CIVIL AVIATION DEPARTMENT

ACCIDENT INVESTIGATION DIVISION

Report on the accident to Canadair CL44 G–ATZH near Waglan Island, Hong Kong on 2nd September 1977

August 1980

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August 1980

His Excellency the Governor
Government House
Hong Kong

Your Excellency

I have the honour to submit the report on the circumstances of the accident to CL44 G–ATZH which occurred near Waglan Island, Hong Kong on the 2nd September 1977.

I have the honour to be
Sir,
Your obedient servant

B D Keep
Chief Inspector of Accidents

Accident Investigation Division
Aircraft Accident Report No 1/80 (Hong Kong)

Operator:		Trans Meridian Air Cargo Ltd
Aircraft:	*Type:*	Canadair CL44
	Model:	D4
	Nationality:	United Kingdom
	Registration:	G–ATZH
Place of Accident:		Near Waglan Island, Hong Kong Latitude 22° 12′N Longitude 114° 21′E
Date and Time:		2 September 1977 at approximately 0038 hours
		All times in this report are GMT (Hong Kong Standard Time is 8 hours ahead of GMT)

Synopsis

The Chief Inspector of Accidents, Hong Kong, instituted an investigation into the accident. The Accidents Investigation Branch of the United Kingdom Department of Trade were requested to provide assistance and a team was despatched to Hong Kong on the same day as the accident.

Shortly after take-off from Hong Kong the aircraft's number four propeller was feathered. The crew reported that the aircraft had suffered an engine failure and that it had been shut down. Five minutes after take-off the crew reported an engine on fire and three minutes later there was an interrupted transmission 'We're going in – the engine's come off'. There were no further transmissions received from the aircraft which was seen to crash into the sea on fire approximately eight minutes after take-off.

1. Factual Information

1.1 History of the Flight

G–ATZH was operating flight KK 3751, a non-scheduled cargo service from Hong Kong to the United Kingdom with Bangkok as its first stop.

The aircraft, with four crew members on board, took off from Runway 13, Hong Kong International Airport, at about 0031 hours. As it became airborne a puff of smoke was seen from the rear of number 4 engine followed, according to one eye-witness, by a torching flame from the jet pipe exhaust which persisted for 10 to 12 seconds. The number 4 propeller was then seen to be stopped, apparently feathered. Radio telephony (RTF) reports from the crew who had been alerted to the smoke emission by Air Traffic Control (ATC) indicated the engine had failed and had been 'shut down'.

Witnesses' accounts of smoke emissions from the aircraft as it climbed out on a south-easterly heading after take-off vary. However, until it was about 2½ nm from the end of the runway at a height of about 450 feet above mean sea level (amsl) it appears to have trailed a thin stream of dark smoke behind the right wing from the vicinity of the engines.

About one minute after take-off the Tower Controller requested the crew's intentions and was told these were to 'go out', dump fuel and then return to Hong Kong.

Shortly after 00.33 hours the aircraft was cleared to contact Approach Control.

At 0033:51 hours the First Officer reported that the aircraft was climbing through 1000 feet and would shortly begin to dump fuel. He then acknowledged the Approach Radar Controller's suggestion to take up an easterly heading from the outer marker (See 1.8) and climb above 4000 feet before carrying out this operation. The aircraft was identified on radar by the Controller as it passed over the outer marker and turned on to the suggested heading.

At 0035:28 hours the First Officer informed Approach Control that the aircraft would have to return and land at Hong Kong without dumping fuel because of an engine fire.

The aircraft was given radar vectors for an immediate approach to Runway 31 and was cleared to descend to 2000 feet on the sea level altimeter setting (QNH) of 1007 millibars. According to the Approach Radar Controller returns from the aircraft indicated that it made a right turn and took up a heading of 295° (M) as instructed. During the turn he informed the crew of the aircraft's position 12 nm south-east of the airport and cleared them to continue the approach visually if at any time this was possible. The First Officer advised that although the flight was in Visual Meteorological Conditions (VMC) radar vectoring was still necessary.

