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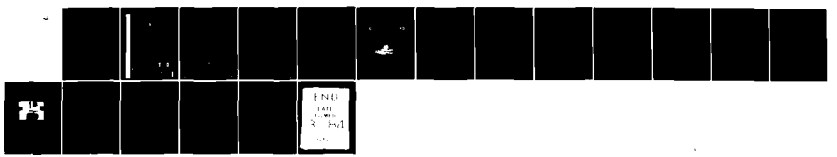

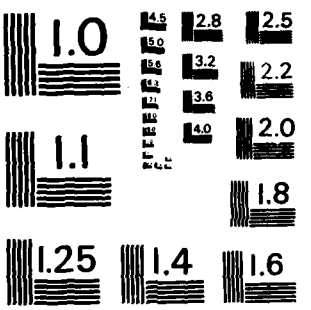

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Structures Technical Memorandum 365

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RETRACTION AND LOWERING OF THE MIRAGE UNDERCARRIAGE

by

S.R. SARRAILHE and B. QUINN

SUMMARY

The retraction and lowering process on the aircraft and operation of the jacks in the laboratory were investigated following a failure to lock down.

Hydraulic system pressures were measured but no faults were found. It was considered that mechanical malfunction of the internal lock was the probable cause of failure.

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CONTENTS

		PAGE NO.
1.	INTRODUCTION	1
2.	THE LATERAL RETRACTION JACK	1
3.	PROCEDURE	2
4.	RESULTS	4
5.	INTERRUPTED OPERATION	7
6.	EMERGENCY OPERATION	7
7.	OTHER TESTS BY ARL	9
8.	DISCUSSION	9
9.	CONCLUSION	11

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1. INTRODUCTION

Following the failure of the main undercarriage of Aircraft A3-03 to lock down, the operation of several jacks was tested at ARL and pressures in the undercarriage hydraulic system were measured during the retraction and lowering sequences on three aircraft. This memorandum describes tests carried out on Aircraft A3-03 and A3-07 at RAAF Williamtown, and Aircraft A3-02 at the GAF facility at Avalon.

2. THE LATERAL RETRACTION JACK

The configuration of the lateral jack and operation of the claw lock are shown in Figs. 1a and 1b.

When the undercarriage is lowered the weight of the leg tends to extend the jack and the speed is controlled by a one-way restrictor in the return line, (connected to port A, Fig. 1). Pressure on the return side of the jack piston also acts on the locking piston. This displaces it to the 'unlock; position and compresses the spring, Fig. 1b. (Note that this figure, copied from the handbook, shows the locking piston being displaced by the locking claws but this will not occur during normal operation). When the leg is fully extended the hydraulic flow ceases and the back pressure in the return line falls, the spring then returns the locking piston to the lock position.

The jack could fail to lock if:

(1) The jack is not fully extended so that the engagement of the locking claws is incomplete.

(2) The locking piston is not returned to the lock position.

Return of the locking piston could be impeded by excessive back pressure, inadequate spring force or excessive sliding friction. The principal objective of the tests on the aircraft was to check back pressures (return line pressure) while the jack extended and locked .

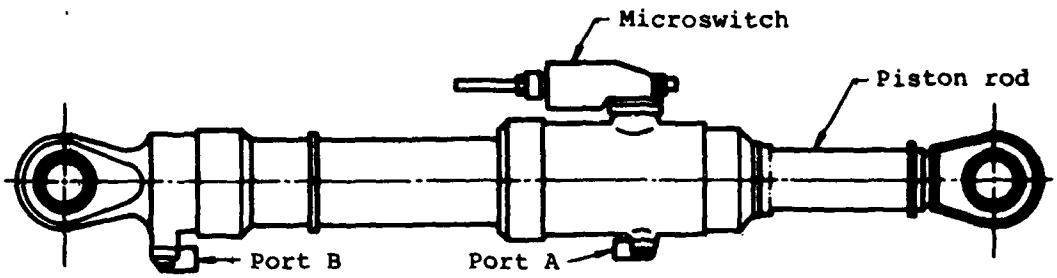
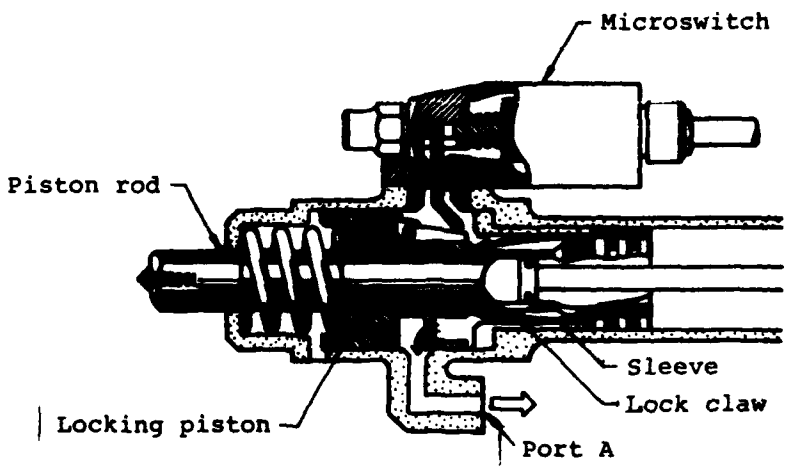


