INCIDENT

Aircraft Type and Registration:	BAe ATP, G-BTPD
No & Type of Engines:	2 Pratt & Whitney PW-126 turboprop engines
Year of Manufacture:	1988
Date & Time (UTC):	22 February 1995 at 1747 hrs
Location:	Aberdeen (Dyce) Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 4 Passengers - 33
Injuries:	Crew - 1 Minor Passengers - 1 Minor
Nature of Damage:	Damage to main landing gear tyres
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	30 years
Commander's Flying Experience:	2,555 hours (of which 2,290 were on type) Last 90 days - 73 hours Last 28 days - 46 hours
Information Source:	AAIB Field Investigation

History of the flight

The Glasgow based crew had spent Tuesday night at Manchester after a 8:51 hour duty period which had finished at 2106 hrs. On Wednesday 22 February, they started their duty day at 1430 hrs with a scheduled departure time of 1600 hrs for a flight to Aberdeen.

The aircraft subsequently departed Manchester at 1614 hrs and climbed, in cloud, to flight level (FL) 170; light icing and turbulence were experienced in the cruise. At 1701 hrs, the aircraft called Aberdeen Radar while descending to FL90; it was cleared for further descent and, at 1710 hrs, joined the Aberdeen visual circuit downwind right for Runway 16. The first officer was the handling pilot at this stage with the commander intending to take control, or below, 1,000 feet on final approach.

When the commander moved the landing gear selector lever towards the DOWN position, it was very stiff and would not go far enough down to allow it to engage in the detent; a "spongy" resistance to further downward movement was felt. He applied more downward force without effect. The landing gear indicators showed 3 red and 2 green lights; the nose gear green light was not illuminated. He then took control of the aircraft while the first officer applied pressure to the lever with both hands, but again to no avail. The aircraft was now on base leg and so the commander passed control back to the first officer and again tried to force the lever down. The aircraft then established on final approach, with 15° flap selected, and as he was unable to resolve the problem the commander instructed the first officer to carry out a missed approach. When the landing gear selector was then moved to the UP position, the landing gear retracted normally and the position lights went out. The commander informed Aberdeen Tower of his intention at 1713 hrs, and was cleared to 3,000 feet and transferred to Aberdeen Radar.

At 1715 hrs, the commander informed ATC of their situation and requested permission to orbit to the west of the airport while he attempted to resolve the problem. He then briefed the cabin crew.

When clear of the immediate area of the airport the autopilot was engaged, the airspeed was checked below 180 kt and the landing gear selector lever was again moved towards the DOWN position; however the landing gear indicators still showed 3 red and 2 green lights. The commander and first officer, in turn, attempted once more to force the lever down far enough to move it into the detent; however they were unsuccessful and so the landing gear was again retracted.

The crew then carried out the Quick Reference Handbook (QRH) drill for ABNORMAL & EMERGENCY LOWERING OF THE LANDING GEAR. The landing gear selector lever was moved towards the DOWN position and it was confirmed that it could not be moved far enough to engage the detent. The landing gear indicators showed 3 red and 2 green lights, as before. Circuit breaker Y14 was confirmed 'in' and the INDICATOR LEGENDS test button was pressed; the nose landing gear green light did not illuminate. The commander withdrew the central light cluster but found it very difficult to remove the defective bulbs and so he put the left cluster into the central position; both the red and green lights illuminated. He then managed to replace one of the defective bulbs and the cluster was refitted into the left position where it gave a normal indication; only one bulb was illuminated in the green section. The landing gear indicator now showed 3 red and 3 green lights and the crew continued with the drill. The hydraulic landing gear changeover lever was pulled and the DC pump was selected ON; the commander noted that the DC pump PRESS caption illuminated almost immediately. A note in the drill confirmed that the landing gear was locked down with 3 red and 3 green lights illuminated, however, as the landing gear selector lever was not in the DOWN detent the following applied:

> **'Hyd L/G changeover must be kept out**
> **DC pump will not now back-up brake accumulators**
> **Do not check operation of brakes while airborne**
> **N/W steering is not now available'**

When the drill had been completed, the first officer went into the cabin to check the main landing gear mechanical indicators. The commander briefed ATC that he had no nosewheel steering and would bring the aircraft to a halt on the runway and wait to be towed to the ramp. The controller acknowledged this and, at 1729 hrs, told him that he would be number five in the pattern since he wished to land other arriving aircraft before 'PD'.

At 1730 hrs, about 8 minutes after the changeover lever had been pulled, the HYD O/HEAT caption illuminated on the central warning panel (CWP). Shortly after this, the first officer returned to the flight deck, checked the nose gear mechanical indicator and confirmed to the commander that all three landing gear legs were indicating down and locked. The commander called the number one cabin attendant to the flight deck and briefed her that it would be a normal landing but as he did not have nosewheel steering available he would stop on the runway and await a tow to the ramp. As a precaution, he asked her to move passengers from the immediate area of the propellers and seat them in the rear of the cabin; he then spoke to the passengers on the PA system.

The crew then consulted the HYDRAULIC OVERHEAT drill. As neither pump indicated an abnormally high pressure, the drill required that both shut-off cocks, in turn, be selected SHUT for 5 minutes then OPEN, to establish which pump was causing the overheat. However the commander decided that, as he was about to begin the approach and was satisfied that the landing gear was locked down, he would not action the drill. He then informed ATC that they were ready to make an approach and the crew then reviewed the ABNORMAL & EMERGENCY LOWERING OF THE LANDING GEAR procedure to verify their actions.