As the aircraft closed the extended centre line of the final approach on a heading of 295° (M) at 0038 hours the Commander warned the Controller to have fire vehicles standing by and advised that the crew had seen flames 'but they seem to be extinguished at this time'. Shortly afterwards he reported 'there's still smoke coming out of it' (the engine). At 0038:17 hours reports from the First Officer indicated control of the aircraft had been lost and 'the engine's come off'. Radar returns from the aircraft then faded from the screen at a position 8 nm south-east of the landing runway threshold. Subsequent attempts to contact the aircraft by RTF proved unsuccessful.

Witnesses on a merchant ship approaching Waglan Island on a north-westerly heading saw the aircraft on fire in the final part of the flight. The fire became a fire ball almost wholly engulfing the aircraft which then made an uncontrolled descent into the sea approximately 2½ nm east of Waglan Island sinking immediately.

ATC alerted the emergency services and a combined sea and air search and rescue operation was mounted. An area of floating debris was found approximately 4 nm south-east of Tathong Point consisting of cargo, landing gear, wheels and tyres, fire extinguisher bottles and an inflated life raft. There were no survivors.

The estimated ground track of the aircraft prior to the loss of radar contact is shown at Appendix A.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Others*
Fatal	2 (plus 2 missing and presumed killed)	–	–
Non-fatal/minor	–	–	–
None	–	–	–

1.3 Damage to aircraft

The aircraft was destroyed by impact forces and fire.

1.4 Other damage

None

1.5 Personnel Information

1.5.1 Commander

Age:	48 years
Licence:	United Kingdom Airline Transport Pilot's Licence valid to 24 July 1978

Aircraft ratings:	Part 1 (in command) Auster Variants, Lockheed Constellation 749, Canadair CL44
Instrument rating:	Valid until 19 December 1977
Last competency check:	2 June 1977
Last route check:	24 August 1977
Last medical examination:	Class 1–2 April 1977 – valid until 31 October 1977 Assessed fit; no restrictions
Total pilot hours:	11,446 hours 30 minutes
Flying hours in command on type:	5,880 hours
Total flying hours in last 28 days:	64 hours 35 minutes, (all in command on type)
Previous landings at Hong Kong International Airport:	20 (estimated)
Rest period:	35 hours 10 minutes prior to last flight

1.5.2 *Co-pilot*

Age:	41 years
Licence:	United Kingdom Commercial Pilot's Licence valid to 25 April 1978
Aircraft ratings:	Part 1 (in command) Piper PA30, PA39; Cessna series 150, 179, 172, 175, 182 Part 2 (co-pilot) Canadair CL44
Instrument rating:	Valid until 10 October 1977
Last competency check:	26 April 1977
Last route check:	20 November 1976
Last medical examination:	Class 1–6 March 1977 – valid until 30 September 1977. Assessed fit; no restrictions
Total pilot hours:	6,356 hours 45 minutes
Flying hours on type:	2,153 hours 15 minutes (all as co-pilot)

Total flying hours in last 28 days:	73 hours 45 minutes (as co-pilot on type apart from 1 hour 10 minutes)
Previous landings at Hong Kong International Airport:	Not determined
Rest period:	35 hours 10 minutes prior to last flight

1.5.3 *Flight Engineer*

Age:	52 years
Licence:	United Kingdom Flight Engineer's Licence valid to 15 April 1978
Aircraft rating:	Canadair CL44
Last competency check:	16 March 1977
Last route check:	14 July 1977
Last medical examination:	17 March 1977 valid until 31 March 1978. Assessed fit; required to have available spectacles which correct for near vision whilst exercising the privileges of the licence
Total hours as Flight Engineer:	11,841 hours
Total hours on type as Flight Engineer:	5,556 hours
Total flying hours in last 28 days:	72 hours 35 minutes
Rest period:	35 hours 10 minutes prior to last flight

1.5.4 *Flight Navigator*

Age:	57 years
Licence:	United Kingdom Flight Navigator Licence valid until 3 May 1978
Last competency check:	7 March 1977
Last route check:	7 March 1977
Last medical examination:	28 April 1977 valid until 30 April 1978. Assessed fit; required to wear spectacles which correct for near vision and have available a second pair when exercising the privileges of the licence
Total flying hours in last 28 days:	58 hours
Rest period:	35 hours 10 minutes prior to last flight

