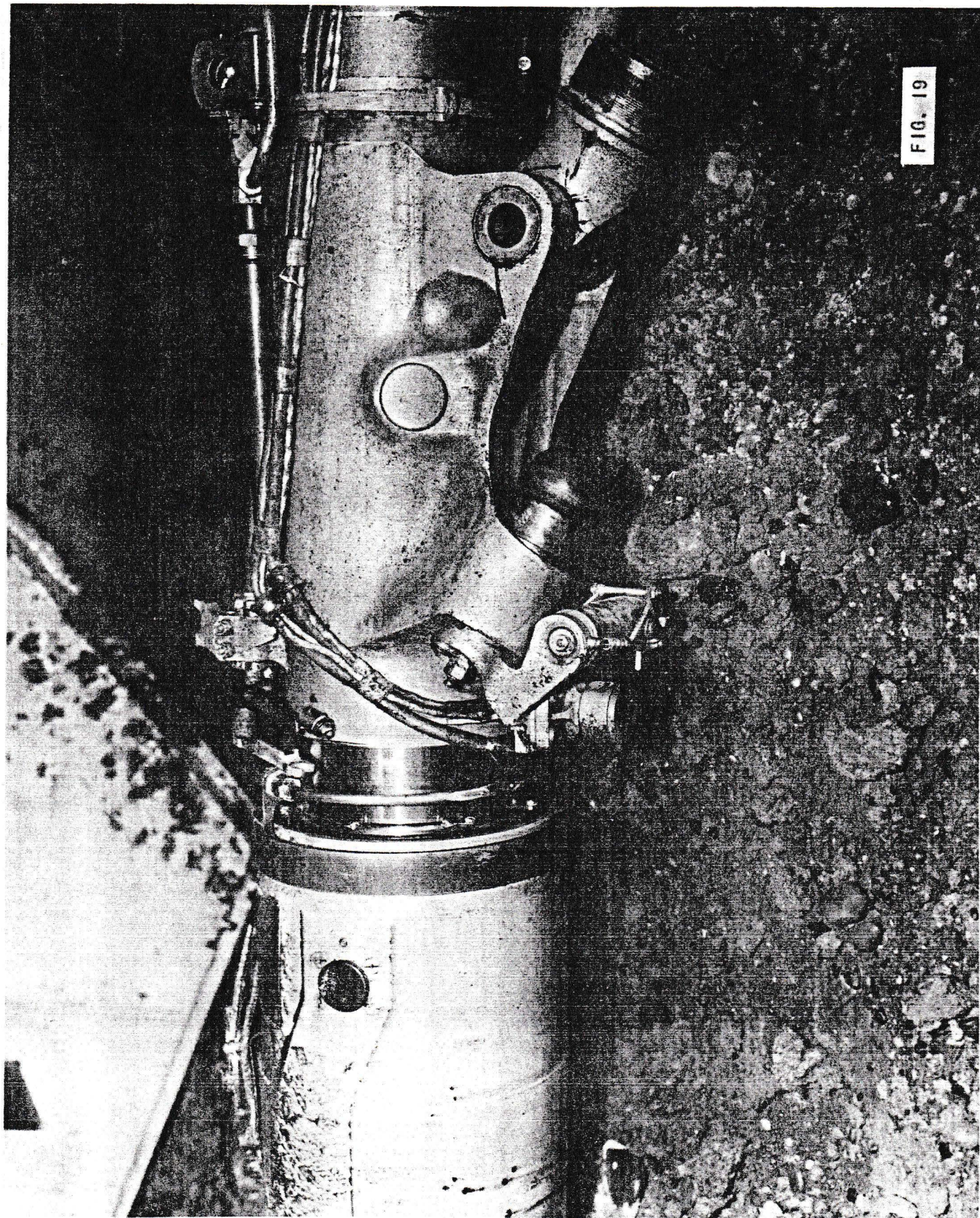
FIG. 18



CONFIDENTIAL

RESTRICTED

FIG. 19



RESTRICTED

~~TAPE RECORDING COMPLING AND SPINNS AFTER~~
~~ASSY TO EXCLUDE DIRT~~

Pivot Point
For Chain
Sprocket.

DUST
COVER

THIS SECTION TAKEN THRO
ROLLINS FOR CLARITY

HEATING IS NECESSARY
IN ALL ROOMS. THE TEM-
PERATURE OF THIS PART MUST NOT
BE 800° F.

ITEMS NO 552 AND 578 MUST BE ASSIGNED TO MAN
ATTING BEFORE ITEM NO 575 (L.A.) OF ITEM NO 125 (R.A.)
CASE 5 TO BE TRIM THE FACE STAMPED 'OUTSIDE' ON ITEM
NO 578 IS POSITIONED AWAY FROM ITEM NO 552 ON ARMY.

MICRO
SWITCH
MOUNTING
PAD

THE PROJECTION OF THE TWO HOLES MARKED
THUS MUST BE WITHIN .005 OF THE
C. OF THESE LUGS

VIEW A DIRECTION OF
ARROW A

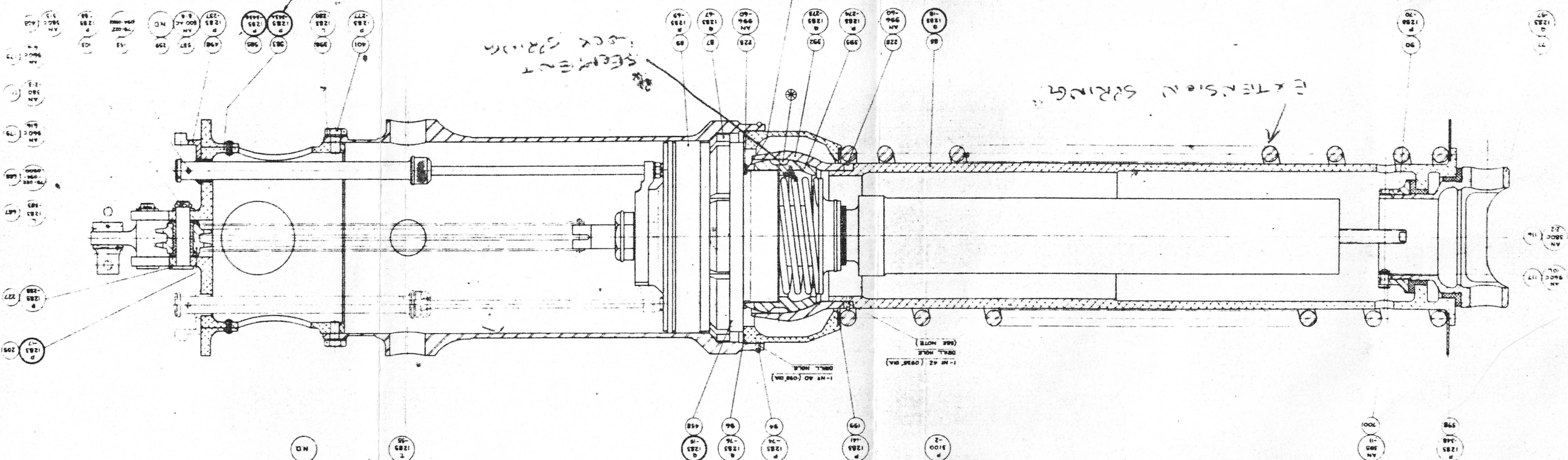
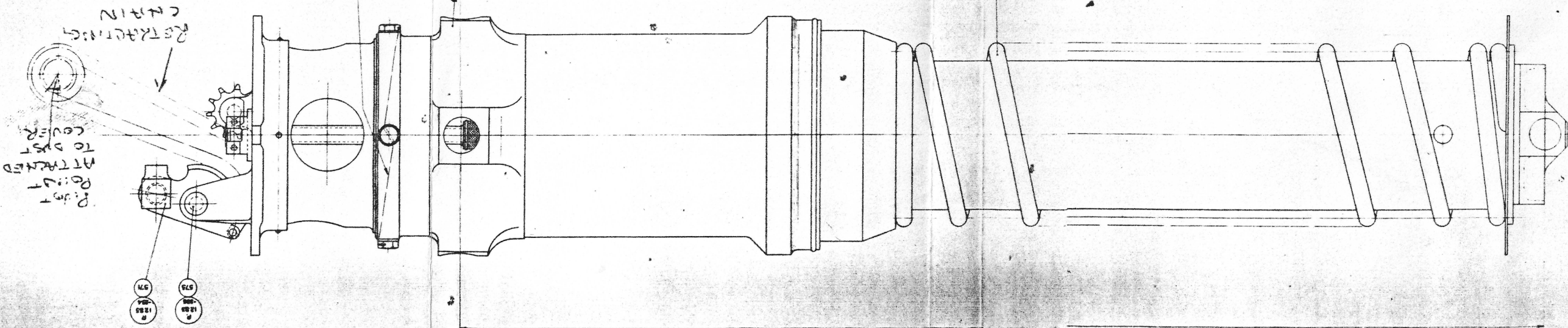
LEFT HAND AS DRAWN

FIG. 23

[illegible][illegible]

THIS EQUIPMENT IS THE PROPERTY OF
DOWTY EQUIPMENT OF CANADA LTD.
ALBA, ONTARIO.
NAME _____
MAIL FIFTING _____
DATE _____
DRIVE No. V _____

UNCLASSIFIED



SECTIONED VIEW SHOWS GEAR EXTENSION
IN LOCKED DOWN POSITION

IT IS REQUESTED THAT SUBMITTER
BEARING BE CHECKED AND NOTED
BEFORE DOWLING LOCKING HOLE

1 IN 48 (0.95 DIA.) DRILL
HOLE

THIS INSPECTION IS LIMITED ONLY TO THE
THE FOLLOWING DETAILS -
BOTH BEING PRESENT IN ONE OF THE 2 HOLES
IN CAP #1233-145 1/2
ADJUSTMENT ONLY AND #1233-146 BEING
FOR DIFFERENT HOLES OF ADJUSTMENT ONLY #1233-147
THIS WAS BEARING USED ON CAP MICRO-MOTION DETAILS
AND CHAIN ADJUSTMENT DETAILS ABOVE IN THE CORRECT
POSITION IN RELATION TO THE MAIN FITTING