At 1738 hrs, they actioned the approach checklist however when they came to the BRAKES & HYDRAULICS check the commander noticed that all four brake operating gauge needles were deflected to about $^1/_3$ scale. At this point, the radar controller requested a left turn, heading 210°, and a report to confirm that the aircraft was established on the localiser. When he had acknowledged this call the commander consulted the HYDRAULIC PRESSURE TRAPPED IN BRAKES drill; he found that it required both pilots to operate the footbrakes repeatedly, until all brake pressures indicated zero. This directly contradicted the advice given in the ABNORMAL & EMERGENCY LOWERING OF THE LANDING GEAR drill and, he reasoned, would probably have left him with no braking. On balance he decided that it would be preferable to land with the brakes partially applied with the consequent risk of one or more tyres bursting. The commander informed ATC of this further problem and shortly afterwards, at 1741 hrs, called localiser established and was transferred to Tower frequency at 9 nm from touchdown.

The Airport Fire Service (AFS) had already gone to 'Local Standby' status and a discussion then took place in the visual control room between the controller and the watch manager about whether or not to upgrade the emergency state. However the local services, both fire and ambulance, would not have had sufficient time to arrive before the aircraft landed and so the watch manager decided that, on balance, it was best to continue with the Local Standby response.

The commander briefed the number one cabin attendant of the new situation and told her to instruct the passengers to assume the brace position for landing. At 4 nm from touchdown, the aircraft was cleared to land and the commander took control. The landing was to be achieved using 20° flap with a V_{REF} of 106 kt; there was a crosswind component of about 15 kt from the right. At 200 feet above ground level the first officer told the passengers to brace and was briefed to close both condition levers should the aircraft leave the runway. He called V_{REF} shortly before the aircraft touched down smoothly on the mainwheels; it became immediately evident to the commander that the brakes were already applied. During the ground run two tyres burst and, as the aircraft slowed, it started to veer to the right; the commander instinctively applied full left tiller and left brake, and the first officer put both condition levers to OFF. The controller reacted immediately with a declaration of "Aircraft Accident" on the OMNI-CRASH system.

The aircraft came to a halt on the grass to the right of the runway and the passengers started to leave their seats. The number one cabin attendant urged them to remain seated. However, this was immediately countermanded by the commander who decided to carry out an emergency evacuation. The front left and rear right doors were opened and the slides were deployed. The overwing exits were opened by nearby passengers; the left hatch was thrown out through the opening and there was some initial confusion as an attempt was made to stow the right hatch inside. Other passengers then started to mill around these exits. The cabin attendants reacted quickly and called them to the front and rear exits where they were then evacuated successfully; some passengers tried to take their baggage, but this was taken from them. The forward cabin attendant and one of the passengers sustained minor injuries during the evacuation.

The AFS, having been at 'Local Standby', were on the scene immediately. The local services, both fire and ambulance, which had been alerted by the OMNI-CRASH system arrived some ten minutes after the aircraft had come to a halt. The airfield was closed as a result of the incident until 2045 hrs.

Weather

An aftercast supplied by the Meteorological Office at Bracknell indicated that the synoptic situation between 1614 and 1747 hrs showed a frontal system lying from Manchester to Berwick-on-Tweed moving steadily eastwards at about 15 kt. At FL170, a considerable portion of the flight up to the Borders would have been in, or just above, the medium level cloud associated with the frontal system the estimated temperature at FL170 was MS 26°C.

The Manchester METAR for 1620 hrs contained the following:

Wind	190° /13 kt
Visibility	>10 km
Weather	Rain
Cloud	Scattered base 1,400 feet
	Overcast base 8,000 feet
Temperature	+3°C
Dewpoint	+2°C
QNH	996 mb

There had been rain and snow during the previous hour.

The Special Weather Report for Aberdeen timed at 1747 hrs contained the following:

Wind	210°/19 kt
Visibility	40 km
Weather	Nil
Cloud	Scattered base 2,000 feet
Temperature	+3°C
Dewpoint	-2°C
QNH	983 mb

Flight Recorders

The Flight Data Recorder was removed and replayed by the AAIB but it contained no useful data which related to the operation of the landing gear. The aircraft had touched down smoothly at a speed of 105 kt on a heading 170°M whilst on the runway, and came to rest on a heading of 217°M. A Quick Access Recorder was fitted which should have contained additional parameters, including landing gear discretes, but the associated cassette had not been changed and thus the incident flight had not been recorded.

The Cockpit Voice Recorder was also replayed and the 30 minute tape contained some discussion of the problem by the crew, in addition to the checklist items carried out. It also covered the period of the final approach and landing.

Aircraft examination

General

With the exception of the main landing gear tyres and wheels, little or no damage had been caused to the aircraft by its departure from the runway. Analysis of the marks left on the runway by the tyres indicated that the aircraft had touched down with all four wheels locked, 326 metres from the start of the runway, and in the middle of the touchdown markers. Some 200 metres and 260 metres into the ground run the right outer and left inner tyres, respectively, had burst. The resulting shedding of load onto the adjacent tyres had started their rotation under the influence of their Maxaret anti-skid units. The right inner and left outer tyres, although damaged, had not burst. The aircraft tracked along the centre of the runway for some 450 metres before deviating to the right and coming to rest on a heading of 220°M with the main gear wheels embedded in the earth and the nosewheels on the edge of Runway 32. The total ground run was 557 metres.

