Aircraft Type and Registration:	Boeing 747-436, G-BNLS
No & Type of Engines:	4 Rolls-Royce RB211-524H High By-pass turbofans
Year of Manufacture:	1991
Date & Time (UTC):	12 August 1993 at 1942 hrs
Location:	Hong Kong International Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 20 Passengers - 311
Injuries:	Crew - None Passengers - None
Nature of Damage:	No 2 engine core cover panels severely burnt
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	Total 15,500 hours (of which 1,200 were on type)
Information Source:	AAIB Field Investigation

During the initial climb after a normal takeoff from Runway 13 at Hong Kong International Airport, as the aircraft passed through about 1,600 feet, the No 2 engine fire warning sounded. The appropriate fire drill was actioned and the fire warning ceased within 30 seconds. An emergency was declared and the aircraft jettisoned about 110 tonnes of fuel before returning to land at Hong Kong.

After landing, when the aircraft had returned to its stand, a brake temperature warning was observed and the crew was advised by Air Traffic Control that flames were visible around the left body landing gear. The fire service was already in attendance and quickly suppressed the No 7 brake fire. Because the aircraft was already on the stand, the emergency slides were not deployed, the passengers being disembarked rapidly through the jetties without any injuries being suffered.

On site examination of the No 2 engine revealed that there had been a fire around the lower half of the core engine which had severely damaged the covering panels which form the inner diameter of the by-pass duct. The lower core cover panels were removed and the fire was seen to have affected the underside of the whole core compressor module. The lower half of the core engine was sprayed with dye penetrant developer, to act as a leak detection agent, and the engine was then motored over on its starter with the fuel cocks 'open' to test for fuel leaks. Although no leaks were revealed by this procedure, the damage was sufficiently serious to require the engine to be changed.

It was decided that the investigation of both the engine and brake fires would be conducted in the UK and therefore both the No 2 engine and the No 7 brake pack were removed from the aircraft and returned, as complete units, by air freight.

Engine investigation

The recently overhauled engine had been fitted to the aircraft two months previously, and had since accumulated 908 running hours over 112 sectors. After return to the UK it was examined, under the supervision of AAIB, first at the operator's base and subsequently at the overhauliers, where several tests and trials were also performed.

The first examination confirmed that there had been a fierce fire, centred in the vicinity of the high pressure (HP) fuel filter on the underside of the core engine (Fig.1). Although the use of dye penetrant had masked the major proportion of the evidence of the development of the fire, there was some evidence of fuel 'washing' of the HP compressor case. This evidence was apparent immediately above the downstream self-aligning connection of this filter, which is fitted as a free mounted component (*ie.* not directly attached to the engine) in the high pressure fuel line. (see Fig.2). The composite honeycomb core cover panels, which form the inner wall of the by-pass duct, had been severely burned on their lower arc and there was evidence of fire inside the core panels.

The engine was then taken to the overhauliers for leak testing of the HP fuel line on the underside of the core engine. In order to do this at realistic pressures and without running the engine, it was first necessary to blank off the fuel manifolds. Before doing this, a tightness check was performed on all connections of the fuel spray nozzles to the primary manifolds and those of the primary manifolds to the main fuel manifolds. The primary manifolds were then removed and the main fuel manifold was blanked at the primary manifold connections. The delivery pipe from the HP fuel pump was disconnected from the fuel inlet to the fuel cooled oil cooler and pressurised fuel from a test rig was applied to the HP fuel pipework between the cooler and the burner manifold, of which the HP fuel filter constituted a part.

As the pressure from the test rig was gradually increased, the whole length of the pipework under pressure was observed. At a pressure of 250 psi, the spherical coupling at the outlet of the HP filter (see Fig.2) became wet, at 300 psi there was a very slow, but steady, drip from both couplings and at 400 psi there were measurable leaks of 1.6 ml/min at the inlet and 3.4 ml/min at the outlet. At 550 psi the leak from the inlet coupling was still a drip but that from the outlet had increased to a steady stream of about 150 ml/min. At 800 psi, whilst the inlet connector leak was similar to the outlet leak at 550 psi, that at the outlet connector was a powerful spray directed against the underside of the HP compressor case (see Plate 1).