1.6 Aircraft Information

1.6.1 Details of Aircraft

Type:	Canadair CL44 D4			
Manufacturer:	Canadair Limited, Canada			
Date of manufacture:	1961			
Certification:	(a) Certificated in the Transport Category (Passenger); the Certificate of Airworthiness was last renewed on 8 August 1977 and was valid for one year. (b) A Certificate of Maintenance was issued after a Service P6 check on 8 July 1977, valid for 850 hours or until 4 November 1977 whichever came first, and valid at the time of the accident.			
Total airframe hours:	29,376 hours since manufacture and 69 hours since its last periodic check			
Engines:	Four Rolls-Royce Tyne 515/12 propeller-turbines; engine maintenance was 'on condition' with specified overhaul periods for hot and cold sections dependent on monitored performance			
Engine position:	1	2	3	4
Year of manufacture:	1962	1961	1961	1961
Hours since manufacture:	19,889	21,439	30,174	28,819
Hours since last shop visit:	4,097	2,552	5,176	1,436
Propellers:	Hawker Siddeley Dynamics, four blade, constant speed, full feathering, fully reversible			
Propeller position:	1	2	3	4
Year of manufacture:	1961	1961	1960	1960
Hours since overhaul:	3,229	4,604	3,123	5,228
Maximum certificated take-off weight:	92,255 kg			
Take-off weight:	84,500 kg (calculated)			

Centre of gravity limits:	at 84,500 kg; between 15.2% and 30.8% MAC
Centre of gravity at time of accident:	26.9% MAC
Retraction of the undercarriage moves the centre of gravity aft:	1% MAC (approx)
Fuel:	at take-off the fuel on board was 17,963 kg of JET A-1 (AV TUR) of which 1,534 kg were in each auxiliary tank with the remainder distributed equally between the four main tanks

1.6.2 *Aircraft Fuel System*

The aircraft fuel system consists of three integral tanks in each wing – one auxiliary and two main tanks. The main and auxiliary tanks are interconnected by a common manifold permitting single-point pressure fuelling and defuelling, cross-feeding and fuel transfer. Fuel from the auxiliary tanks may be supplied directly to the engine fuel system or to the main tanks (when their levels are depleted). During normal operation each engine is fed from its associated main tank and the manifold system is isolated. Fuel is delivered from the appropriate tank via the booster pump, selector valve and firewall shut-off valve to the engine.

1.6.3 *Engine Fuel System*

The engine fuel system is connected to the aircraft fuel system at the engine nacelle firewall and consists of the firewall shut-off valve, fuel heater, low pressure fuel pump, flowmeter, fuel filter, high pressure fuel pump, fuel control unit (FCU), LP shaft governor and HP fuel valve.

1.6.4 *Engine Controls*

The power levers and engine condition levers are installed on a centrally mounted pedestal on the flight deck. The engine condition levers are used for starting and stopping the engines, trimming the fuel flow from the FCU to cater for variations in ambient temperature, selecting positive coarse pitch for propeller feathering, arming the fire extinguisher system and operating the fluid (fuel, generator constant speed drive oil and hydraulics) shut-off system. Selection of a condition lever to the 'FEATHER' or 'FUEL OFF' position closes the HP fuel valve. Selection to the 'PULL UP TO ARM FIREX' position closes all the firewall fluid shut-off valves and arms the fire extinguishing system of the affected engine.

1.6.5 *Fuel Jettison*

An electrically operated system controlled by two guarded switches on the system operator's panel enables fuel to be gravity dumped from the main tanks via two valves and an extendable chute located on the underside of each wing between the inner and outer engine nacelles. The operation can be started or stopped as required, but once extended chutes cannot be retracted in flight.

1.6.6 *Master Warning System*

The system consists in part of red master warning lights and amber master caution lights located in pairs at the pilot's and systems operator's stations coupled with an annunciator panel for each pilot. A serious malfunction of an engine or aircraft system is indicated by simultaneous flashing of the red master lights and is identified by illumination of the relevant captioned window on each annunciator panel. The warning is cancelled and the system re-set by depressing one of the red master lights but annunciator panel captions remain illuminated whilst a malfunction persists. Similarly the master caution lights and annunciator panels provide indications of non-critical malfunctions.

1.6.7 *Engine Fire Warning*

An engine fire is indicated by illumination of the red lights of the master warning system together with an alarm bell on the flight deck. The engine concerned can be identified both by the associated warning light on the engine fire control panel and by another on the engine condition lever.