Landing gear

The aircraft is supported by a hydraulically retractable tricycle landing gear with twin wheels on each axle. Both the main and nose gears retract in the forward direction. Normal landing gear operation is by means of a hydraulic selector valve, located in the nose gear bay, itself operated by a selector lever at the bottom of the first officer's instrument panel. This system is shown in Figure 1. The selector lever mechanism in the cockpit, which contains a solenoid baulk to prevent a gear UP selection whilst the aircraft is on the ground, is configured such that the lever is held in a positive detent at both the 'up' and 'down' limits of its travel. To clear these detents the lever must be pulled axially out of the panel before vertical motion can take place. When the lever is fully located in either of these detents, a microswitch is operated which allows the appropriate red indicator lights to extinguish on the instrument panel. (The green gear down and locked indicator lights are signalled directly from the landing gear down locks). Connection between this mechanism and the selector valve is effected by a Bowden cable which passes through a bulkhead connector at the pressure floor in the cockpit, and which operates on a simple lever mechanism at the valve input.

Brakes

Aircraft braking is achieved by hydraulically operated multi-disc carbon brake units fitted to all four main landing gear wheels. Brake control is from master cylinders, operated by toe pedals on the rudder bars at both crew stations, and also from a parking brake lever on the centre console. A four element brake control valve is hydraulically connected to these master cylinders, senses applied pressure and delivers proportional hydraulic pressure to the appropriate brake unit. Each unit is connected to a fully adaptive anti-skid unit, but locked wheel touchdown protection is not provided.

Examination

After the landing incident the aircraft was towed into the operator's maintenance hangar at Aberdeen where it was examined on the following morning by the AAIB and representatives of the manufacturer and operator. It was apparent that the selector lever was positioned approximately 0.25 inches from the fully down position and was therefore not in the gear DOWN detent. An examination of the selector system failed to reveal any external evidence of a restriction to movement and, when normal hand pressure was applied to the lever, it moved down and engaged the detent. After further checks of the aircraft, it was placed on jacks such that all three landing gears were clear of the ground. Electrical power, and subsequently hydraulic power, were applied. With the lever in the down detent, three greens lights were illuminated. With the lever in the 'as found' position, three green and three red lights were visible and the gear remained down and locked. (It was apparent when observing the gear position indicators that it was very difficult to detect if each were being illuminated by one or two bulbs. Thus it appeared that for a period of time prior to this incident the nose gear indicator had been illuminated by one bulb, and that the second bulb had failed on the initial gear DOWN selection on the subject flight). During functional testing of the complete system, the landing gear and its indicator lights were seen to operate correctly but it was apparent that the mechanical operation of the selector lever, with and without hydraulic pressure applied, was extremely stiff, 'notchy' and awkward to operate. However, during these tests the lever could always be operated over its full range. The peak load to operate this lever, measured parallel to the instrument panel, was 7 kg. The manufacturer's stated maximum is 9 kg (20 lb). [When the aircraft was returned to service, with appropriate replacement parts, the load required to operate the landing gear lever was measured at 5.5 kg (12 lb)].

In an attempt to locate the cause of the stiffness, it was decided to progressively disconnect parts of the system, starting with the final pin joint at the selector valve input. However, attempts to remove this pin (Figure 1) were unsuccessful since it was an extremely tight fit in the fork end of the valve. Rather than risk disturbing this joint, the pin connecting the lower end of the Bowden cable was removed. However, operating loads at the cockpit lever only reduced slightly. It was intended that the next joint to be disconnected would be that at the upper end of the cable to the mechanism in the cockpit but, as access was being gained to this area behind the central instrument panel, it was noticed that the mounting for the Bowden operating lever was not 'square' to the airframe mounted bracket to which is shimmed and bolted. It was apparent that this mounting had been incorrectly shimmed, one of the two spacer plates being found as shown in Figure 2. Upon loosening the bolt causing the distortion, the threads of which were found to have been stripped, the mounting resumed its correct position and the lever operating loads, with the cable attached, were measured at 2.5/3 kg. After disconnecting the upper end of the cable, lever operating loads fell to very low levels and its operation became quite smooth.

The component parts of the operating system were then removed for a more detailed examination. As the cockpit lever assembly was removed from the panel, two small items were discovered within the mechanism; a small plain nut and a broken ring crimp, both of a type associated with electrical wire terminations. Despite a close inspection, no evidence was found to indicate that either of these items had caused the mechanism to jam. The mechanism was assessed as being fully serviceable, despite damage to the threads of the bolts associated with the mis-assembled shim.

The cable was removed in two sections by disconnecting the upper and lower sheaths at the bulkhead connector and cutting the cable at this location. Prior to dis-assembling these items, they were X-rayed and operating loads were measured, without end load applied, at room temperature and at -15°C. At the lower temperature, frictional loads increased by approximately 20%. Examination of the disassembled cable revealed the upper half to be in a good condition, sufficiently lubricated with the correct specification grease. The lower section, however, was not so well lubricated and rust was present on the cable itself, although the grease was to the correct specification. Corrosion was also found in the lower part of the bulkhead connector.