A review of the approximate fuel pressures experienced at the filter showed that at idle and high altitude cruise powers the pressure would be below 200 psi, but would rise above 1,000 psi for a sea level takeoff. This indicated that the leak, as found, would not have revealed itself with the engine being motored on the starter.

After this test, the tightness of the two connections was measured both by the torque required to slack them off and that required to return the connector nuts to the same position relative to the filter body (torque was restored on the first end tested before the second end was released). This gave the following results (Torque specified in lbf ins) :

	Inlet	Outlet
Break torque	110	100
Restored position torque	110	150
Mean	110	125
Specified torque loading	876	1,188

A trial was performed to obtain an estimate of the order of distance that the nut advanced down the thread of the union to obtain these torque values. This showed that, to achieve the specified torque values, the large union nut, at the filter outlet, advanced about 0.0052 inch and the smaller nut, at the inlet, about 0.0045 inch. Referring to Fig.3, A & B, the inference of this trial was that the specified clamping torque could theoretically be lost by a change in misalignment of about 10 minutes of arc.

As a result of this investigation and its associated trials, the overhaulier has introduced a revision to their standard practices used to fit and align this type of spherical coupling.

Brake investigation

The brake unit which had been subjected to the fire was examined and it was seen that the exposed part of one of the actuator pistons was covered in a gummy residue (see Plate 2). Hydraulic pressure was applied to the unit and fluid immediately began to weep from the insulator foot of the actuator and run onto the pressure plate.

The brake pack was dismantled and the insulator feet removed from all of the actuators. This revealed that the actuator which had leaked was visibly wet inside the adjuster mechanism which is in the dry zone in the piston (see Plate 3 & Fig.4). The actuator was removed from the caliper unit and the seal assembly between the pressure and dry sides of the main piston was dismantled. This revealed that both the O-ring seal and its back-up washer had become entrained into the hole between the two sides of the piston and become damaged (see Plates 4 & 5 and Fig.5). This damage was similar to that seen by the operator on other units of this type of brake which had been dismantled as a result of hydraulic fluid having leaked onto the pressure plate.

The brake manufacturer has issued a Service Bulletin (2-1515-32-9) introducing a modified adjuster assembly (Part No 107-369-3). They recommend that operators should fit modified adjusters to all brake units which have leaking adjusters and to units which are being overhauled. They also recommend that these adjusters are fitted to spare brake units before these are fitted to aircraft.