1.6.8 *Airworthiness Requirements*

Original type certification was in accordance with FAA requirements CAR 4b. Where 'Fireproof' construction was required the constructors employed the interpretation of FAA FSSR 453 (Flight Standards Service Release) of 9–11–61, '..... must be capable of carrying the loads and performing the function for which designed when subject to a 2000° F flame for 15 minutes'.

1.6.9 *Recent History*

Aircraft and engine records did not indicate any recent relevant recurrent problems, or relevant equipment deficiencies at the time of the last take-off. Routine records of the operational parameters of each engine up to 20–8–77 were available, and no significant features or trends over the preceding period were apparent.

1.7 Meteorological Information

The weather at the time of the accident was good.

The following observation was recorded at Hong Kong International Airport at 0038 hours:

Surface wind:	080°/7 knots
Visibility:	10 kilometres
Cloud:	1/8 2,000 feet 3/8 30,000 feet
Temperature:	+29° C
Dew Point:	+23° C

QNH:	1007 millibars
QFE:	1006 millibars

The Waglan Island 0105 hours weather was recorded as:

Surface wind:	030°/10 knots
Visibility:	14 kilometres
Cloud:	1/8 cumulus 2,500 feet 4/8 cirrus 20,000 feet
Temperature:	+29.7° C
Dew Point:	+23.5° C

The accident occurred in daylight.

1.8 Navigation Aids

The airport was equipped with an ILS on runway 31. A non-directional beacon (NDB) was co-located with the ILS outer marker at latitude 22° 14′ 27″ N longitude 114° 17′ 07″ E (Tung Lung Island). All three radio aids were operating and serviceable at the time of the accident as was the terminal VHF omni-directional range (TVOR) located at latitude 22° 14′ 26″ N longitude 114° 17′ 11″ E.

The radar unit was equipped with Secondary Surveillance Radar (SSR) which was not in use at the time of the occurrence as it was outside the published operating hours. Secondary radar information including an altitude read-out, and normally displayed on a screen in the Air Traffic Control Centre, was not therefore available, although prior to departure the aircraft had been allocated a transponder code to 'Squawk' as a standard procedure. Primary radar information was displayed at the Area Controller's, the Approach Controller's, and the Co-ordinator's positions.

1.9 Communications

The following ATC units were in contact with the aircraft during its last flight:

(a) Ground Movements Control which issued 'start up', 'taxi', and 'airways' clearances on 121.6 MHz.

(b) Tower Control which took over control of the aircraft on 118.7 MHz prior to its entering the active runway.

(c) Approach Control which took over control of the aircraft on 119.1 MHz during the climb-out and provided radar vectoring when advised of the emergency.

Each of these frequencies were recorded on tape for the relevant period of the flight and were subsequently transcribed by the Hong Kong Civil Aviation Department. Normal two-way communication was maintained with the aircraft until the accident occurred.

1.10 Airport Information

Hong Kong International Airport is at an elevation of 4.57 metres (15 feet) amsl and has one asphalt/concrete surfaced runway (13/31) from which the aircraft took off to the south-east. Runway 13 is 3329 metres long x 61 metres wide. No bird remains or debris from the aircraft were found during an inspection of the runway after the accident.

1.11 Flight Recorders

The aircraft was equipped with a Sundstrand FB 542 flight data recorder and a Sundstrand V557 cockpit voice recorder, neither of which was recovered.

1.12 Wreckage

1.12.1 Location and Recovery

The wreckage position, as indicated by aviation fuel rising to the surface at latitude 22° 11′ 54″ N, longitude 114° 21′ 10″ E, was buoyed. The charted water depth in the vicinity of this position is approximately 100 feet.

Attempts to locate and salvage wreckage commenced on the day of the accident and continued intermittently until 5 August 1978. Although not particularly suitable for the task the sonar and echo-sounding equipment available for use revealed possible wreckage contacts. The contacts in the area adjacent to the buoy were investigated initially by Royal Navy divers and subsequently by commercial divers, the use of trawlers being precluded by the risk of damage to a number of undersea communication cables which traversed the immediate area.

Diving operations were severely restricted by adverse weather, and the search for wreckage was hampered by very poor bottom visibility. Divers reported a layer of mud up to 10 feet thick covering the sea bed but there is evidence that wreckage did not initially sink into the mud to any appreciable depth.