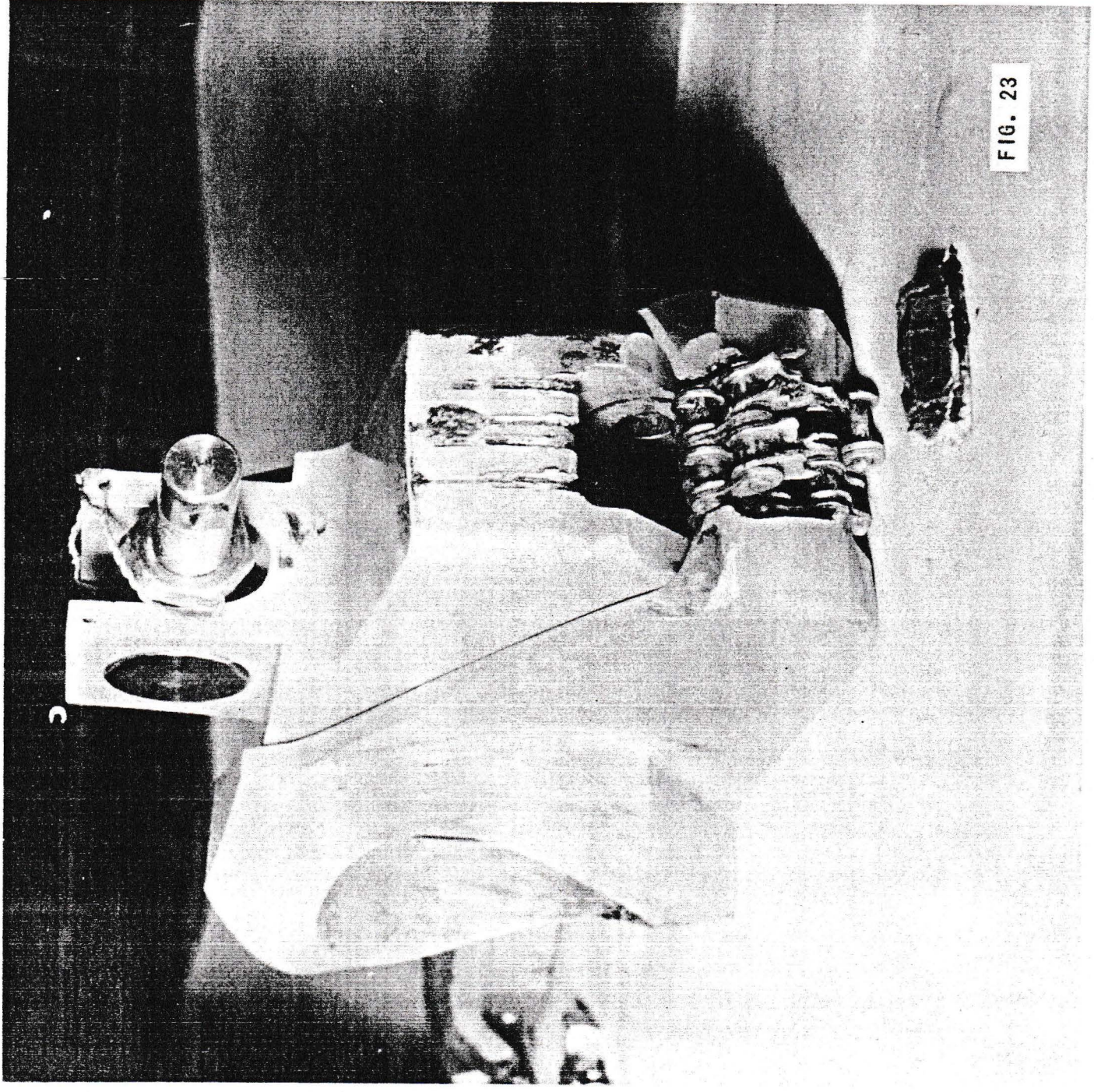
V1233-144 LEFT HAND AS SHOWN
RIGHT HAND AS SHOWN NOTED

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	1240	1241	1242	1243	1244	1245	1246	1247	1248	1249	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260	1261	1262	1263	1264	1265	1266	1267	1268	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	1281	1282	1283	1284	1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295	1296	1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	1332	1333	1334	1335	1336	1337	1338	1339	1340	1341	1342	1343	1344	1345	1346	1347	1348	1349	1350	1351	1352	1353	1354	1355	1356	1357	1358	1359	1360	1361	1362	1363	1364	1365	1366	1367	1368	1369	1370	1371	1372	1373	1374	1375	1376	1377	1378	1379	1380	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	1403	1404	1405	1406	1407	1408	1409	1410	1411	1412	1413	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	1434	1435	1436	1437	1438	1439	1440	1441	1442	1443	1444	1445	1446	1447	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	1458	1459	1460	1461	1462	1463	1464	1465	1466	1467	1468	1469	1470	1471	1472	1473	1474	1475	1476	1477	1478	1479	1480	1481	1482	1483	1484	1485	1486	1487	1488	1489	1490	1491	1492	1493	1494	1495	1496	1497	1498	149
---	---	---	---	---	---	---	---	---	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	-----

~~CONFIDENTIAL~~
UNCLASSIFIED

~~CONFIDENTIAL~~
UNCLASSIFIED

FIG. 23



UNCLASSIFIED

UNCLASSIFIED

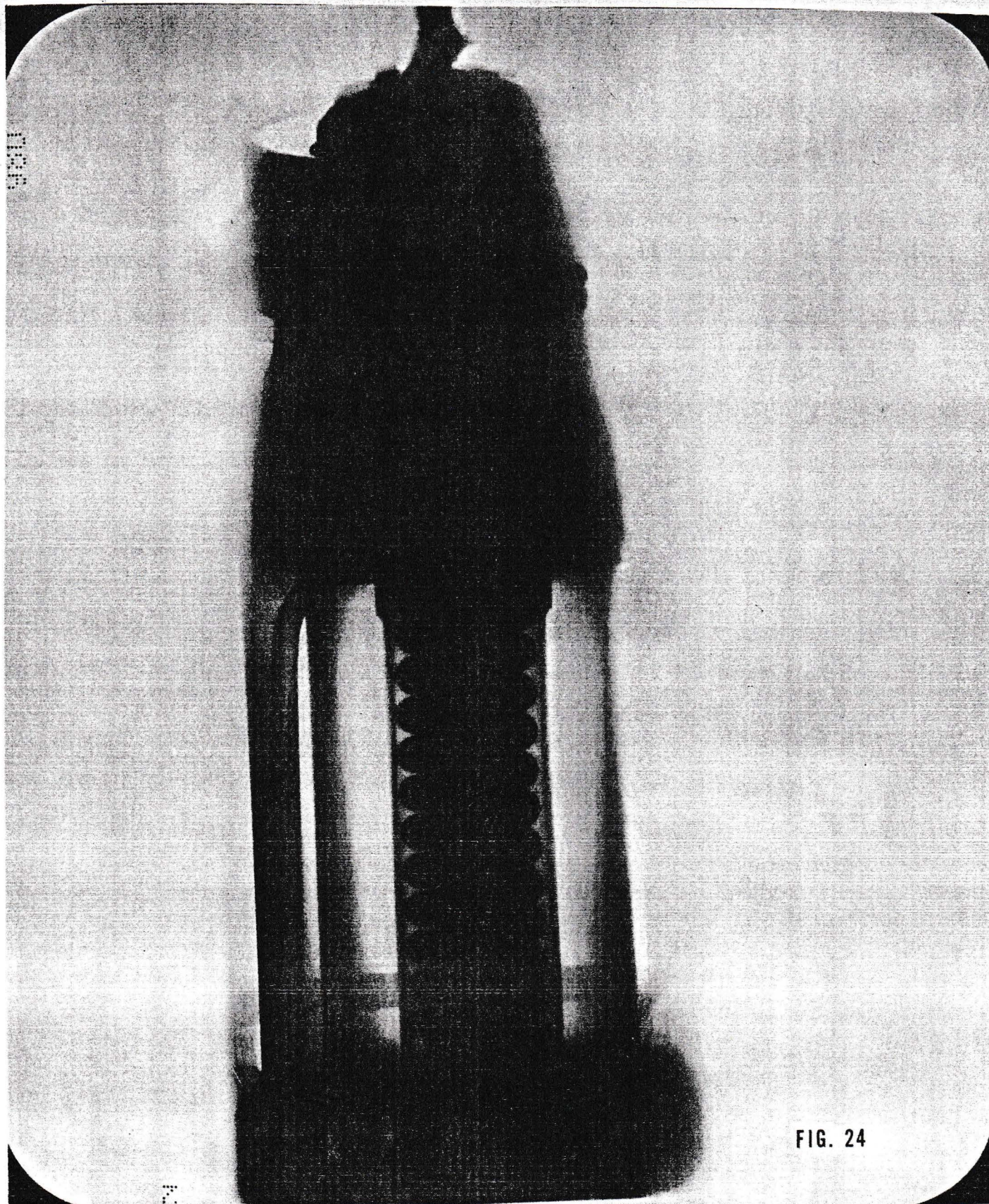


FIG. 24

~~CONFIDENTIAL~~
UNCLASSIFIED

~~CONFIDENTIAL~~
UNCLASSIFIED

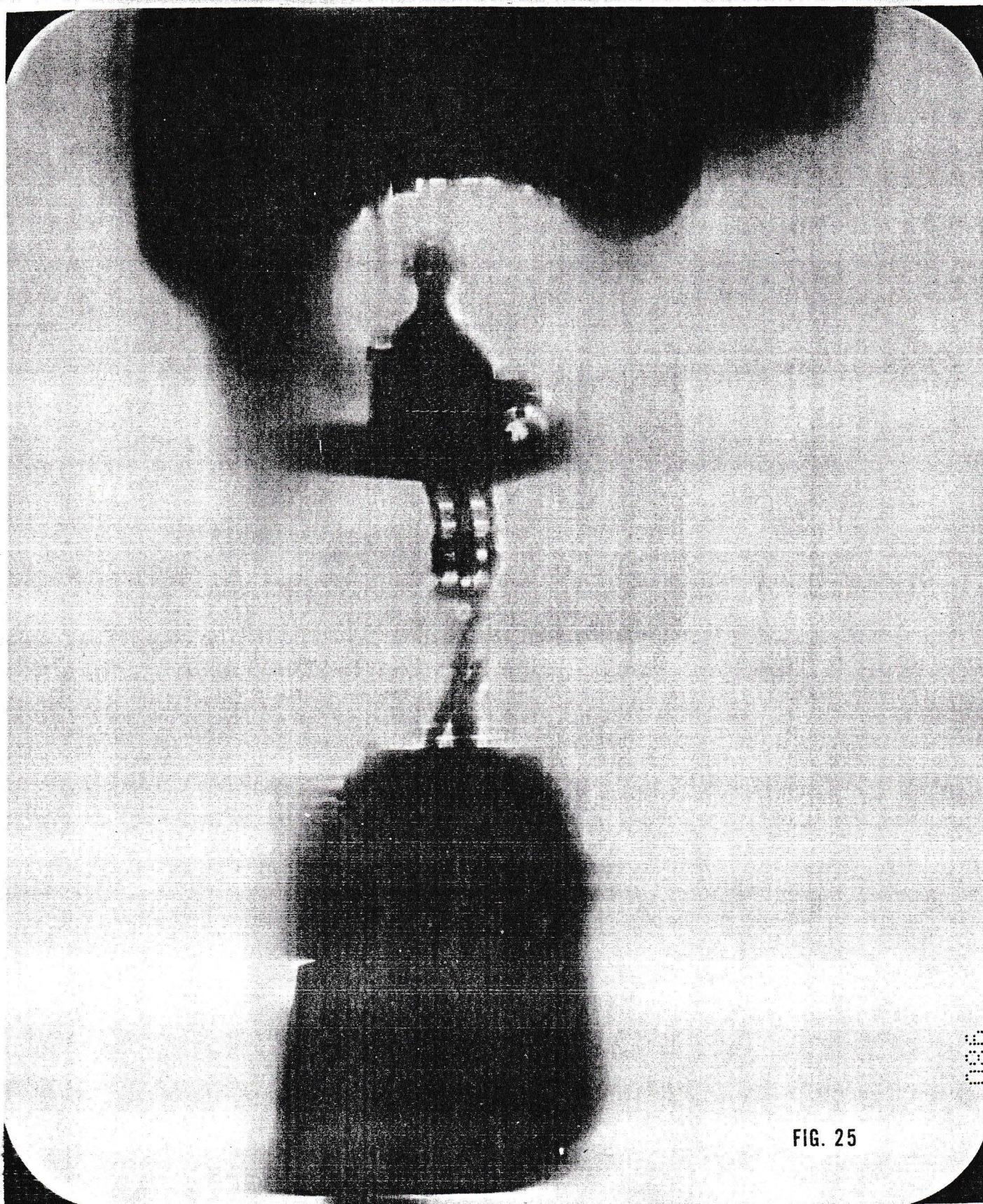


FIG. 25

~~CONFIDENTIAL~~
~~UNCLASSIFIED~~

~~UNCLASSIFIED~~

- 5 -

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

UNCLASSIFIED

- 6 -

UNCLASSIFIED

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 micro-switch and Figure 38 shows the left-hand tires.

UNCLASSIFIED

UNCLASSIFIED

- 7 -

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.

CONFIDENTIAL

8 -

RESTRICTED
UNCLASSIFIED

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.)