FIG 1(a) RETRACTION ACTUATOR - MAIN UNDERCARRIAGE



Beginning of locking

FIG 1(b) PRINCIPLE OF OPERATION OF JACK CLAW-LOCK
MAIN UNDERCARRIAGE

The relevant piston areas are:

Extending area 1.6 square inches*
Retracting area 2.5 square inches
Lock piston area 2.0 square inches.

Lock spring effort: lock position = 425 pounds force
fully compressed = 542 pounds force

3. PROCEDURE

The aircraft was supported with its wheels clear of the ground, and the undercarriage retracted and lowered using appropriate external sources of electrical and hydraulic power. Two pressure transducers were fitted into the hydraulic pipes in the wheel bay to measure pressure in the supply and return lines of the lateral jack, pressure in the lateral and longitudinal jack or pressures in the return lines of both port and starboard legs during lowering . Details are given in Table 1. Three aircraft were tested, A3-03 (which suffered in-flight malfunction) was investigated comprehensively during normal retraction and lowering, emergency lowering, and retraction and lowering with the operation interrupted by opening the speed brake or by switching off electrical power. The lateral jack operation was checked on A3-02 (at Avalon Aerodrome) and on A3-07 (at Williamtown).

The transducers for the lateral jack were fitted next to the flexible hoses so that the transducer in the line to Port A (i.e. supply for retraction, return for lowering) was between the jack and the one-way restrictor, it therefore measured pressure in the return side of the jack as the leg was lowered and locked. Five operations of the leg were usually carried out with each transducer arrangement. The first and last operations were recorded by a digital oscilloscope and all operations were recorded on magnetic tape.

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* English units are used because the pressures on this aircraft are indicated in pounds per square inch in the cockpit gauges and in the servicing gauges.

Transducers were calibrated just before the tests and were accurate to 2 psi at pressures down to as low as 30 psi.

TABLE 1 - PRESSURE MEASUREMENT

Side	Starboard			Port		
Jack	Lateral		Longitudinal	Lateral		Longitudinal
Port (*)	A	B	A	A	B	A
Aircraft						
A3-03	X	X	-	-	-	-
"	-	X	X	-	-	-
"	-	-	-	X	X	-
"	-	-	-	-	X	X
"	X	-	-	X	-	-
A3-02	X	X	-	-	-	-
"	-	-	-	X	X	-
A3-07	X	X	-	-	-	-

Note:

Port A - Supply port for retraction, return port for lowering. Measurement between jack and one-way restrictor.

Port B - Return port for retraction, supply port for lowering.

4. RESULTS

The pressure sequences for all operations of both port and starboard undercarriages of the three aircraft were practically identical showing both lowering and retraction cycles to be consistent. Typical traces of pressure during lowering and retraction are shown on Figs. 2 and 3 with explanations in Tables 2 and 3.