The normal landing gear hydraulic selector valve was also removed and subjected to functional testing and strip examination. Apart from a higher than specified internal leakage rate, it operated satisfactorily. It was noted, however, that side load applied to the protruding end of the spool would raise the operating load significantly. The strip examination failed to reveal any evidence of damage that might have suggested that the spool had been jammed by, for example, foreign matter.

The examination of this system, whilst revealing several defects which helped to explain the stiffness and rough action felt when operating the lever, did not indicate any positive evidence as to why the lever could not, in flight, be moved fully down into the lower detent. However an assessment of the system by the AAIB and the manufacturer revealed an area where, potentially, if ice or frost were to form, a restriction to the travel of the cable might occur. This area was at the lower end of the fixed portion of the sheath, where its end fitting is clamped to the airframe. From this fitting a fixed tube protrudes, within which the cable itself slides, the cable being attached to the moveable end fitting, the larger diameter tube of which slides over the smaller diameter fixed tube. This outer tube moves towards the airframe clamp upon a gear DOWN selection such that, should there by any build up of ice in this area, a restriction to the full normal travel of the cable might occur (Figure 5). The manufacturer has conducted icing trials in the laboratory, using the cable end fittings from 'PD' mounted onto a specially constructed test rig, but so far has been unable to substantiate this possibility. Following previous problems with ice contamination of the normal landing gear and changeover valve input mechanisms in the nose gear equipment bay, a modification was introduced to fit a cover over these mechanisms in the top right corner of the bay (Figure 4) to prevent direct contamination by water/slush thrown off by the nosewheels. This was fitted to 'PD' in September 1991. As may be seen, the mechanisms are protected from direct contamination and, although the area in which they are mounted is open to the general nose gear bay environment, no clear indications were seen of any residue that might have been deposited by water spray. A review of the complete gear selection system is being conducted by the manufacturer.

Hydraulic system

Two schematic diagrams of the hydraulic system are included at Figure 3 showing status in the changeover and normal modes.

Description

The hydraulic system on the ATP aircraft provides power to operate the landing gear, nosewheel steering, wheelbrakes and airstair systems. Two variable displacement pumps are each mounted on, and driven by, the propeller reduction gearboxes. System pressure is controlled by an integral pump pressure control system that reduces pump delivery pressure to zero when system pressure reaches 2,450 psi. The pumps are designated main and standby, the main pump being installed on the left engine. Mineral based fluid is supplied to these pumps from a reservoir, located in the right wing fillet, which is pressurised by air from the airframe de-icing system. The reservoir is fitted with two detectors, one to indicate low hydraulic fluid level and the other to indicate high fluid temperature. Associated warnings are displayed by amber captions on the cockpit Central Warning Panel (CWP). Electrically operated hydraulic shut-off cocks are located in the suction lines downstream of the hydraulic reservoir. A single accumulator provides a stored reserve of hydraulic pressure. An auxiliary direct current (DC) driven hydraulic pump, mounted in the nose gear bay, supplies fluid at a pressure of 2,500 psi to the auxiliary hydraulic system. This system is provided to pressurise the hydraulic system for the following abnormal or maintenance reasons:

Abnormal
Extension of the landing gear, by operation of the landing gear changeover lever. Pressurising the wheel brake system.

Maintenance
All services, in conjunction with a Ground Service Valve.

The auxiliary pump is supplied with fluid from an auxiliary reservoir, also mounted in the nose gear bay, and this is automatically replenished with fluid from the main reservoir. This pump is controlled by a switch on the left side panel in the cockpit which, when pressed, supplies DC power to the motor and illuminates an adjacent white ON caption. When output pressure reaches 1,800 psi a white PRESS caption also illuminates. Fitted between the return pressure lines and the auxiliary reservoir from the return system rather than the main reservoir, when the auxiliary pump is operating.

Modification No 10303A (SB ATP-332-41)

The hydraulic system on G-BTPD, and other ATP aircraft, had been modified such that the wheelbrake operating master cylinders on each of the four rudder pedals are topped up with hydraulic fluid and bled of air by being permanently connected to the return (low pressure) side of the aircraft's hydraulic system. It may been seen from Figure 3 that this connection to the system is made downstream of the pressure operated check valve at a position which normally experiences auxiliary/main reservoir pressure. Whenever the DC pump is operating and producing pressure, this connection is exposed to the return manifold pressure by the opening of the check valve. When the hydraulic system is in normal use, the return line pressure is likely to be similar to, or slightly above, the main reservoir pressure (18 psi), depending upon the demand on the system. However, when the landing gear changeover lever is operated, engine driven pump output is routed directly, in the changeover isolation valve, into the return system, the consequent high fluid flow rates raising both the pressure and temperature of the fluid in the now combined pressure and return hydraulic lines. This fluid pressure will vary throughout the system, the highest pressure being at the pumps output, the lowest (18 psi) as it re-enters the main reservoir.