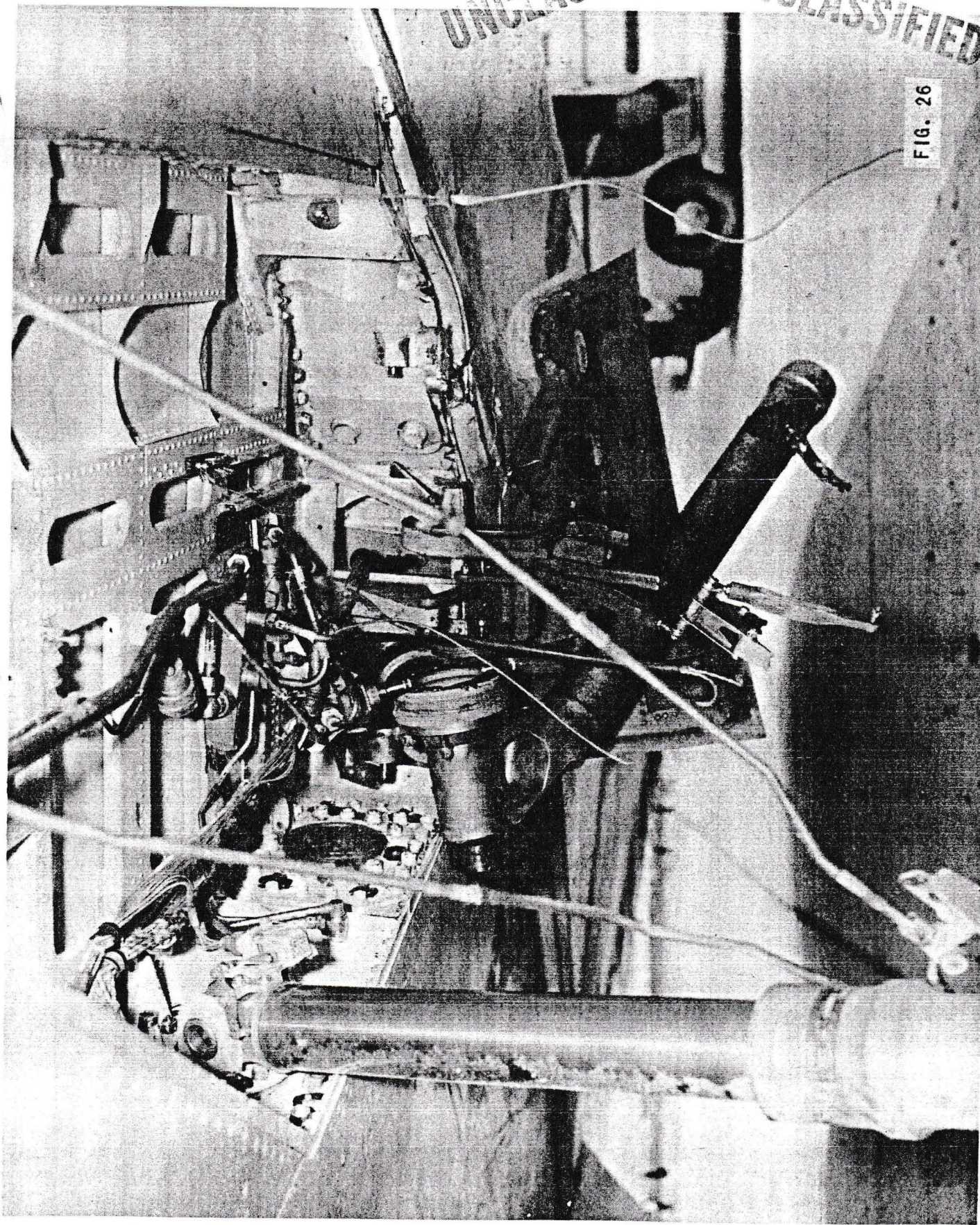
The bulb in the cockpit undercarriage selector handle was tested for continuity and found to be serviceable. The following checks were then conducted:

- 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.

UNCLASSIFIED

RESTRICTED
UNCLASSIFIED

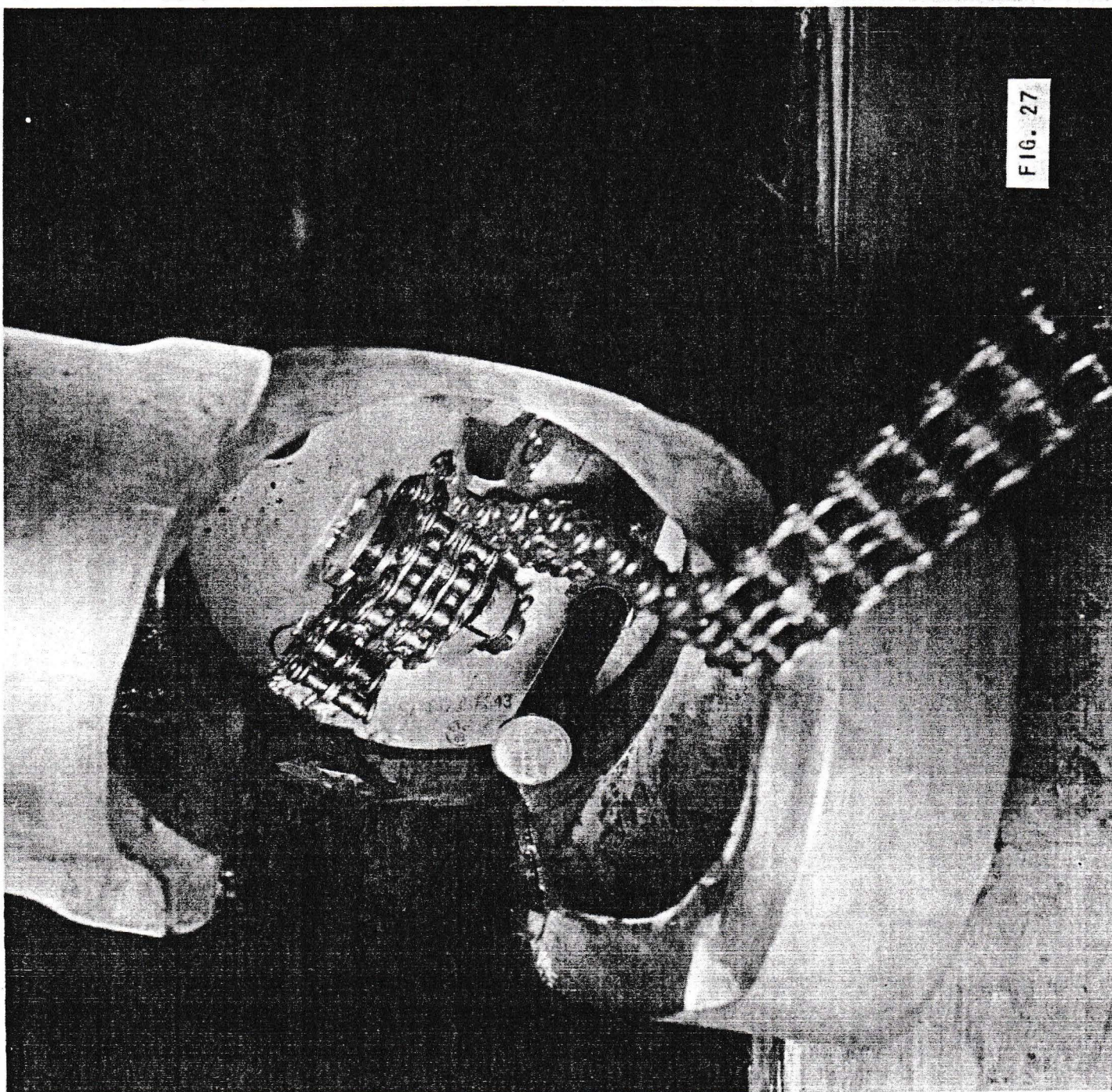
FIG. 26



~~CONFIDENTIAL~~
UNCLASSIFIED

~~CONFIDENTIAL~~
UNCLASSIFIED

FIG. 27



UNCLASSIFIED

CONFIDENTIAL

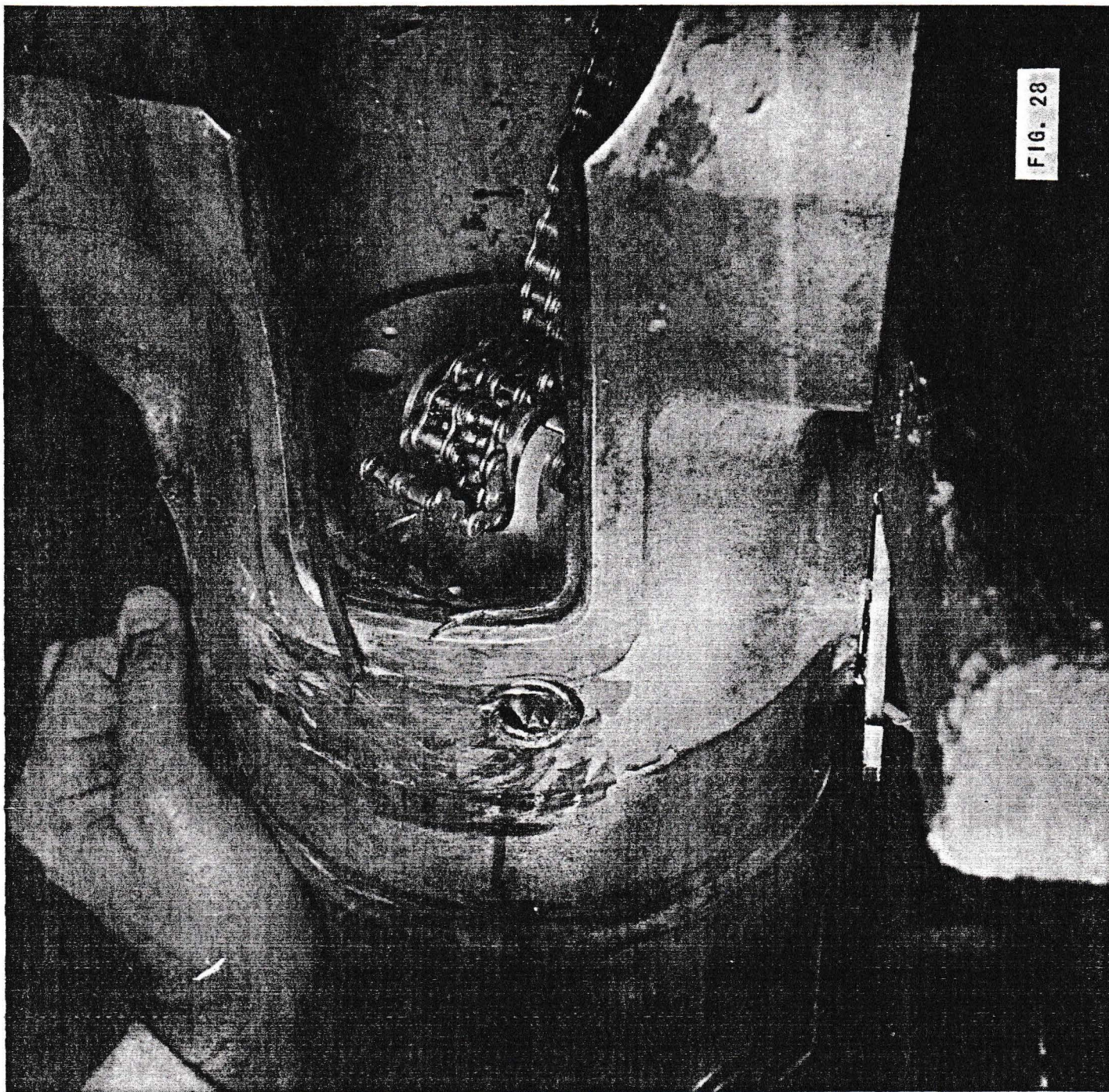
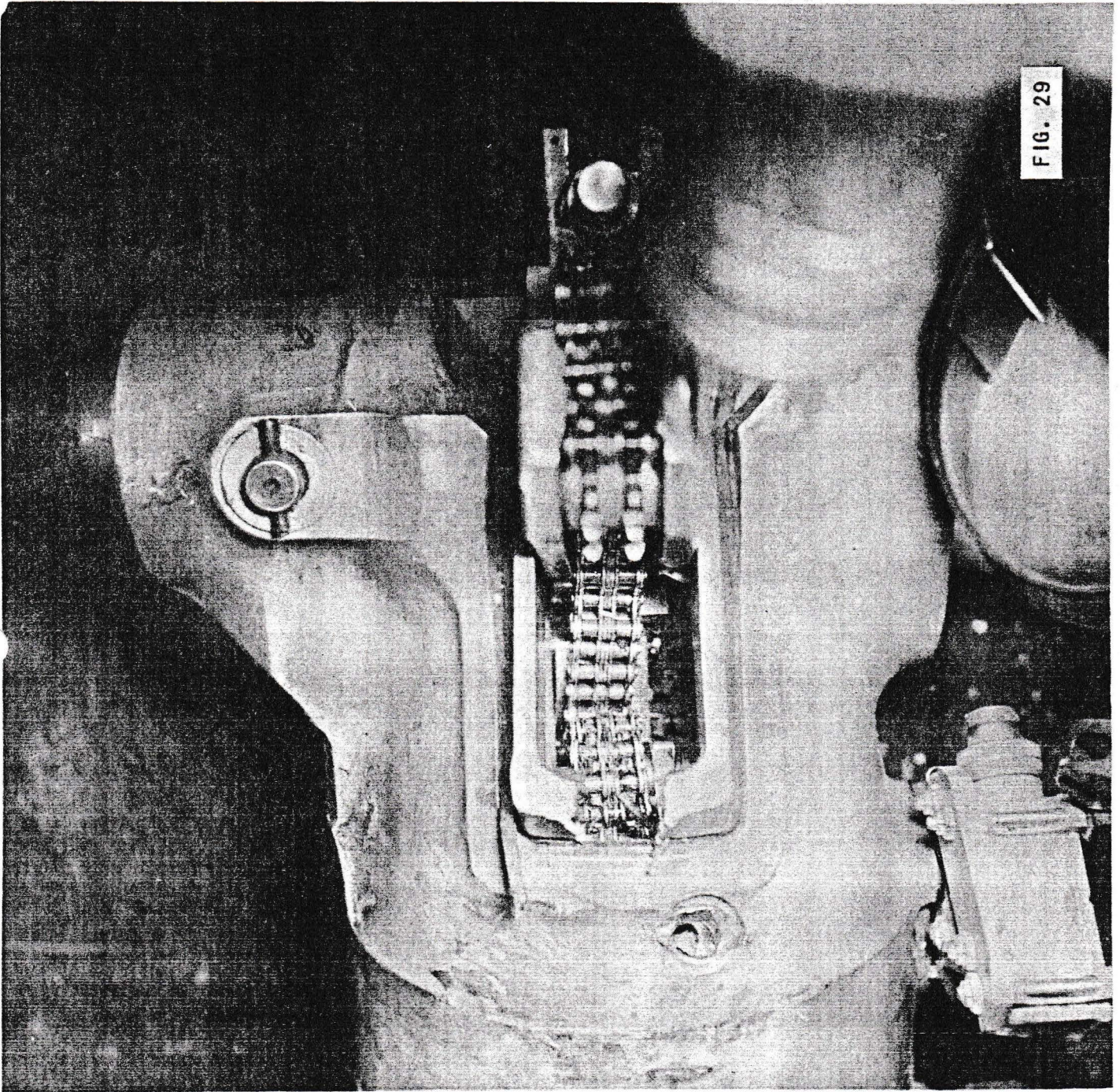