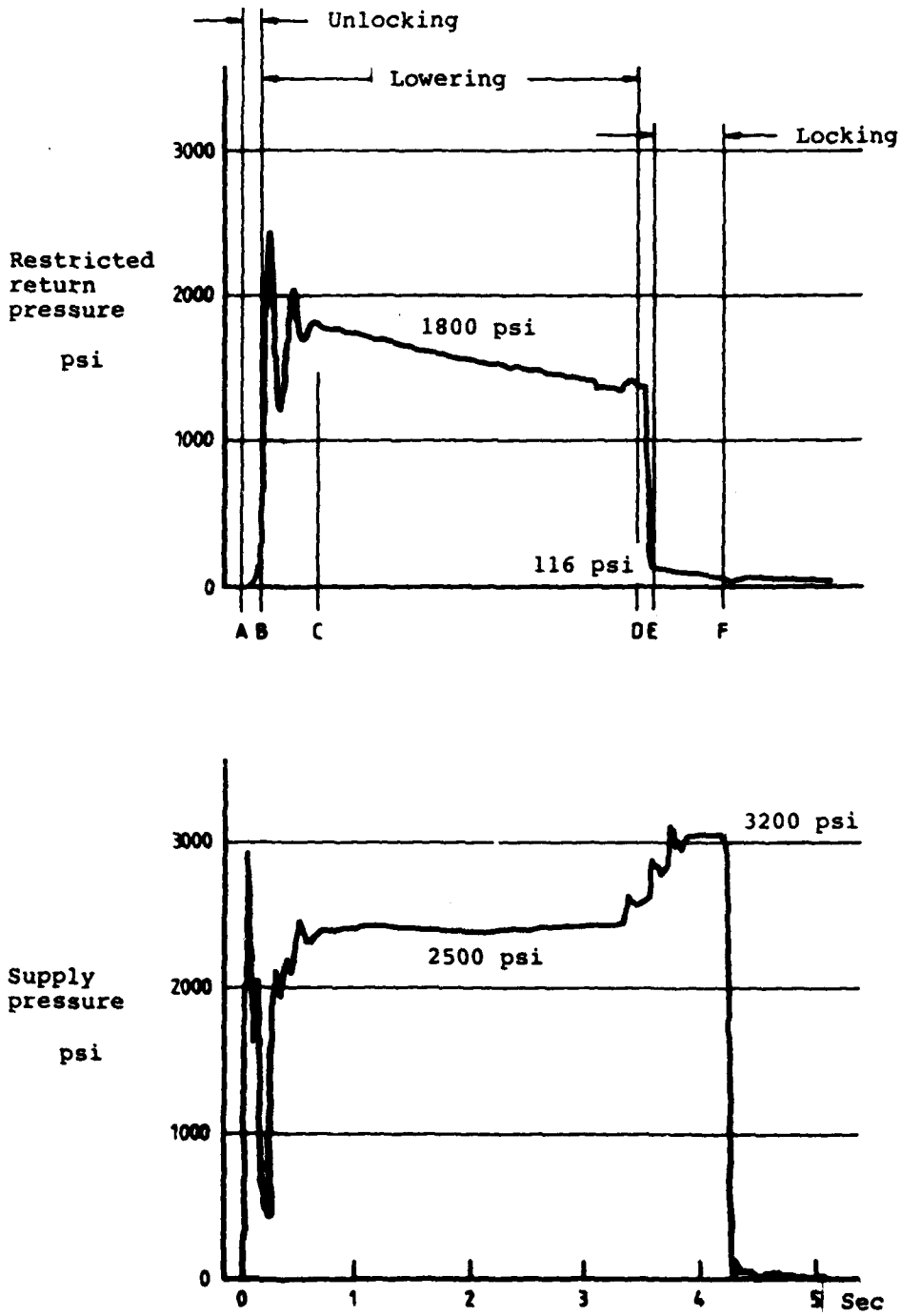

FIG 2 MIRAGE MAIN UNDERCARRIAGE LOWERING LATERAL JACK PRESSURES - A3-03 STARBOARD

TABLE 2 - MAIN UNDERCARRIAGE LOWERING

(Refer Fig. 2)

Reference	Event	Approx Pressure p.s.i. Supply	Return
A	Pressure applied to release up-lock and lower leg.	3000	0
A-B	Leg falls; pressure in return side moves lock piston compressing spring. Flow out of jack restricted.		
B-C	Pressure fluctuates as leg 'bounces' on jack.		
C-D	Steady lowering established. Return pressure on piston balances gravity moment plus supply pressure acting on smaller piston area. Return pressure diminishes as leg gets more vertical.	2500	1800
D-E	Leg down, flow censes, return pressure drops, supply pressure increases to system pressure.	3200	
E-F	When return pressure falls to 116 psi, spring moves locking piston, displacing fluid through the restrictor and maintaining a pressure of 116 to about 80 psi.		
F	When fully locked the micro switch operation cuts off hydraulic pressure. Supply and return pressures fall to very low values.	0	22

Note: Flow rates and pressures across the restrictor during C-D and E-F both correspond to the specified restrictor performance.