Due to the non-availability of commercial divers salvage operations were halted early in April 1978 and were abandoned early in August 1978 after attempts to locate the remaining wreckage by United States Navy divers proved fruitless.

Approximately 25 per cent of the total aircraft structure was recovered comprising portions of the forward and rear fuselage including most of the flight deck and empennage, inboard portions of both wings with parts of wing torque boxes, numbers 1 and 3 engines, number 2 and 3 propellers and the main landing gear. Little of the centre fuselage or cargo was recovered. (See Appendix B).

1.12.2 Examination

A detailed examination of the salvaged wreckage was carried out. There was insufficient wreckage to establish conclusively whether or not the aircraft had been intact on impact with the water. The degree of break-up and the pattern of structural failures indicate it had struck the sea with a fairly high rate of descent in a right wing low, moderately nose-down attitude.

A high proportion of the rear fuselage and right hand tailplane and elevator was recovered. All upper surfaces showed clear evidence of brief exposure to intense, external in-flight fire. The whole of the fin and rudders had also suffered similar exposure. The extent of fire exposure could not be determined because of lack of wreckage. However, it included inboard sections of the left hand tailplane and elevator, and extended forward along the fuselage at least to the swing tail break on the left side and to the rear underfloor freight bay door area on the right side. The fire had not caused any apparent structural failure in flight.

Number 3 engine jet pipe overwing tunnel structure had also been exposed to an external fire, and the tunnel roof aft access panel had reached a temperature estimated to be in excess of 500° C. The extent to which the nacelle had been exposed to fire could not be ascertained due to lack of wreckage, but number 3 engine showed no signs of internal or external fire damage.

The recovered portions of number 4 fuel tank showed clear evidence of a fire and possible explosion in the vapour space, with overheat damage progressively more marked towards the outboard end of the tank. The damage comprised internal paint sooting and charring of outboard portions of the tank top skin, and electrical cable damage towards the outboard end of the tank was also consistent with a fire in the vapour space. Evidence was also found that the top skin of the tank had had some fire exposure after sustaining a number of fractures.

Number 4 engine and propeller were not found. The only part of number 4 nacelle recovered consisted of the wing torque box undersurface and a small portion of forward spar, together forming the lower part of the nacelle protected area rear boundary; and most of the right hand sidewall and side segment of the overwing section of the jet pipe tunnel. This included a jet pipe mounting bracket and an adjacent section of engine centrifugal oil breather pipe. The portions of nacelle protected area rear structure exhibited sooting and paint blistering, and associated electrical cables had suffered insulation burning and conductor external embrittlement, clearly indicating that a fire had occurred in the nacelle protected area.

The jet pipe tunnel side segment showed no signs of external overheat, but examination and metallurgical tests showed that internal overtemperature had occurred in this area. The tunnel sidewall was estimated to have attained a temperature in the region of 350° C, and the sidewall heat shield had reached in excess of 520° C in the vicinity of the jet pipe bracket. The bracket had attained 600-800° C compared to a normal operating temperature of 120° C, and the titanium parts of the bracket exhibited a pattern of overheat blueing indicative of a heat flow from the jet pipe. It was not possible to establish when the overtemperature had occured, or its duration. A flexible coupling joining 2 inch diameter rigid stainless steel sections of the engine oil breather pipe and installed adjacent to the jet pipe bracket also showed clear signs of overheat. The silicone rubber had almost completely disappeared from the coupling, leaving only the woven glasscloth wrap. Similar couplings recovered from other nacelles showed no signs of deterioration, following similar marine environment exposure. Expert opinion was that for an 8 minute high temperature exposure period, for example, the condition of the number 4 nacelle coupling was consistent with a temperature of 800° C or greater.

Evidence was found that the number 4 engine TGT (turbine gas temperature) gauge was reading 678° C at impact. This was approximately 18-28° C in excess of the normal value at take-off power.

Neither fire extinguisher bottle from nacelle 4 was recovered. Neither bottle from nacelle 1 had been fired.