Examination and tests

When first examined, the aircraft's hydraulic system had no apparent leaks, there was sufficient fluid in the main reservoir and the landing gear changeover lever had been operated. Subsequent testing of the landing gear, using ground electrical and hydraulic power, showed that the aircraft's hydraulic system operated correctly. During this testing, the inflight sequence of events was repeated, ie the gear was lowered by operation of the landing gear changeover lever, and with the DC pump selected on. The gear successfully lowered and locked down, brake pressures of approximately 700 psi were seen on the indicators for all four wheels and, after some 7 to 8 minutes, a hydraulic overheat warning occurred. This procedure was repeated on another ATP aircraft of the same operator, with the same result. Subsequently, the manufacturer also repeated the above phenomenon on their development aircraft, both on the ground and in flight. From these tests it was confirmed that this was a system characteristic, not peculiar to 'PD', and that the elevated pressure in the hydraulic system return lines was sufficient to cause the brake pedal foot motors to signal the brake control valves to apply pressure to the wheelbrakes. Pressures of up to 200 psi have been recorded at the auxiliary reservoir by the manufacturer during tests after operation of the changeover lever when following the procedure detailed in the un-amended QRH. Such pressure, applied to the master cylinders, is reported as being consistent with the observed wheelbrake pressures of 700/1,000 psi.

Action by the manufacturer

The manufacturer is carrying out a technical investigation which will lead to a modification of the hydraulic system to ensure that there is no possibility of residual brake pressure following the use of the landing gear changeover lever. It has been indicated that this modification will be made mandatory by the CAA.

Certification

The pressure bleed modification (10303A) for the master cylinders was classified as a 'minor modification' by the authorities and approved partly on the basis of a similar system fitted to the Jetstream 41 aircraft, and the fact that the ATP hydraulic system was derived from that on the HS 748 aircraft. (The main difference is that the hand pump on the 748 is replaced by the DC pump on the ATP). Although an analysis of the effect of the change to the system was conducted it was reported that no associated testing of the system had been carried out when the modification was introduced.

Quick Reference Handbook (QRH)

The ABNORMAL & EMERGENCY LOWERING OF THE LANDING GEAR drill in the QRH has been modified so that the main hydraulic pumps are isolated by shutting both hydraulic cocks before the changeover lever is pulled. If the drill later requires the changeover lever to be pushed back out, the hydraulic cocks remain shut. A Notice to Aircrew to this effect was issued by the manufacturer on 25 February 1995; the operating company simultaneously issued a Flight Crew Notice to the same effect.

Landing Gear Selector Mechanism

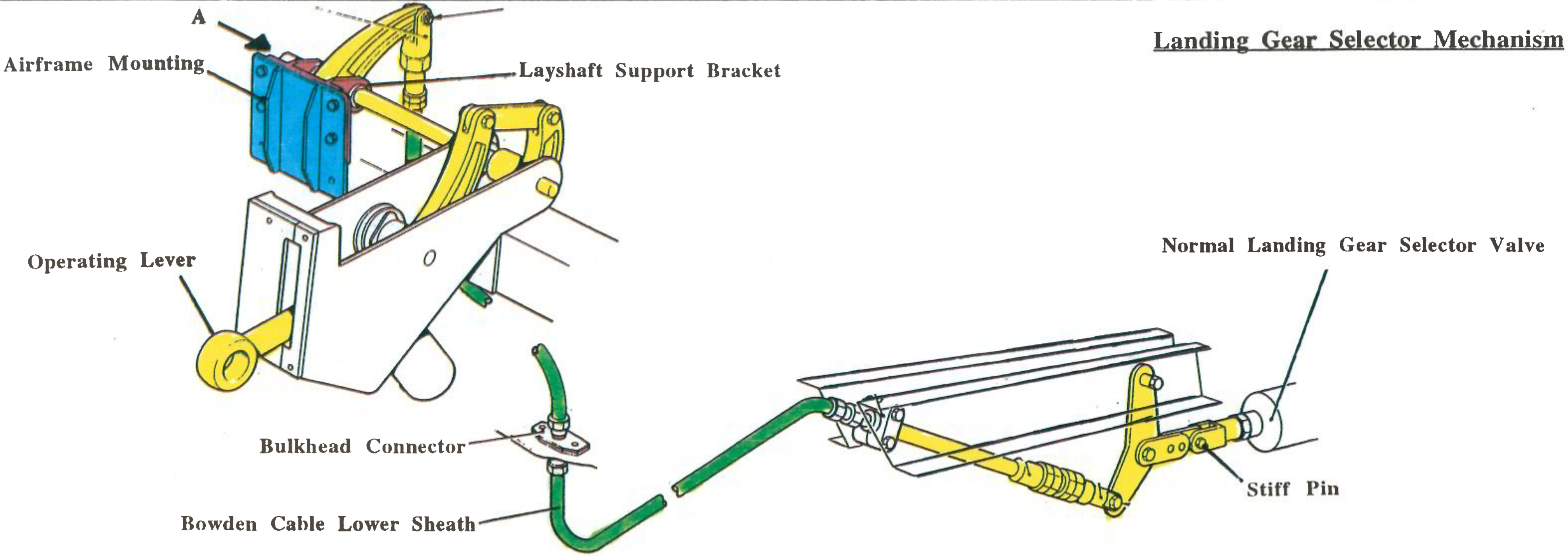
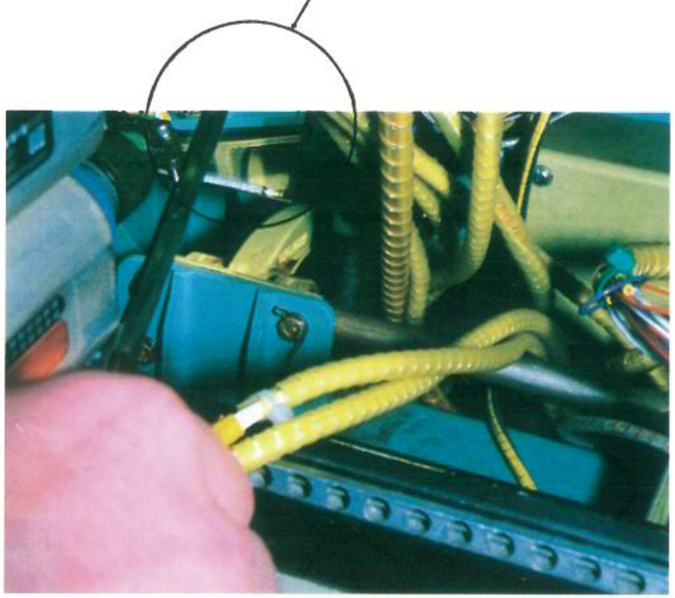
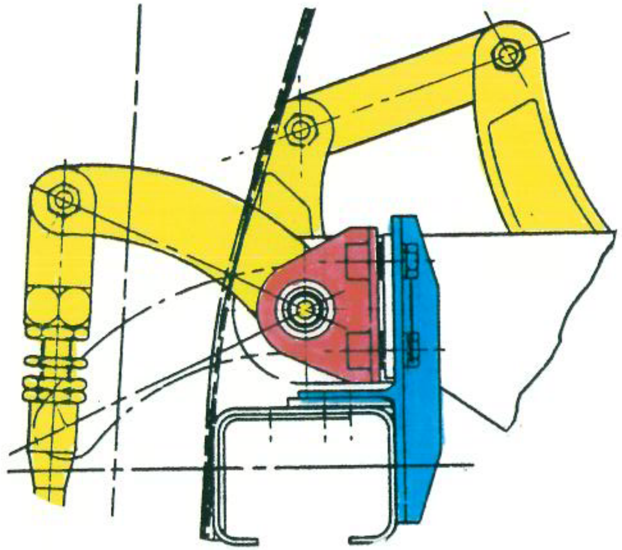