FIG. 28

CONFIDENTIAL

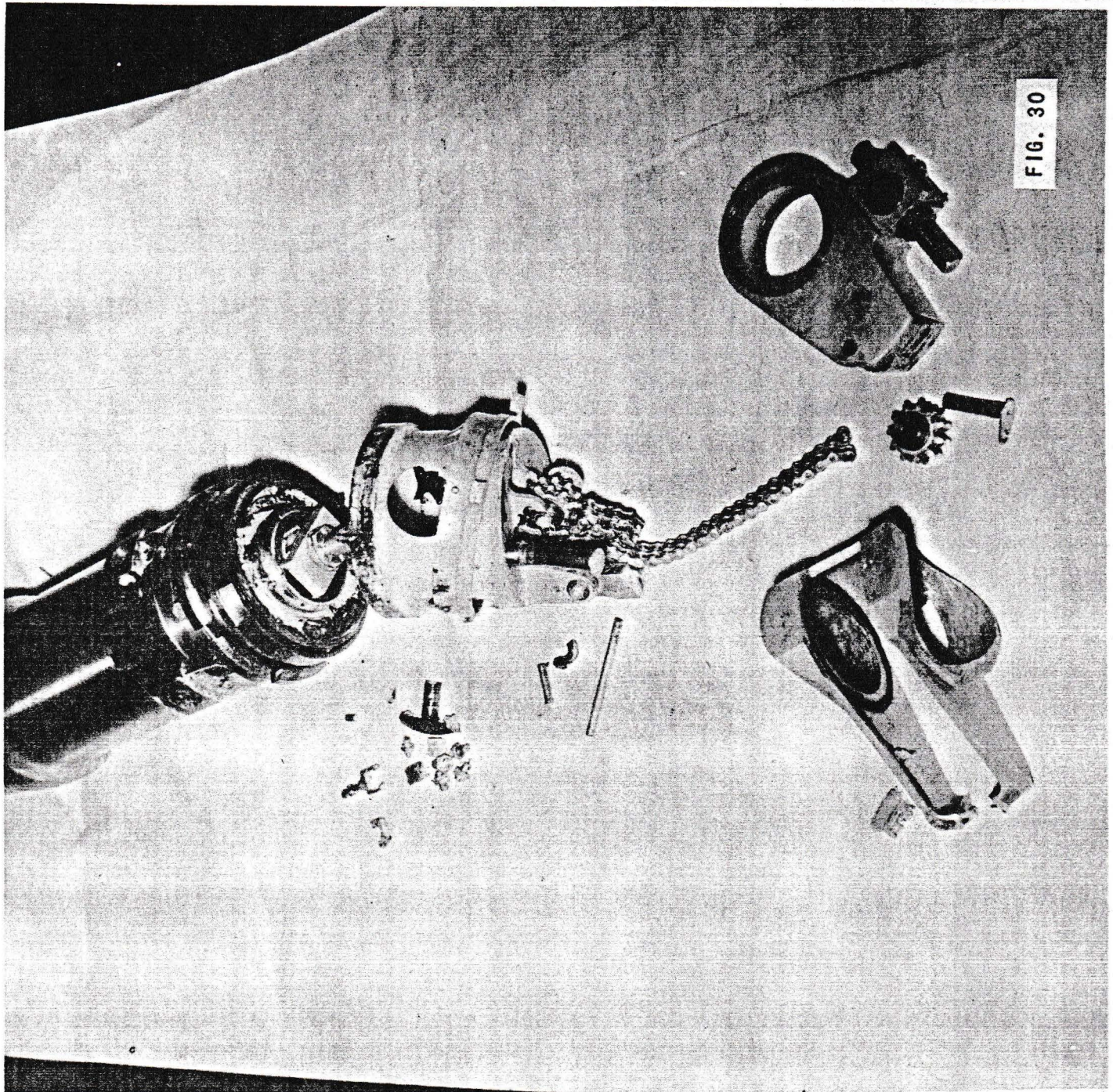
RESTRICTED

FIG. 29



~~CONFIDENTIAL~~
~~UNCLASSIFIED~~
~~UNCLASSIFIED~~

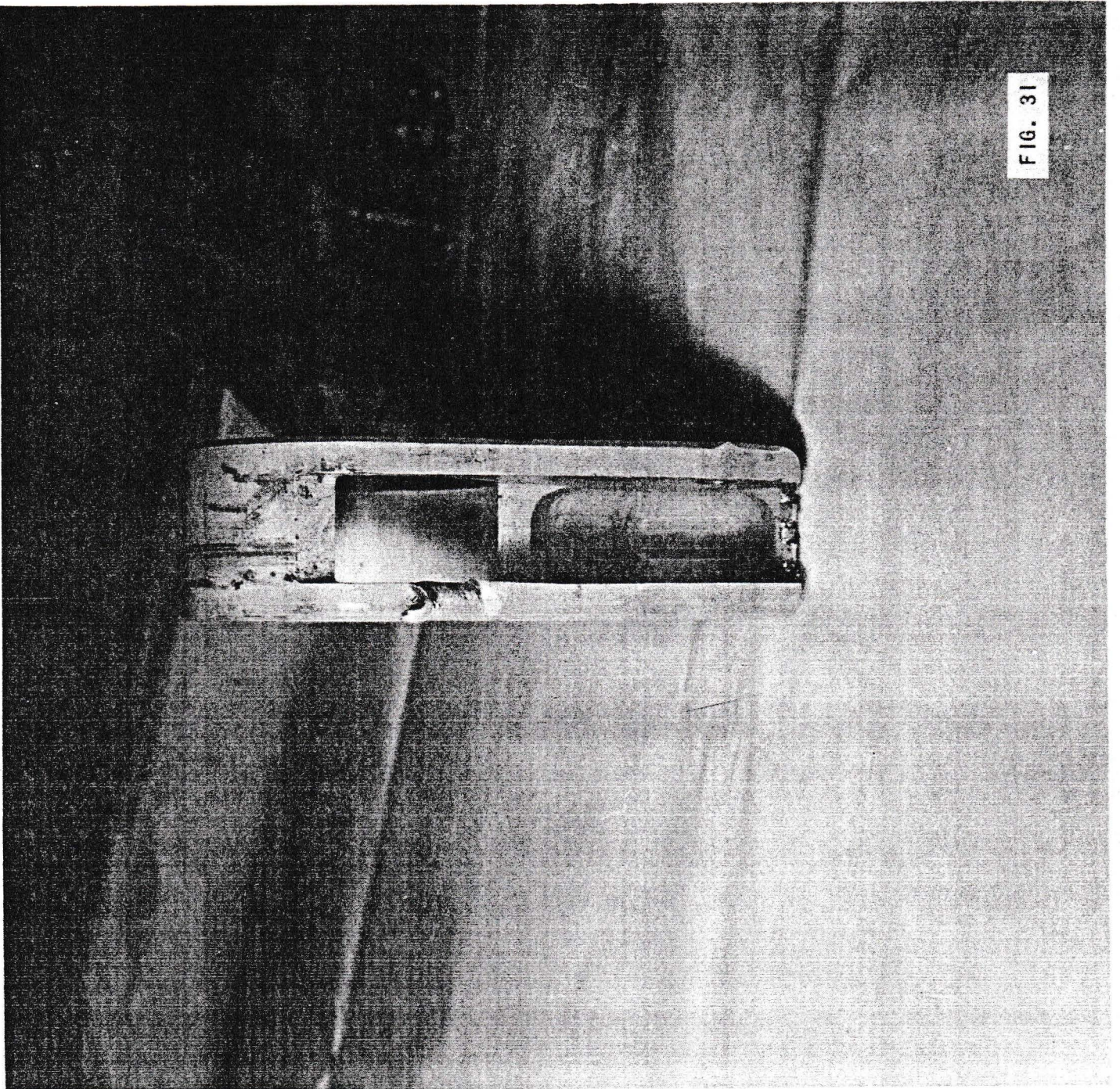
FIG. 30



CONFIDENTIAL

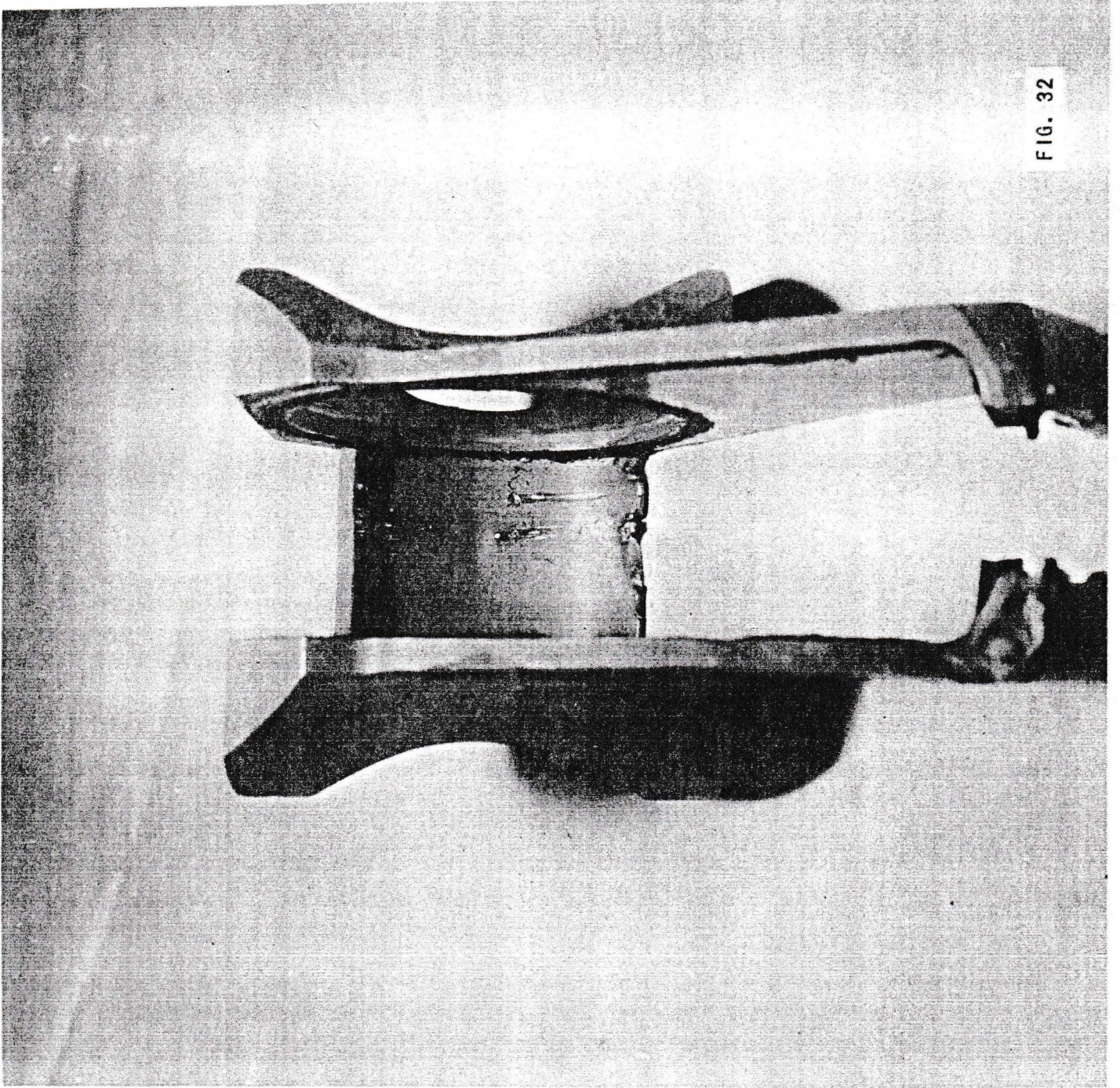
RESTRICTED

FIG. 31