It was established that at the time of impact with the sea:

(i) both main landing gears were extended;

(ii) Numbers 1 and 3 engines were running but not under high power;

(iii) Numbers 1, 2 and 3 fuel tank selector switches were at Tank-Engine;

(iv) Number 4 fuel tank selector switch was at OFF;

(v) Number 4 fuel tank selector valve was closed;

(vi) Number 1 fuel tank selector valve was at Tank-Engine;

(vii) Number 4 propeller Beta range warning light was on, either indicating pitch below flight idle setting or resulting from wiring damage;

(viii) all four fuel dump valves were closed (the dump chutes were not recovered);

(ix) the System operator's (Flight Engineer) master warning and master caution lights were on;

(x) the electrical generation systems were in a state consistent with correct operation following a Number 4 engine failure.

Annunciator panel warnings as determined from parts of one panel were:

(i) Number 4 engine fuel temperature high – on;

(ii) Number 4 engine breather overheat – evidence suggested that the warning was on, but this was not conclusive;

(iii) control surface locks engaged – on.

As found, all four power levers were almost fully advanced, Number 4 condition level was selected to the feather position and the remaining condition levers were in the 'rich sector' of the fuel trimming range.

1.13 Medical and Pathological Examination

Post mortem examination of the only two occupants whose bodies were recovered, the First Officer and the Flight Engineer, showed the former had died from severe multiple injuries. The latter had also sustained multiple injuries but had died from severe head injuries.

Toxicological examination of the First Officer was not possible. Salicylic acid found in the urine of the Flight Engineer suggested he might have taken aspirin for some minor illness or headache.

1.14 Fire

According to eye-witnesses the aircraft was almost wholly engulfed by fire prior to making an uncontrolled descent into the sea. This was confirmed by some of the portions of wreckage which were subsequently recovered and which bore clear indications of exposure to intense in-flight fire. (See Appendix C.)

1.15 Survival Aspects

It was impossible to determine if the pilots were wearing safety harness or the remaining two crew members were wearing lap straps. However, the nature of the impact was such that the accident is considered to have been non-survivable.

1.16 Tests and Research

In the light of information gained from an examination of the recovered wreckage, which showed some evidence of pre-impact fire damage and in-flight failures, a review was made of the relevant areas of aircraft and engine design and maintenance, and of past incidents.

1.16.1 Design and Maintenance Review

Reviewing the design details with the manufacturers and the United Kingdom Civil Aviation Authority a number of points of concern were uncovered. However, none could be directly related to the accident. The areas highlighted were as follows:

(i) Fuel, hydraulic and constant speed unit (CSU) oil shut-off valve mountings, mounting plates and valve bodies, which are effectively part of the engine firewall, were manufactured of light alloy. It is questionable whether the construction maintains the integrity of the firewall as a 'Fireproof' barrier (see 1.6.8).

(ii) There was no positive means of (or manufacturer's requirement for) maintaining a minimum separation between the fuel firewall shut-off valve cable and the firewall.

(iii) There was no indication on the flight deck of the position of the firewall fluid shut-off valves, and furthermore there was no requirement for frequent checks of shut-off valve operation.

(iv) Flexible couplings forming part of engine oil breather ducts were not considered to be of Fireproof standard, although it was understood that they were required to be so by original certification requirements. Each duct incorporates a number of flexible couplings in its passage through zones 1 and 2, the nacelle protected area and the jet pipe tunnel.

(v) There was evidence of poor engine nacelle drainage with a number of undrained pockets containing pools of oil seen on aircraft in service.

(vi) There were reports of blocked and misaligned engine drain pipes on aircraft in service.

(vii) Flame traps were not fitted to main fuel tank outlets.

(viii) Some cases had been reported of fuel dump system operation where dump chutes failed to extend and the opening of dump valves was not automatically inhibited.

1.16.2 *Review of Previous Incidents*

A number of recurring problems related to the Tyne engine were identified, notably failure of the HP turbine cooling air manifold. This and other failures have resulted in twelve known cases where turbine blades were released, penetrating the cowl in nine cases. In four of these cases serious nacelle damage was reported to have resulted. All engines on ZH incorporated a modified manifold, and there has to date been no primary failure of this type of manifold.

Eleven cases of Tyne engine fires were recorded between 1962 and 1975, excluding those resulting from released turbine blades, where oil, fuel or titanium fires or combustion flame break-out had occurred. Nine of these incidents involved engine or auxiliary gearbox oil fires, the majority of which occurred as a result of bearing or oil seal failure. Detailed information on nacelle damage in many of the cases could not be found, but the following significant points stood out:

(i) In five cases the oil fed fire burnt its way out of the engine and in two cases out of the nacelle as well. In one case the fire penetrated the nozzle box although this is considered to have taken several hours to occur.