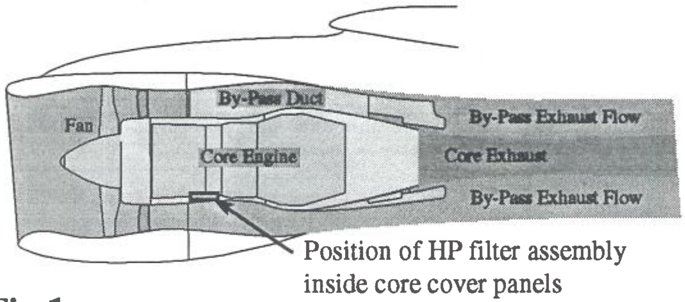


Fig.1
Diagramatic Cross Section of RB 211-524H

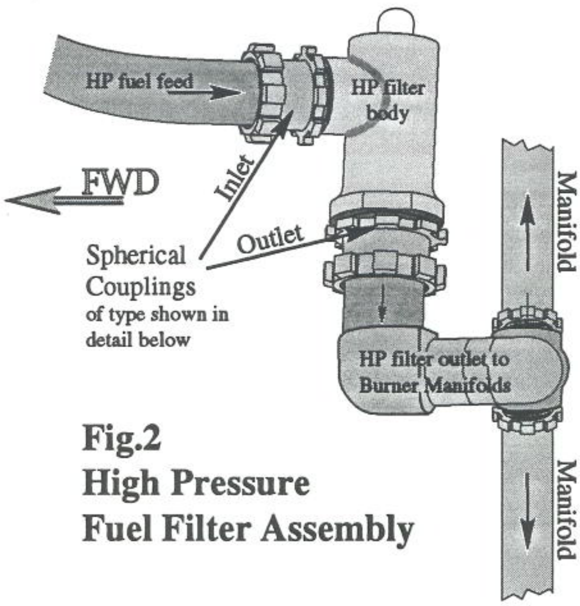
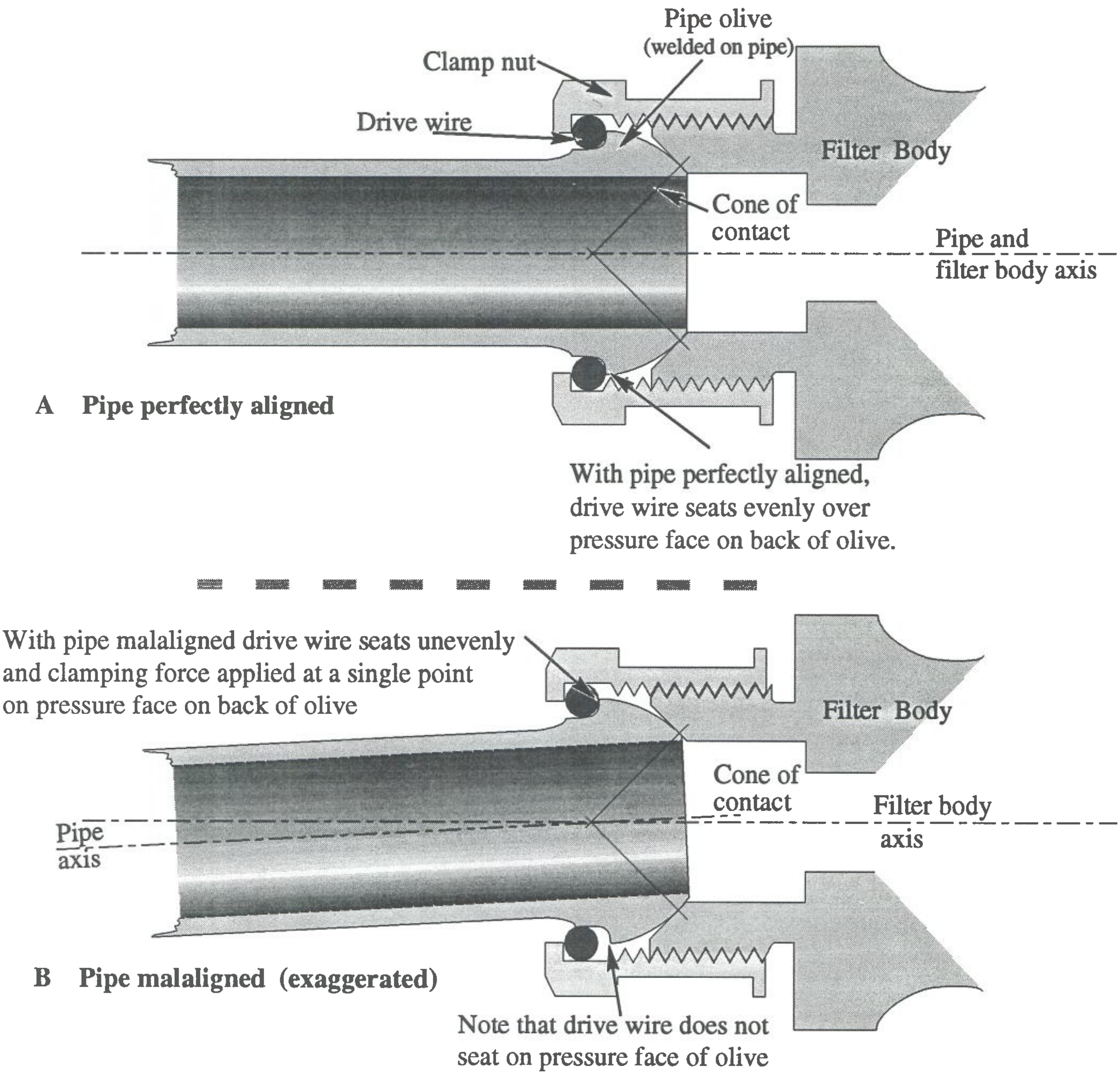