Figure 1





View on Arrow A

Arrangement of Shims, as Installed

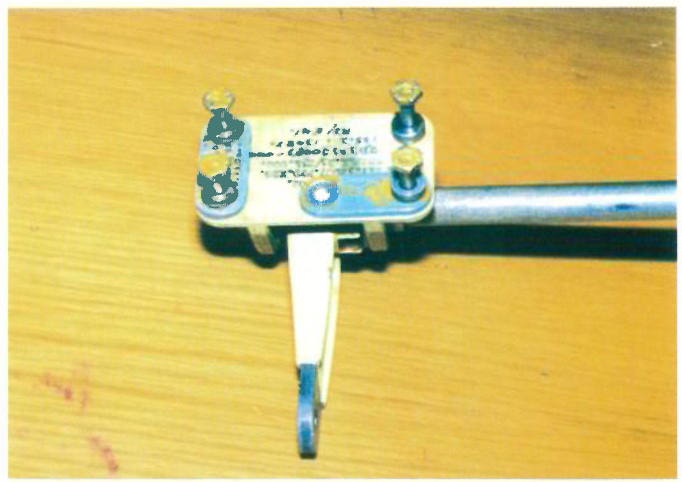
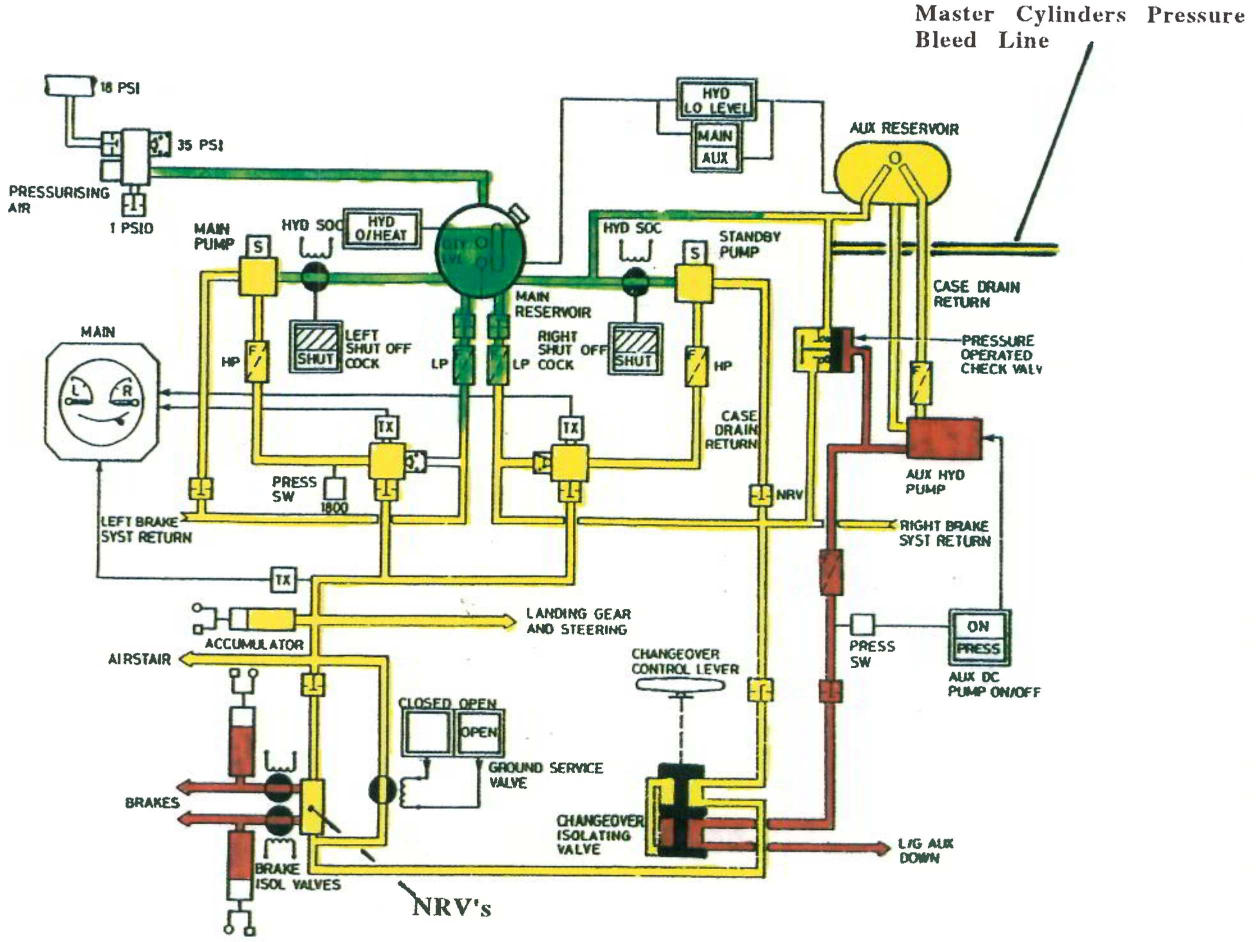
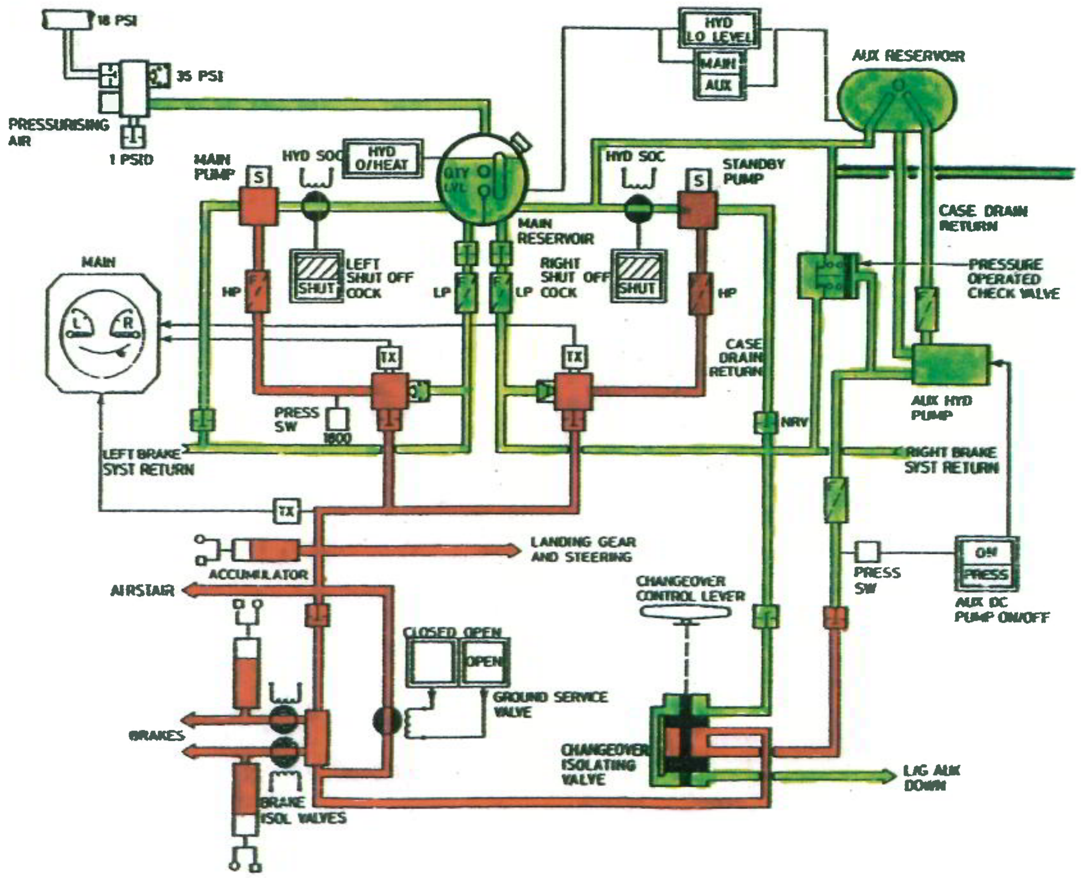