(ii) These internal engine fires did not always produce an engine fire warning indication. This would not necessarily be expected while the fire remained within the engine.

(iii) In one case the engine fire was reported to have persisted until after the aircraft had landed.

(iv) In one case the aft fire bulkhead (zone 2-NPA) was found to be distorted, apparently by the release of hot engine gas, and in this and another case overheat damage in the nacelle protected area was reported.

(v) In one case the leading edge of the wing was ruptured some 6 feet outboard of the nacelle by a zone 2 access panel apparently blown off by hot engine gas.

The above events were largely concerned with three particularly outstanding cases, namely engine fires experienced by a Vanguard in 1966, a CL44 10 minutes after take-off from Jeddah in 1972, and a CL44 5 minutes after take-off from Hong Kong in 1975. In each of these incidents overheating or burning in zones 1, 1A and 2 was reported. In the 1972 Jeddah incident an engine oil fire entered zone 2 and burned a large hole through the firewall into zones 1A and 1. The fire penetrated the auxiliary gearbox oil cooler hoses and ignited the oil. This resulted in a rupture in the low pressure fuel system with a fuel fed fire in zone 1. It was reported that the engine mounting structure was overheated and that the propeller did not fully feather. The engine fire warning system had alerted the crew to the situation. Prior to the incident flight there had been ample warning of impending engine problems; on each of the previous three flights the engine had been shut down due to low oil pressure indication, associated with massive oil consumption grossly exceeding allowable limits.

Modifications aimed at preventing recurrence of the failures that caused the above incidents have been introduced, and some were incorporated in ZH's No 4 engine. Previous incidents did show that serious nacelle damage can occur in the event of an engine internal oil fire or combustion flame release.

1.17 Other Information

1.17.1 *Extract from Aircraft Flight Manual, Section 3, Pages 8 and 8a 'Propeller feathering and Engine Shutdown'.*

Condition lever:	FEATHER
Fuel booster pump:	OFF
Fuel selector switches:	as required to isolate dead engine
Electrical power:	Manually Trip constant frequency ac generators and check changeover. Check ac power normal (27 volts)
De-icing:	All propeller cowl and nacelle scoop de-icing OFF for dead engine.
In the case of No 3 engine shutdown:	Prop Synchrophase switch OFF Prop Synchrophase Computers switch OFF
Fuel management:	In accordance with normal fuel Consumption Schedule (Section 2) within permissible asymmetric fuel limits

2. Analysis

The evidence points quite clearly to the cause of the accident being a loss of control following an in-flight failure of aircraft structure which had been weakened by severe fire damage caused by intense and extensive fuel-fed fire. The main effort in the investigation was, therefore, directed towards establishing the origin of the fire and its method of propagation.

2.1 Recovery of the Wreckage

Only some 25 per cent of the aircraft wreckage was recovered after a protracted salvage operation. The recovery was hampered by the depth of water, the depth of mud on the sea bed and the poor underwater visibility. In addition, specialized underwater location equipment was not available and adverse weather conditions precluded diving operations for relatively long periods of time. The non-recovery of the bulk of the aircraft structure, in particular the number 4 engine and propeller, together with the flight data and cockpit voice recorders made the conduct of the investigation and the resolution of the cause of the accident extremely difficult and precluded identification of the primary failure.

2.2 The Wreckage

2.2.1 *The Engines*

The number 4 engine and its propeller were not recovered. However, there were clear indications that number 4 engine had been shut down and the number 4 fuel selector valve put to 'off' before impact. There was no indication as to when these actions were carried out, apart from the crew's comments on RTF that they had shut an engine down within a minute of starting the take-off roll. At that time they did not indicate if an engine fire warning had occurred, but some five minutes later reported that they had an engine on fire. Although the crew did not mention number 4 engine as the failed engine there is little doubt that it was. It was not possible to establish whether the number 4 engine firewall shut-off valves were closed. The number 4 condition lever was found at 'FEATHER', but could have been in the 'FIREX' position prior to impact.