UNCLASSIFIED
UNCLASSIFIED
UNCLASSIFIED

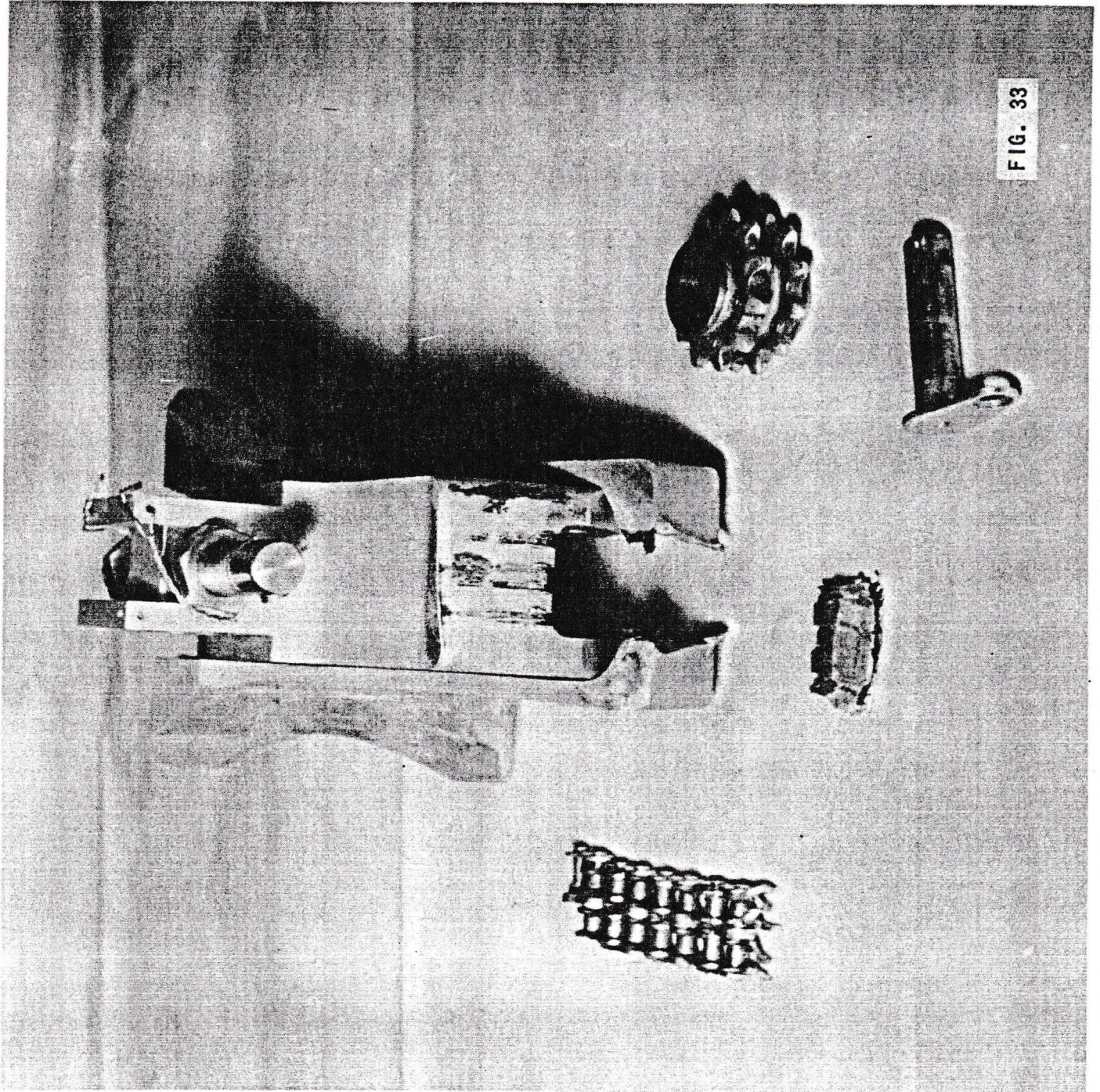
FIG. 32



CONFIDENTIAL

RESTRICTED

FIG. 33



~~CONFIDENTIAL~~
UNCLASSIFIED
~~CONFIDENTIAL~~
UNCLASSIFIED

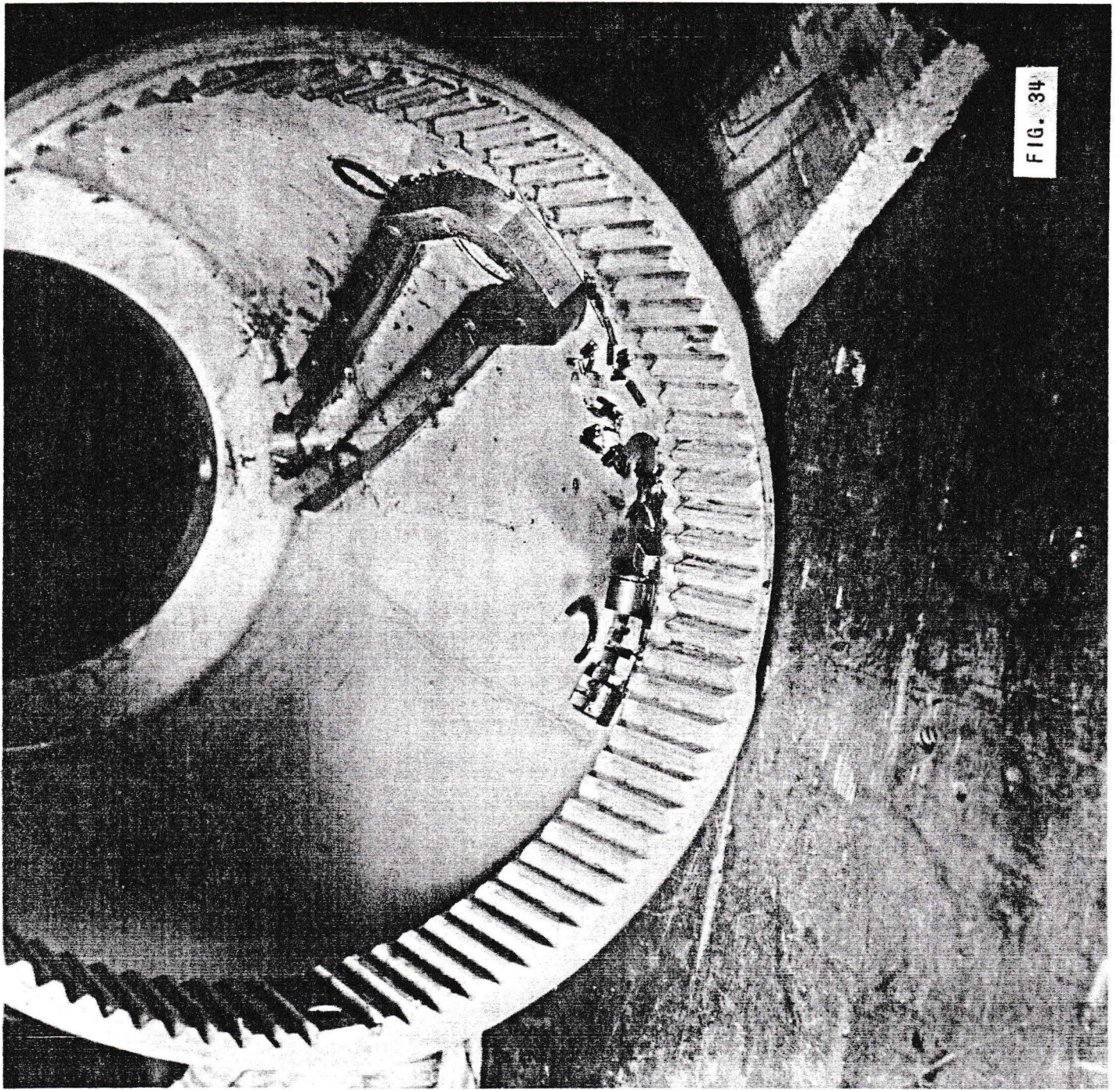
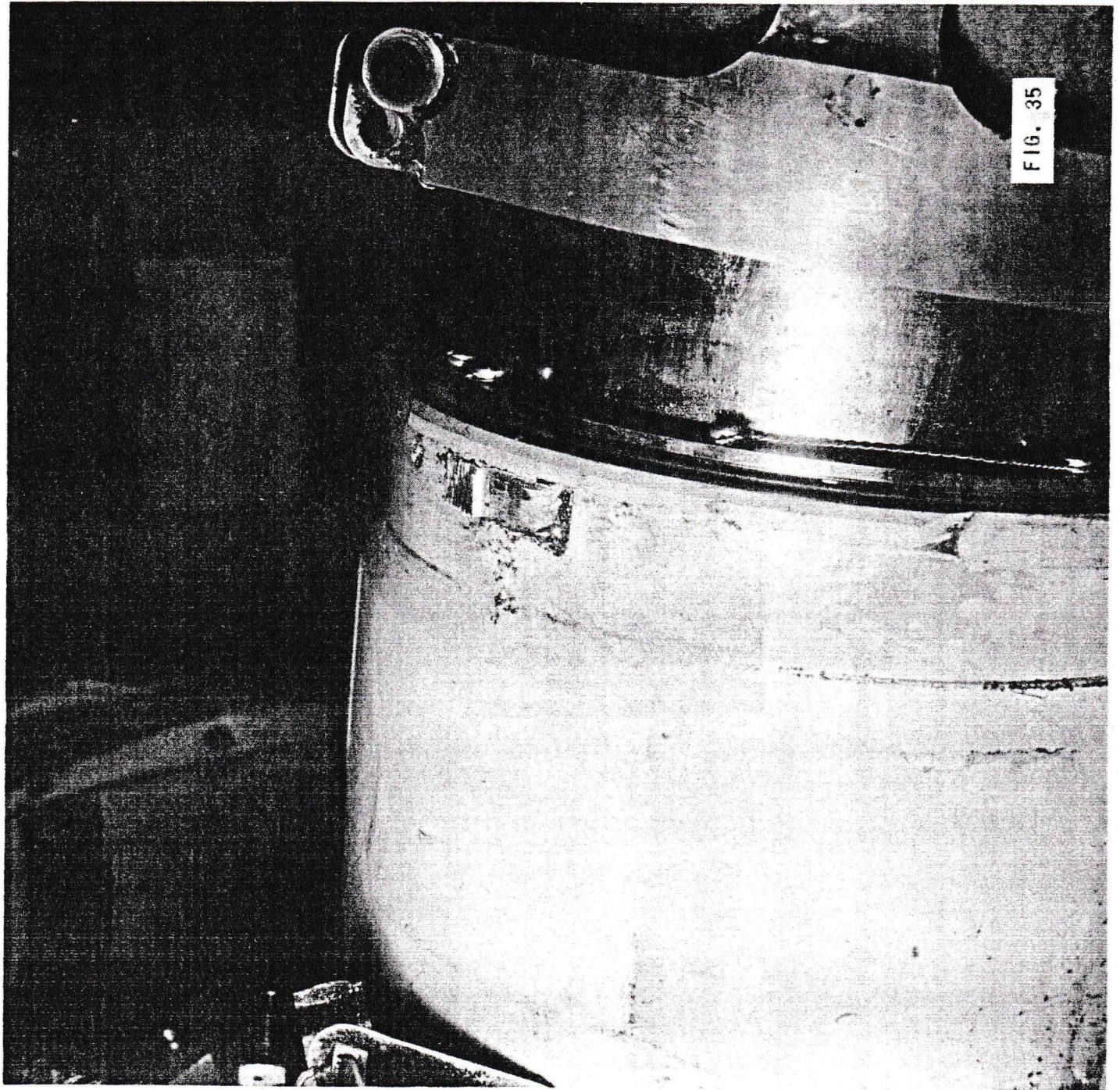