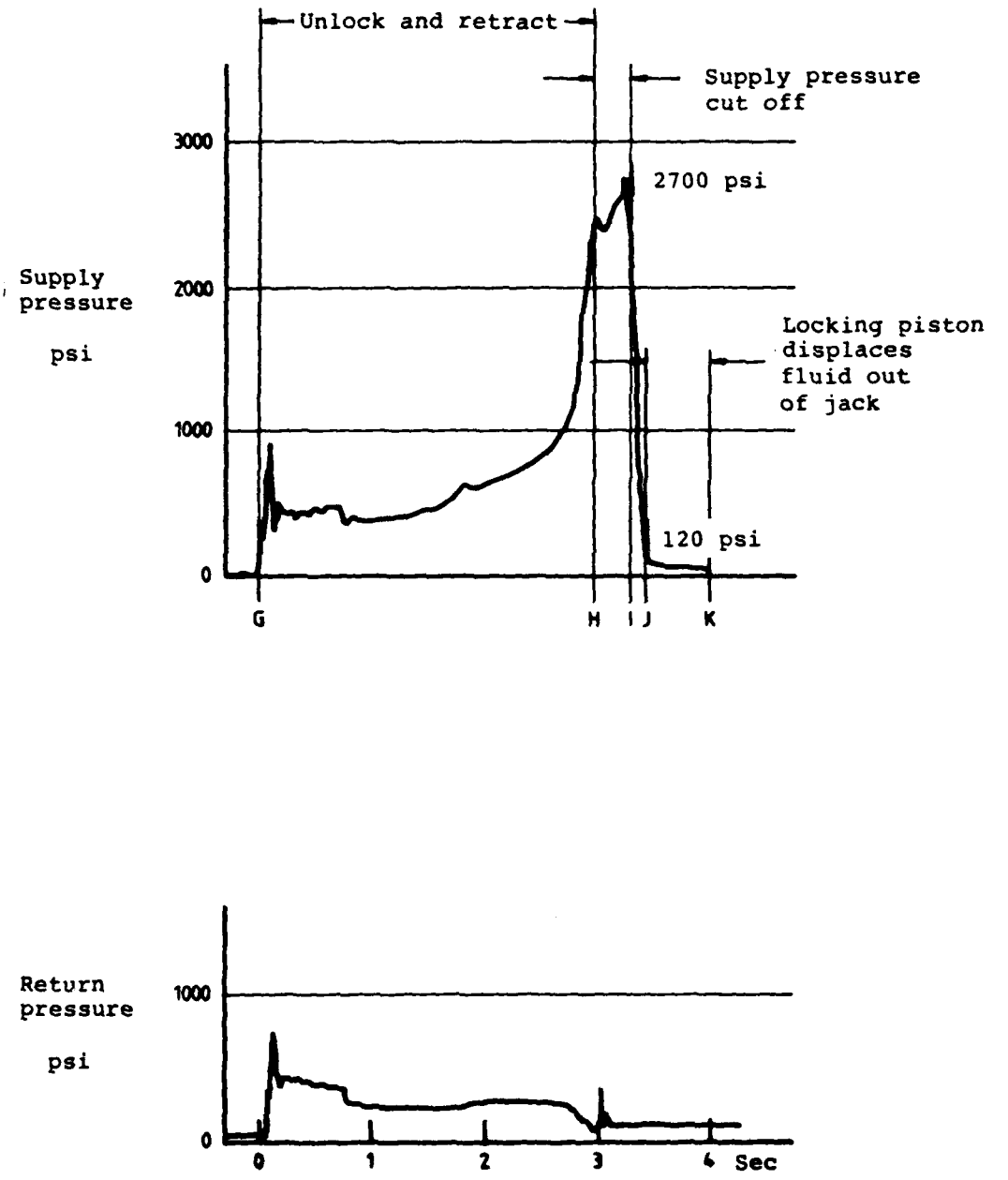

FIG 3 MIRAGE MAIN UNDERCARRIAGE RETRACTION LATERAL JACK PRESSURES A3-03 STARBOARD

TABLE 3 - RETRACTION

(Refer Fig. 3)

Reference	Event
G	Pressure surge into jack on selection "up" unlocks locking piston and accelerates jack causing surge in return line. (Note: one-way restrictor in "supply" line to jack allows full flow for retraction).
G-H	Leg retracts with increasing pressure as gravi moment increases. Internal "snubbing" in jack slows leg just before "up" (H) increasing "sup " pressure and reducing "return" pressure.
H-I	Leg "Up" doors close, supply pressure cut at I
I-J	Pressure decreases to about 120 psi.
J-K	Locking piston moves under influence of spring to displace fluid out of jack against one-way restrictor. This corresponds to the final stage of "Lowering" (E-F) Fig. 2. At K pressure in supply lines fell to less than 30 psi. Return line pressure also less than 30 psi.