Fig.2
High Pressure Fuel Filter Assembly

Fig.3
Details of clamping action in Spherical Couplings



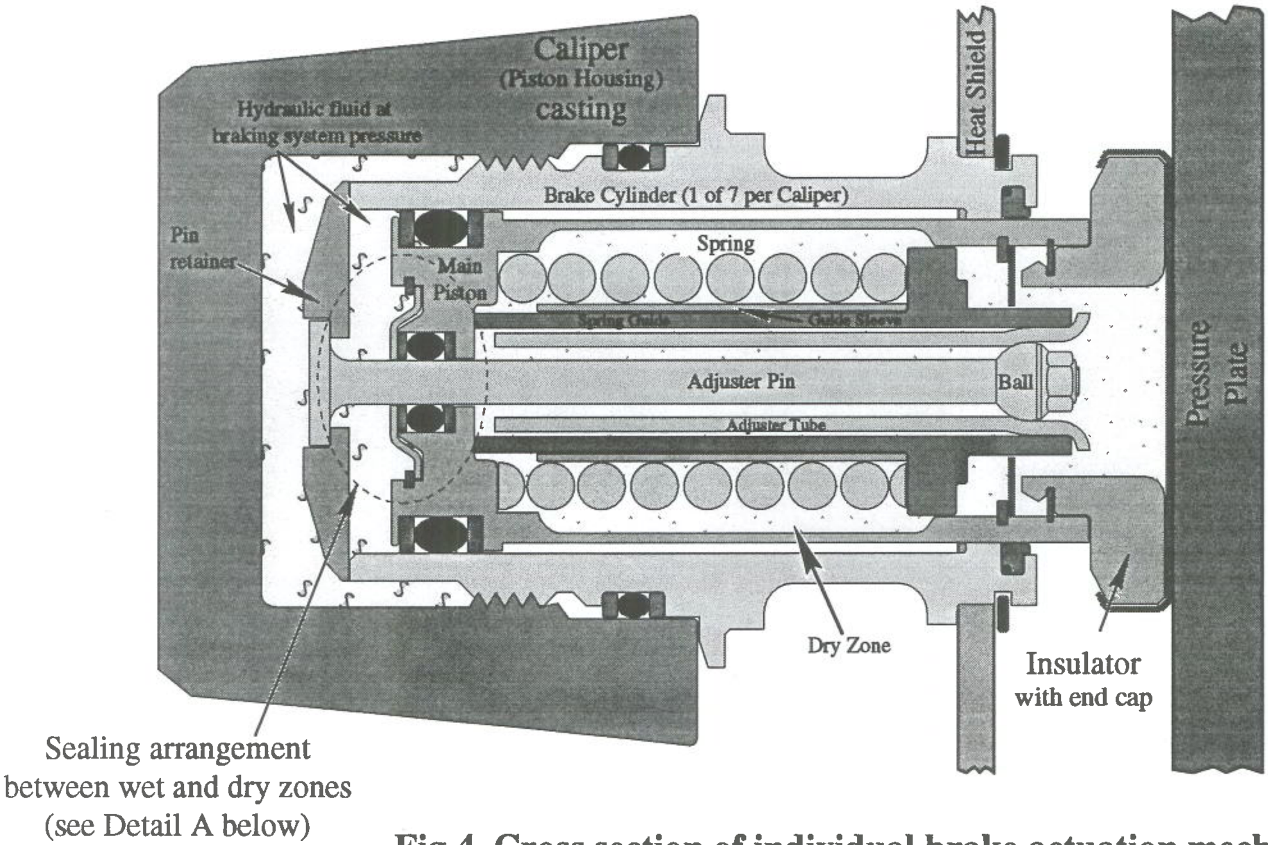
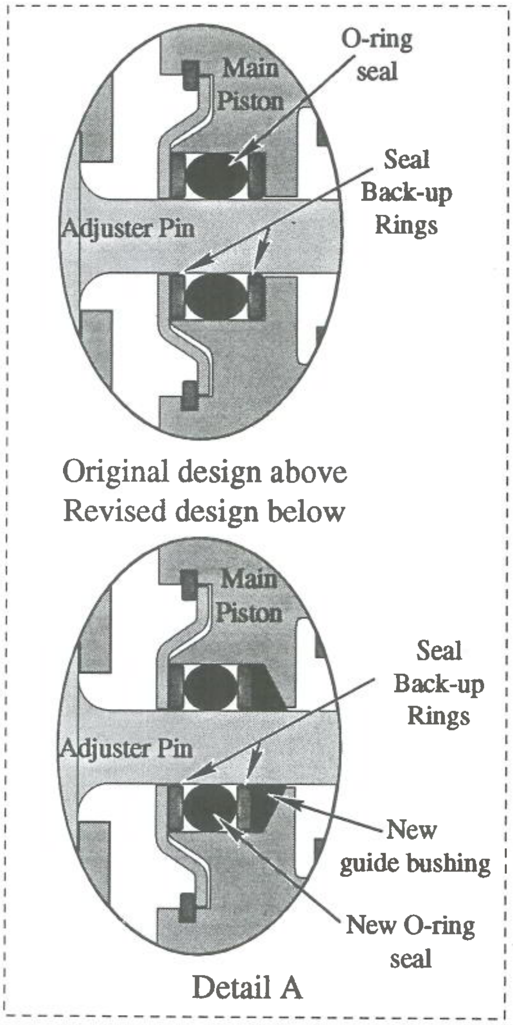