Figure 2



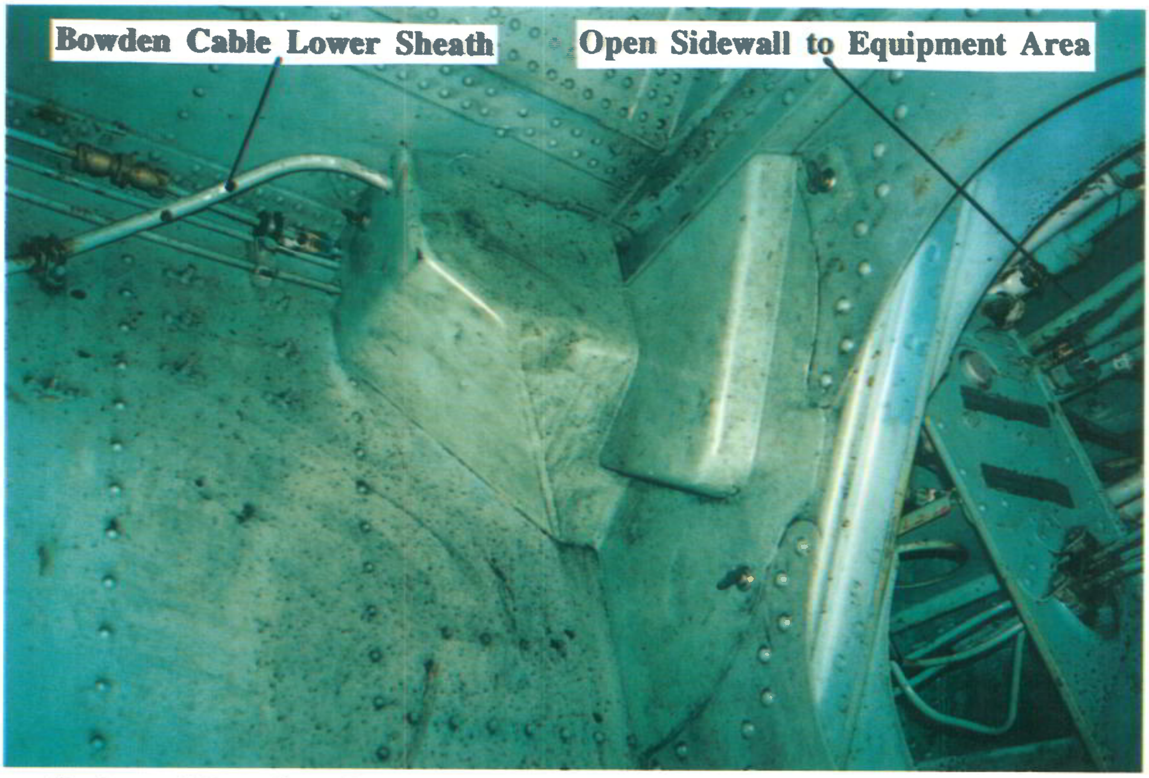
Hydraulic System Configuration, Changeover Control Lever Pulled

High Pressure — Base Pressure — Elevated Pressure



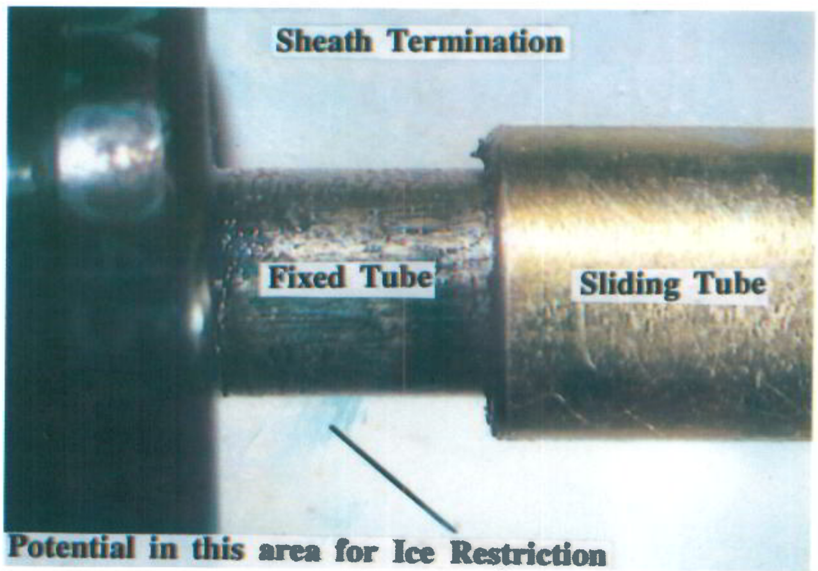
Normal Configuration of Hydraulic System

Figure 3



Installation of Landing Gear Selector Mechanisms Cover, Top Right Forward Corner of the Nose Gear Bay

Figure 4



Bowden Cable Lower End Arrangement

Tube Position Shown Close to Gear Lever Fully Down

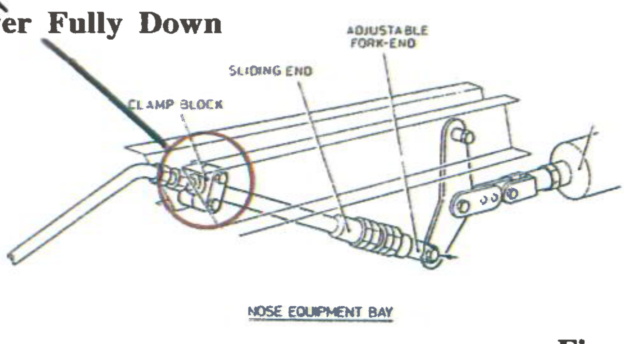


Figure 5