5. INTERRUPTED OPERATION

Operation of the speed brakes diverted hydraulic power from the undercarriage, this caused a temporary loss of pressure and slowed the operation. Cutting electric power stopped or slowed operation but restoration of power or completion of speed brake opening restored normal operation to the undercarriage.

6. EMERGENCY OPERATION

This was slower than normal operation but engagement of the lock with pressure variation as shown on the upper trace of Fig. 2 E-F was evident.

7. OTHER TESTS BY ARL

The lateral jack which failed to lock was subjected to tests at ARL to determine locking and unlocking pressures. These were generally within handbook limits.

After these tests the jack was dismantled and the imperfection shown on Fig. 4 was discovered, at the side of the microswitch slot. Similar marking was evident on the piston from A3-80 which crashed after the undercarriage failed to lock down in 1981.

A new locking piston, examined through the microswitch hole, did not have the imperfection.

The locking piston from A3-03 was measured and found to be slightly oversize. Six diameters were measured and found to be from 0.000 to 0.019 mm below the nominal diameter, i.e. -0.000 to -0.019 whilst the correct size is -0.030 to -0.060. The dimension from the top of the imperfection to the opposite side of the piston was 0.033 above the nominal diameter. The cylinder bore should be from +0.0000 to +0.046 above the nominal diameter, however it was not available for measurement.

It has not been possible to demonstrate any correlation between the imperfection and excessive friction in the locking piston, even with an intentionally burred piston. It is however considered that a correlation could exist.

8. DISCUSSION

Flow and pressures were consistent between tests and correlated to the restrictor specifications. Operation was always achieved with pressures well below available system pressure and operation was restarted after any imposed interruption. After completion of the operation the return line pressure fell to less than 30 psi, this pressure did not, and should not prevent the jack from locking.

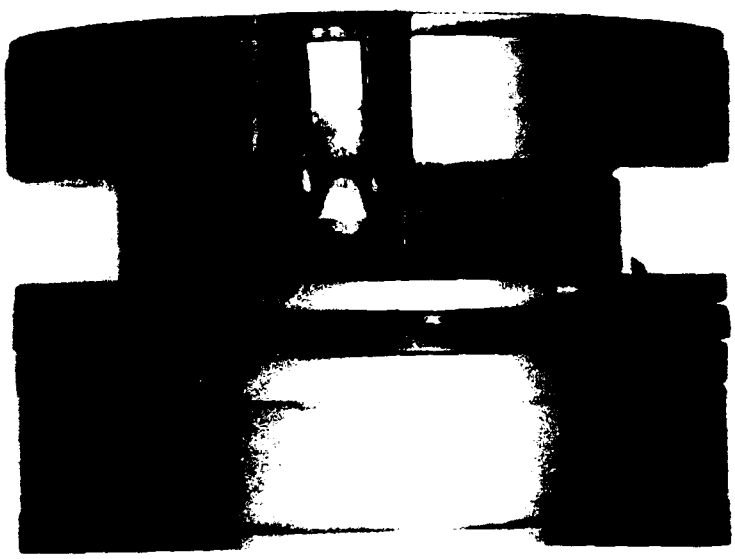

FIG 4 LOCK PISTON SHOWING IMPERFECTION BY MICRO SWITCH SLOT

The tests did not show any charactistic in the hydraulic system which could be identified as a possible cause of the malfunction in A3-03 but the traces do highlight the disparity between the forces on the locking piston available from hydraulic pressure in the jack, (e.g. 3000 psi x 4 square inches = 12000 pounds force), and the force from the spring to return the locking piston (about 500 pounds force).

9. CONCLUSION

The performance of the hydraulic system did not show any reason why the lateral jack could fail to lock.

It was noted that the spring force available to engage the lock piston is low relative to hydraulic forces and it is considered most likely that the lock piston was prevented from engaging by excessive mechanical friction, although it is not apparant why this only occurred once.

A small imperfection, detected in the lock piston of the jack which failed on A3-03, could be relevant but as yet there is no proof either way.

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16. Abstract (Cont'd)		
17. Imprint		
Aeronautical Research Laboratories, Melbourne		
18. Document Series and Number	19. Cost Code	20. Type of Report and Period Covered
STRUCTURES TECHNICAL MEMORANDUM 365	31 1756	
21. Computer Programs Used		
22. Establishment File Ref(s)		

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