Fig.4 Cross section of individual brake actuation mechanism



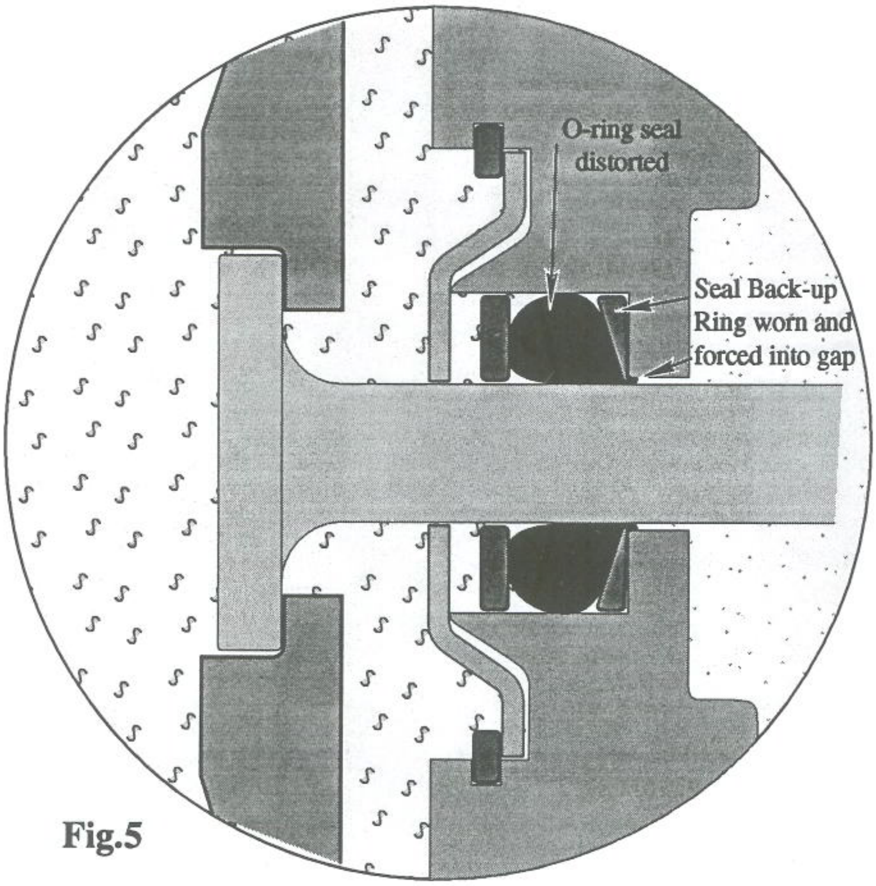


Fig.5

Mode of failure of seal between Wet and Dry Zones in the original design sealing arrangement