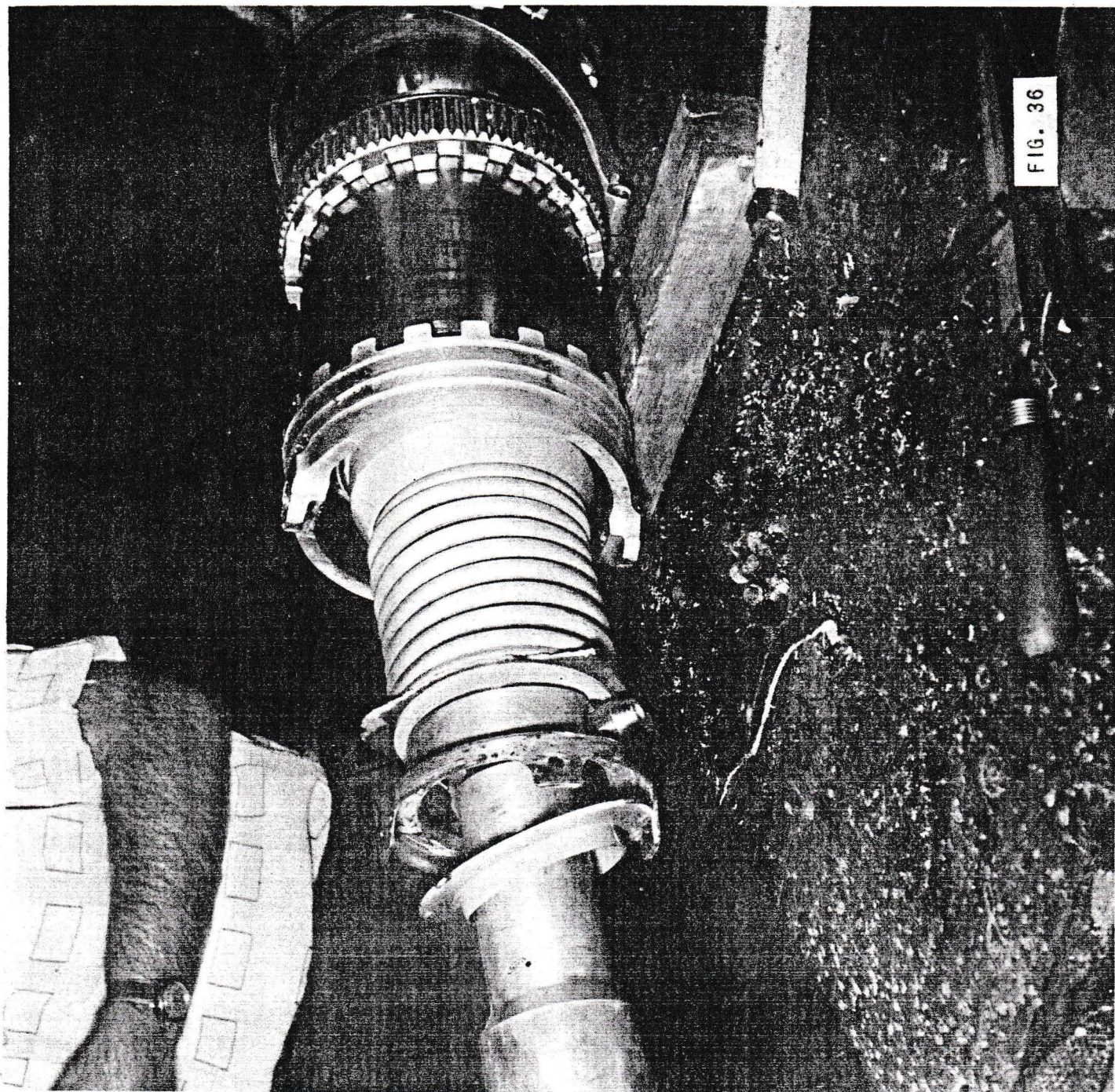
FIG. 34

~~CONFIDENTIAL~~
UNCLASSIFIED



UNCLASSIFIED

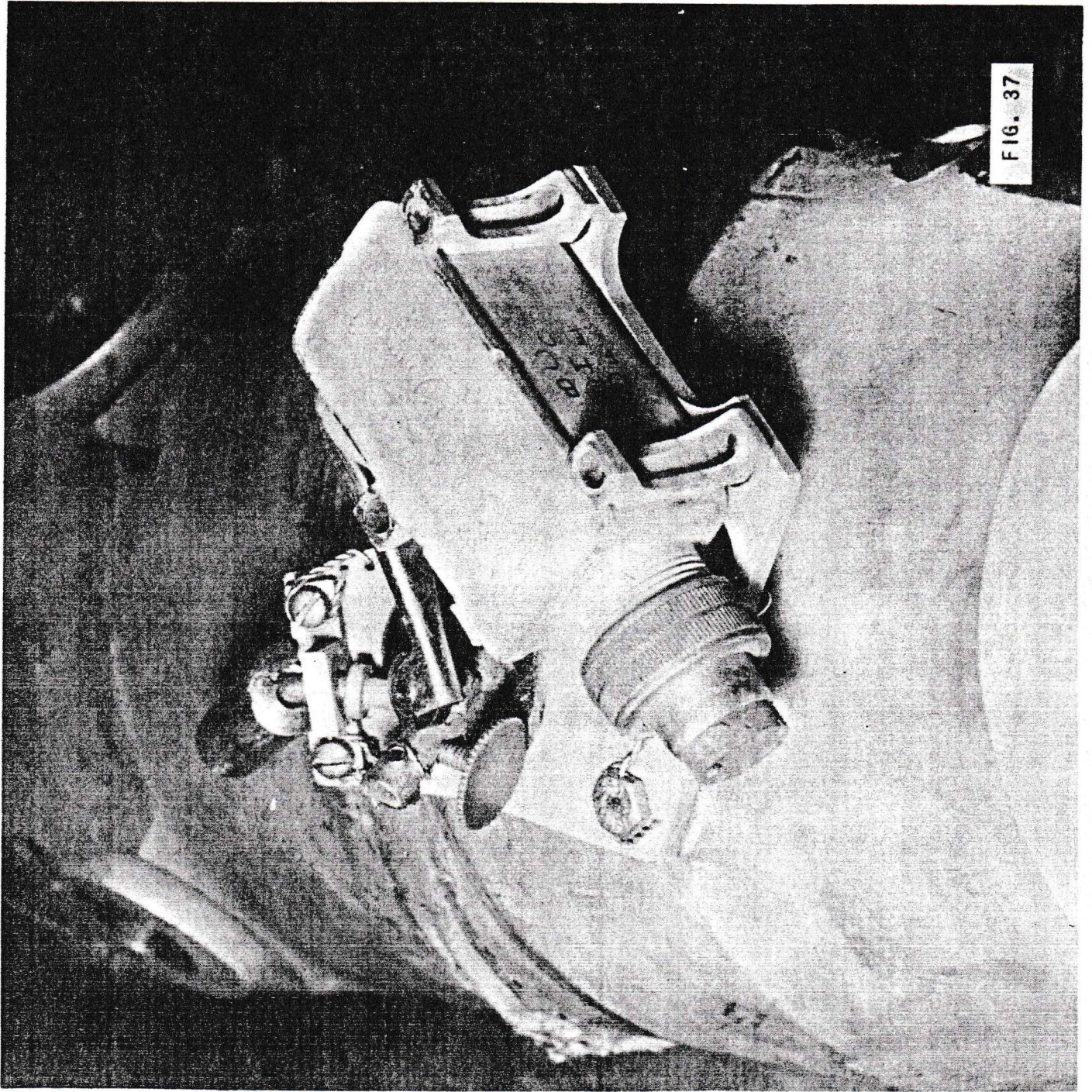
RESTRICTED



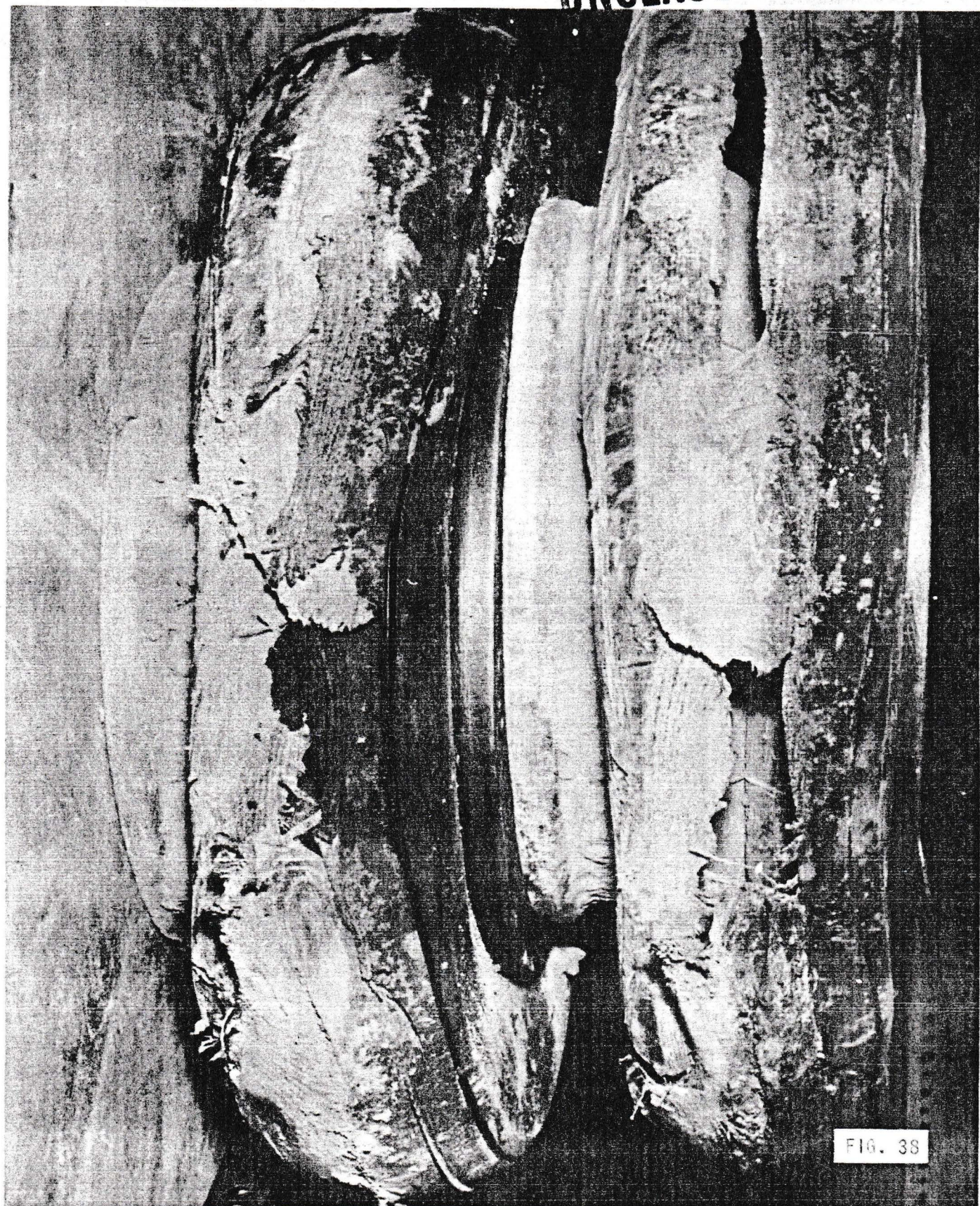
CONFIDENTIAL

RESTRICTED

FIG. 37



~~CONFIDENTIAL~~ ~~RESTRICTED~~
UNCLASSIFIED



~~CONFIDENTIAL~~

~~RESTRICTED~~

- 9 -

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 gear 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.

~~CONFIDENTIAL~~

- 10 -

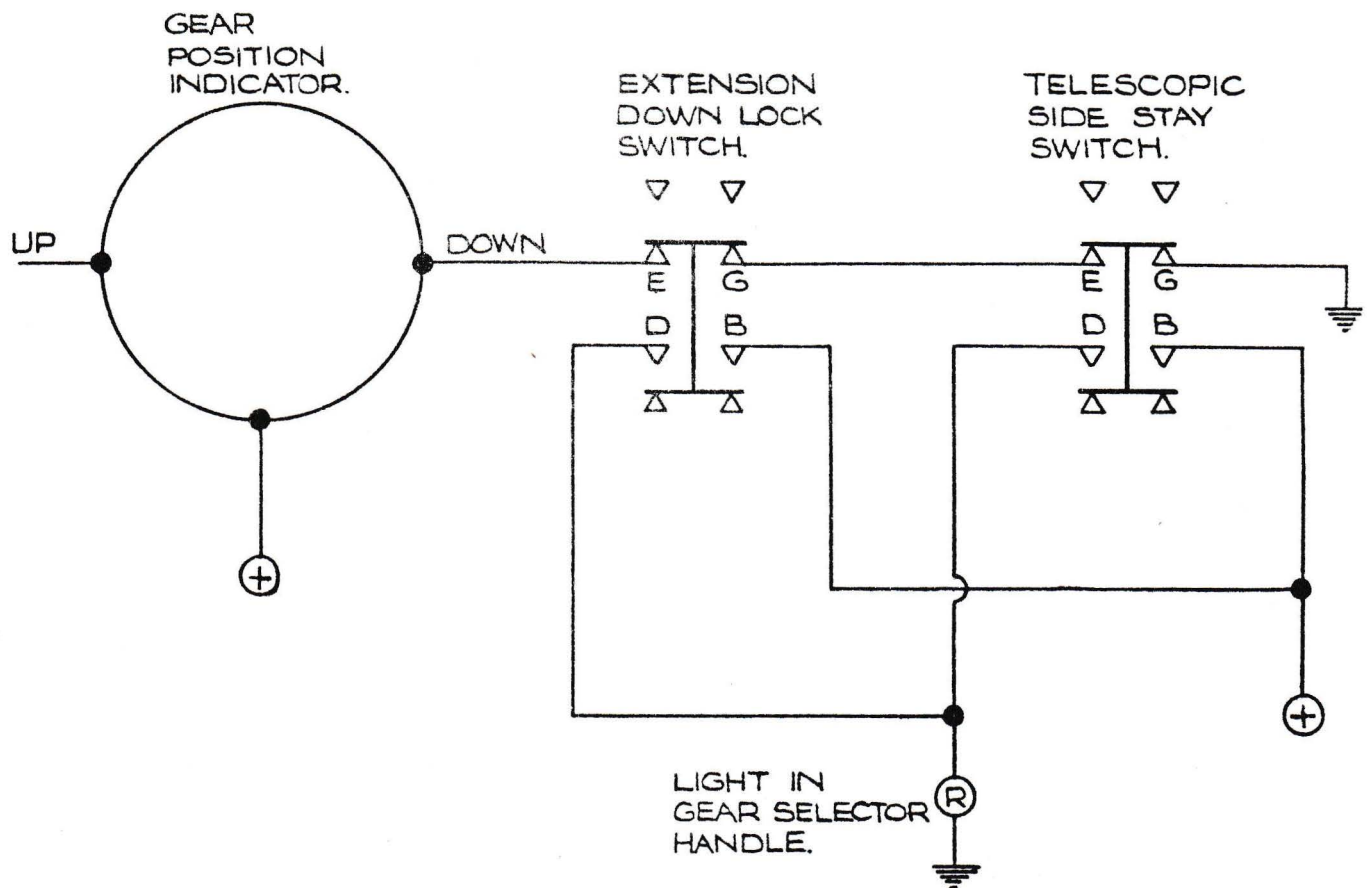
~~CONFIDENTIAL~~
UNCLASSIFIED

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.

~~UNCLASSIFIED~~
~~CONFIDENTIAL~~

~~RESTRICTED~~
~~UNCLASSIFIED~~



SCHEMATIC OF MAIN LANDING GEAR ELECTRICAL SYSTEM-COCKPIT INDICATOR.

FIG. 39

UNCLASSIFIED

11

UNCLASSIFIED

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 the barrel 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 value 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.

UNCLASSIFIED

RESTRICTED

- 12 -

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 flight 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).