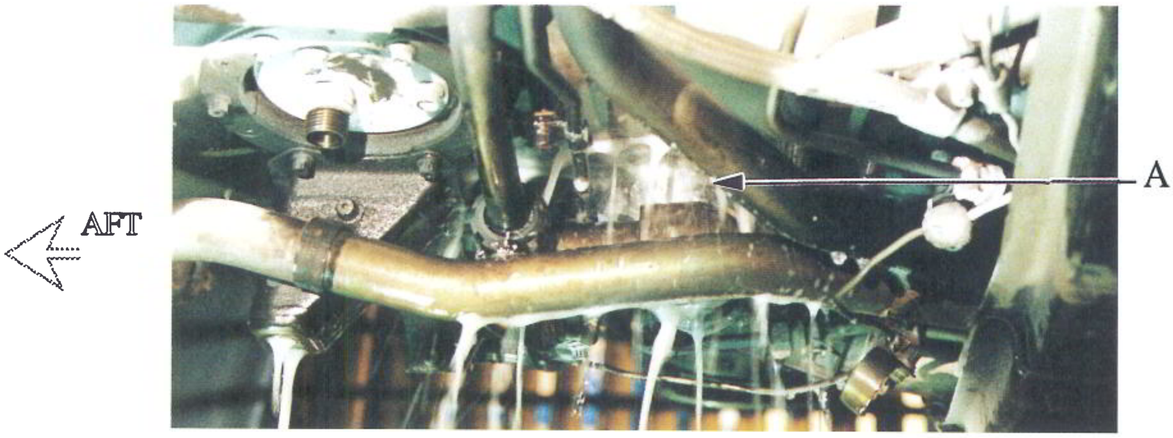
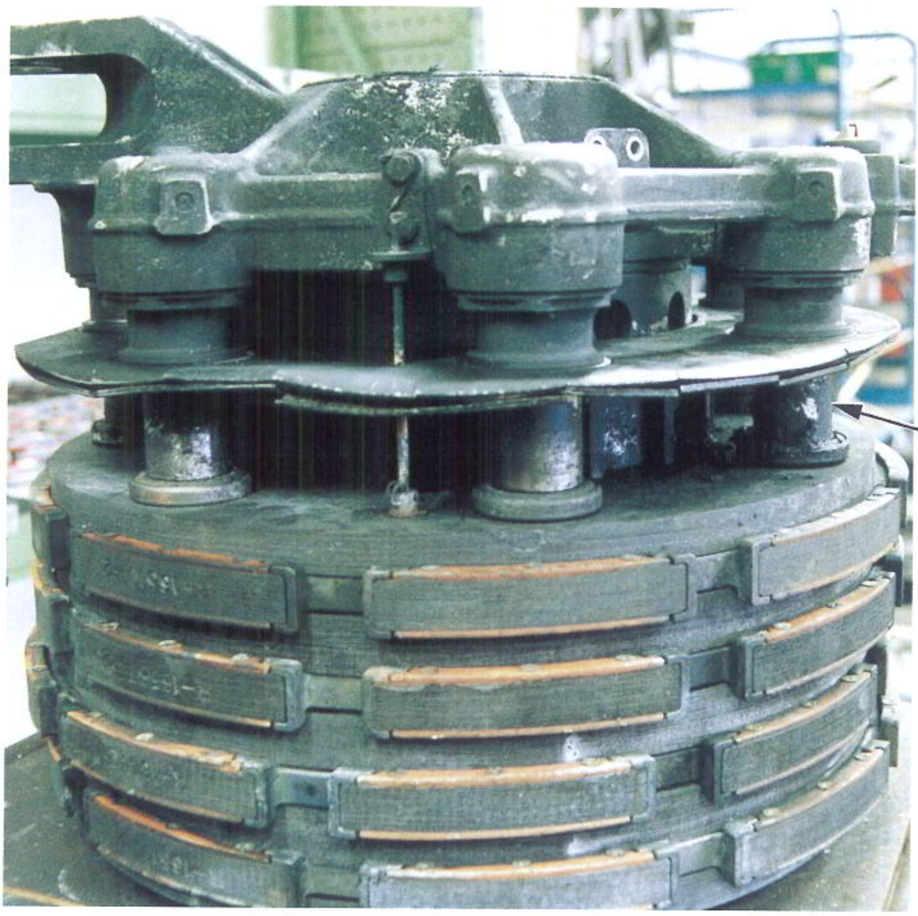


Plate 1

View of underside of engine from right side during test with 800 psi fuel pressure. Note spray of fuel issuing from HP fuel filter at top of outlet connection (Arrow A) and fuel froth dripping from compressor case and air pipe below engine.



Note piston and top of insulator covered in gummy deposit

Plate 2

Brake pack assembly, as received.

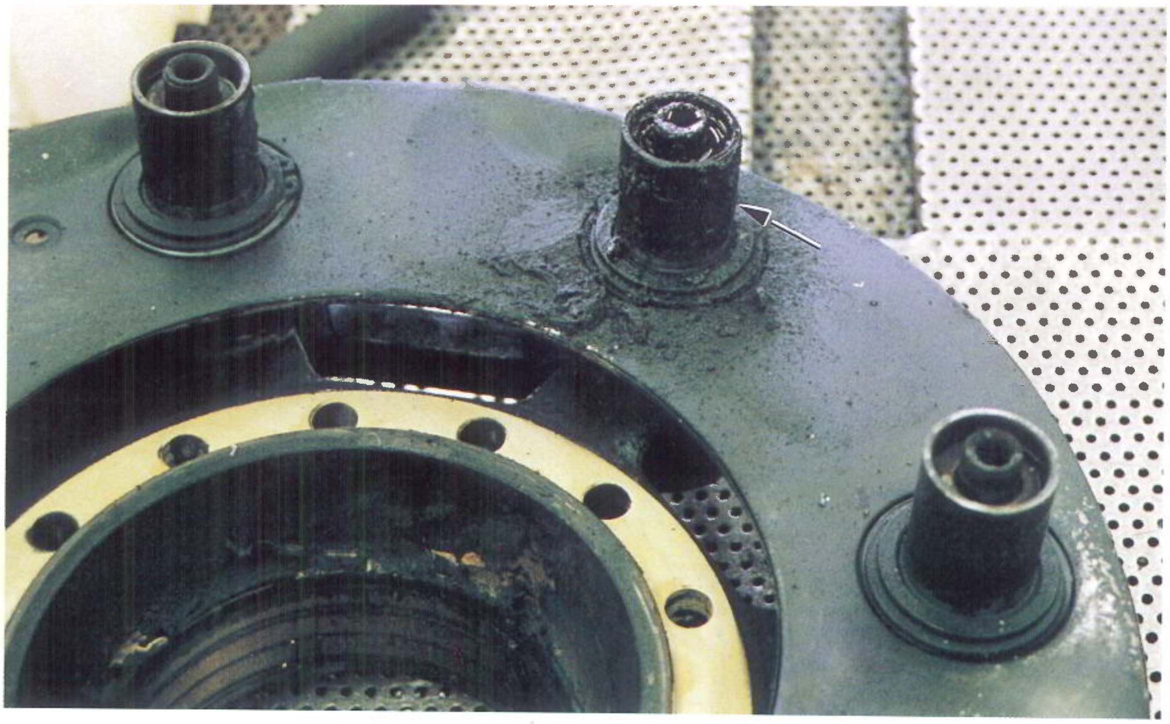


Plate 3

Three brake pistons with insulators removed.
Note middle piston - wet and covered with gummy deposits

Note 'Feather' of washer material drawn out.

Plate 4

Seal and dry-side back-up washer from brake adjuster.

Plate 5

View of seal showing area where material has been pinched off between adjuster rod and piston.