~~CONFIDENTIAL~~
UNCLASSIFIED

~~RESTRICTED~~

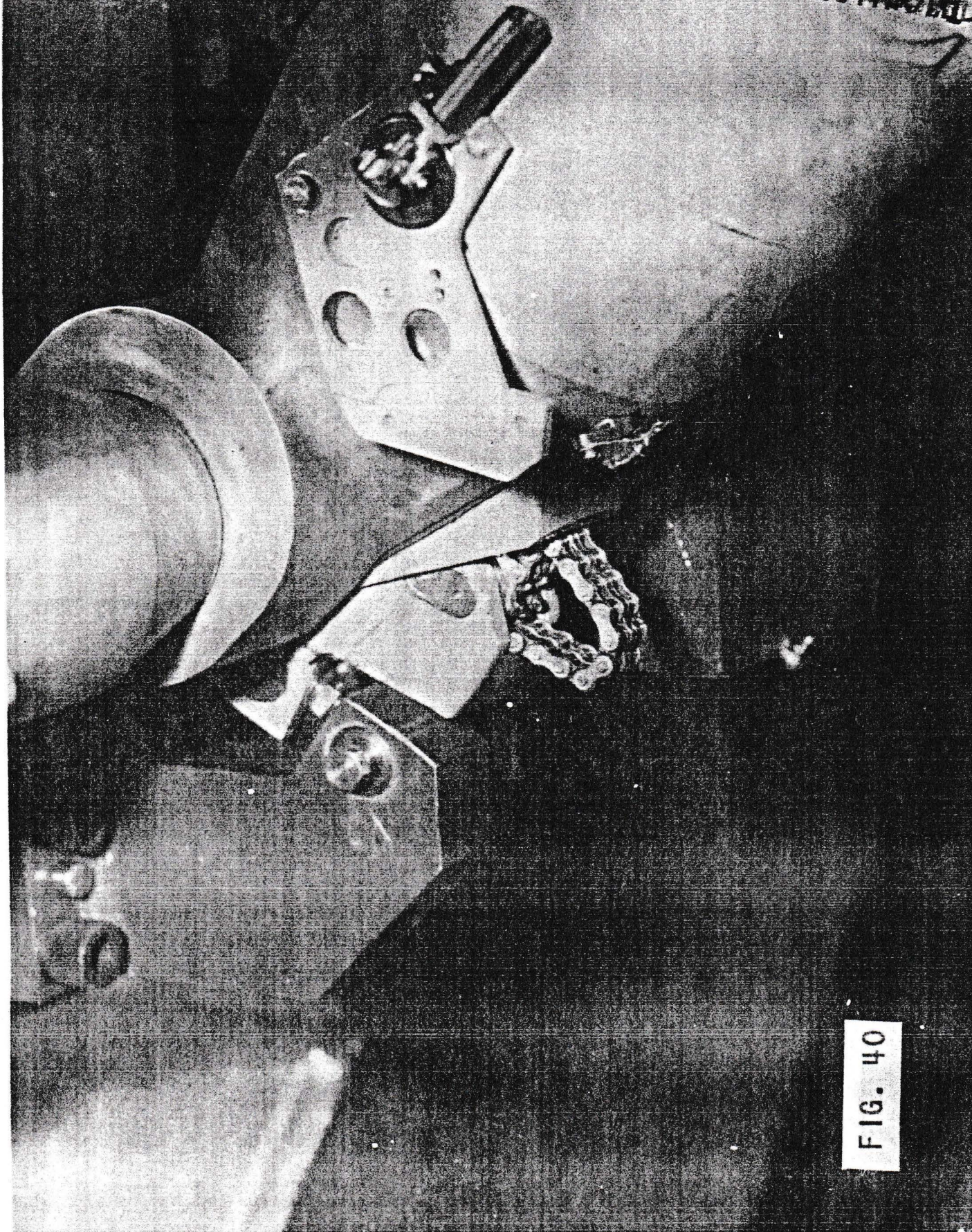


FIG. 40

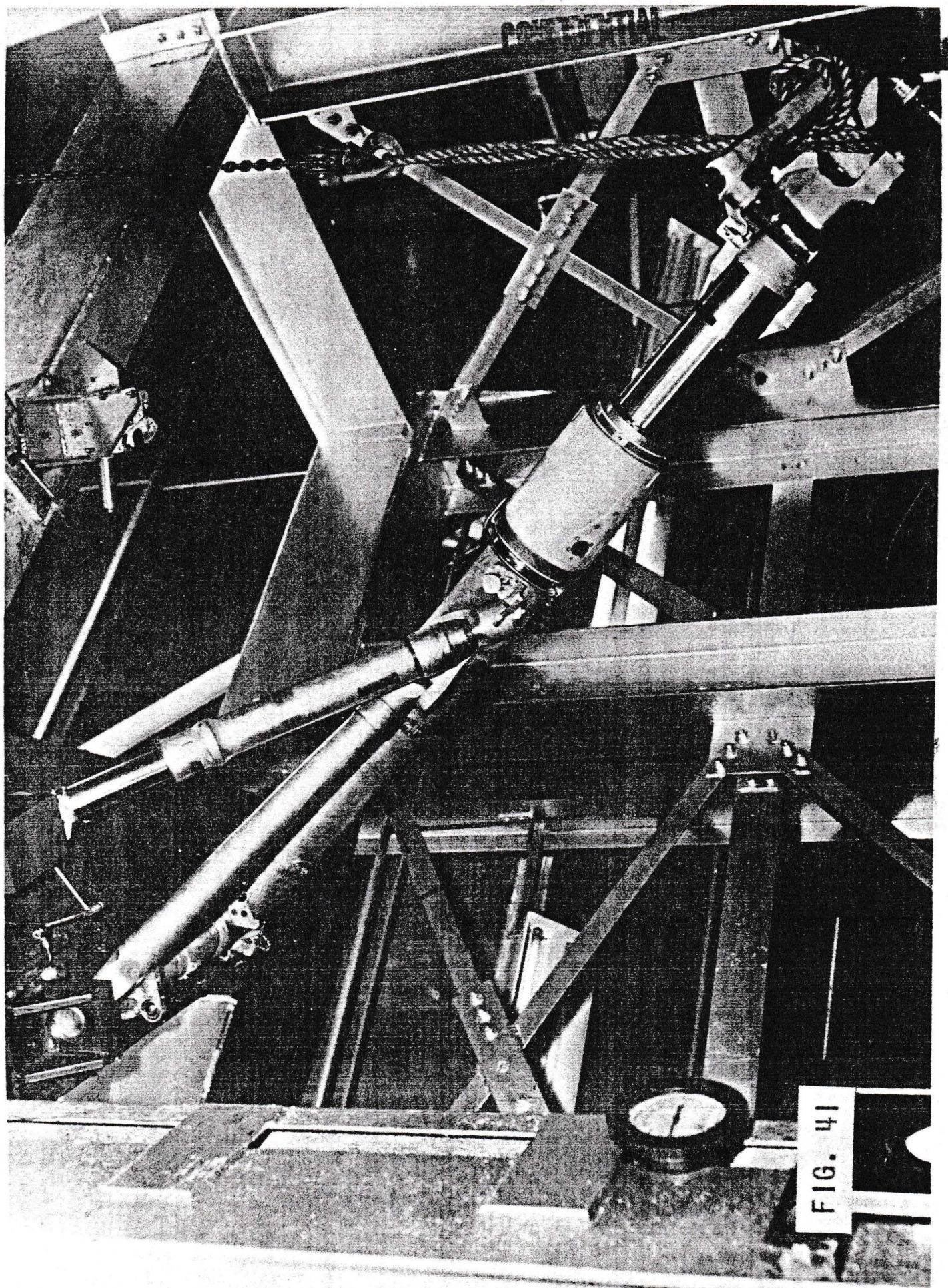


FIG. 41

CONFIDENTIAL

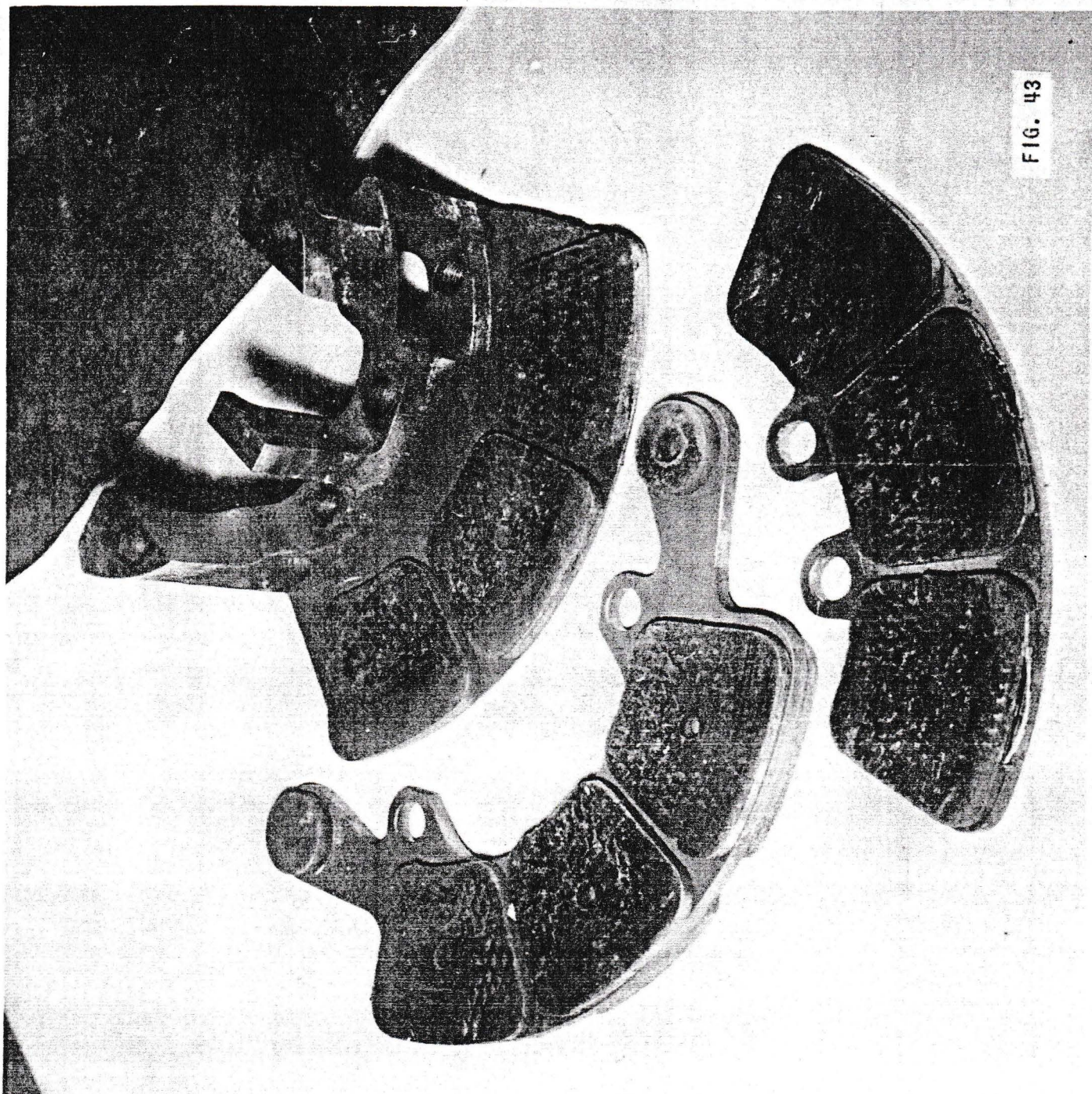
CONFIDENTIAL



FIG. 42

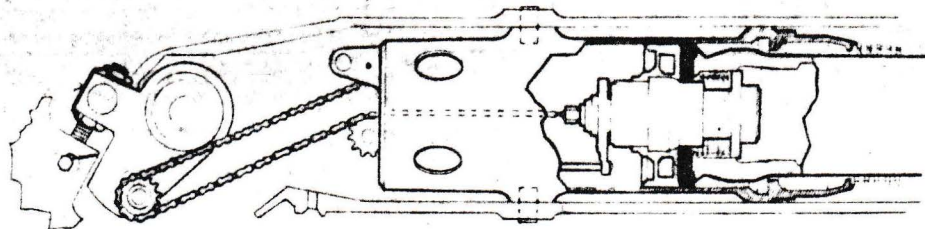
~~CONFIDENTIAL~~
~~UNCLASSIFIED~~

FIG. 43

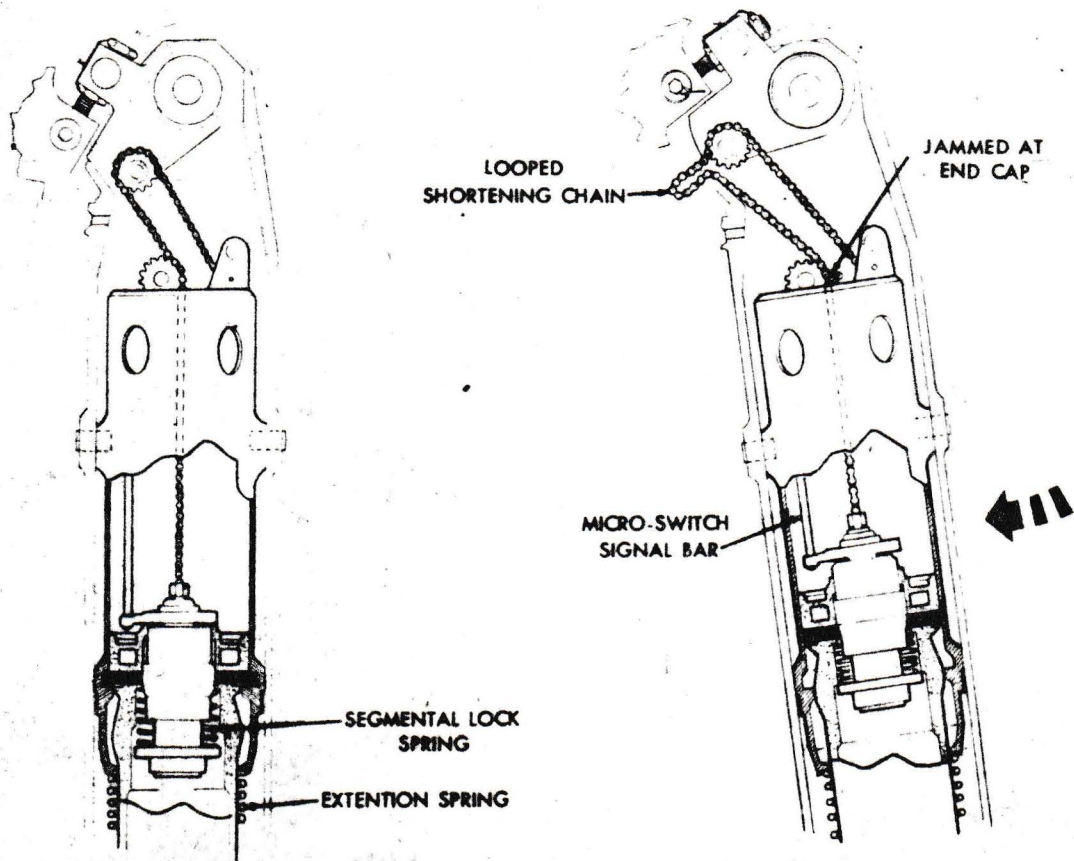


UNCLASSIFIED

UNCLASSIFIED



NORMAL RETRACTED POSITION



NORMAL EXTENDED POSITION

ABNORMAL EXTENDED POSITION

FIG. 44 DETAIL OF LEG SHORTENING MECHANISM