The reading of 678° C obtained from number 4 TGT gauge was considered to be a reliable indication of the reading at impact, and most probably represented the temperature sensed at the time that the engine thermocouple signal wire was severed, less gauge reading driftdown at about 18° C per second for the period between the wire severance and the loss of the TGT gauge power supply on impact with the sea. If the thermocouple wire had been cut at lift-off, for example due to engine disruption, gauge driftdown over approximately 7 minutes would have driven the gauge reading to zero before impact. If the thermocouple signal wire were open circuited at the time of number 4 engine detachment, estimated at in the order of 15-30 seconds before impact, driftdown would mean that TGT indication at the time of engine separation would have been 950-1200° C. Although not conclusive, the number 4 engine TGT gauge reading would thus have been consistent with a fire internal to the engine or in zone 2 at the time of engine separation.

The illumination of the Central Warning Panel (CWP) number 4 engine high fuel temperature caption and possibly the breather overheat caption could be an indication of a fire in zone 1, but would also be consistent with the earthing of sensor cables in number 4 nacelle as a result of disruption of the structure. It is most likely that stray earths were responsible for the number 4 propeller Beta range and control lock CWP warnings.

Examination of the two engines (1 and 3) and propellers (2 and 3) recovered, and the associated nacelle structure for number 2 engine (the engine itself not being recovered), showed no sign of any fire damage or pre-impact mechanical failure. The damage observed was consistent with water impact at a fairly low power setting.

The absence of any wreckage associated with number 4 engine nacelle forward of the wing torque box though not conclusive is entirely consistent with a pre-impact separation of number 4 engine. This is also supported by evidence from eye-witnesses.

2.2.2 *Fire Damage*

Examination of the small amount of wreckage recovered associated with number 4 nacelle showed that the structure had been exposed to fire or severe overheat conditions at some time, including moderate fire damage at the rear of the nacelle protected area (NPA). It is not considered likely that this fire damage would have produced a sufficiently elevated temperature in number 4 fuel tank to have ignited its contents.

Although there was evidence that components located in the interspace between number 4 engine jet pipe and the nacelle tunnel side wall had been significantly overheated there was no indication that a fire had occurred in this space. The high temperature to which a number 4 engine jet pipe mounting bracket had been subjected and the pattern of overheating indicated that the jet pipe had overheated. This was consistent with the engine having experienced an internal fire, but it was not possible to determine when this occurred. None of the number 4 engine breather pipe flexible couplings located in zones 1 or 2 or the nacelle protected area was recovered, but a coupling further downstream in the jet pipe tunnel had clearly been severely disrupted by fire. Estimates of temperatures attained by surrounding components indicated that the coupling damage had resulted from internal overheat. The degree of post-impact deterioration of the degraded coupling could not be determined, but it was questionable whether it continued to perform its function of containing breather pipe contents prior to impact. Both the damage to the jet pipe bracket and to the flexible coupling was consistent with an internal engine fire continuing after engine shutdown.

The decision by the crew, after shutting down number 4 engine, to dump fuel before landing strongly suggests that if an engine fire existed at that time the crew were not aware of it. If there had been indications of a persistent engine fire there would have been a strong incentive to land quickly and it is most improbable that they would have elected to proceed with fuel dumping under those circumstances. Indeed, some five minutes after take-off, when they observed that they had an engine fire they stated on RTF 'we won't be able to dump, we've got an engine on fire .....'.

The evidence of an in-flight fire and possibly an explosion in number 4 fuel tank was quite clear, but it was not possible to establish when this occurred with relation to other events. The type and pattern of fire damage was consistent with a fire having persisted for a short period, but without causing any significant damage, with a tank vapour space explosion when the aircraft was inverted or subjected to a negative 'g' condition. However, this evidence was not totally consistent or conclusive.

The wing plank forming the top of number 4 fuel tank had suffered a number of in-flight fractures the extent of which made it probable that the right-hand wing outboard of number 4 engine became detached in flight.

There are a number of ways in which an uncontrolled fire centred on number 4 nacelle could result in ignition of fuel in number 4 fuel tank. These include an external flame or hot gas impinging on the unprotected number 4 fuel tank vent outlet located close to the nacelle; fire or hot gas escaping from the jet pipe into the muff and thence via the muff spill pipe to the wing leading edge anti-icing duct, having burned through the light alloy anti-ice system shut-off valves.

A fire in the NPA could also penetrate light alloy portions of anti-ice ducts located within the NPA. It was also noted that a main fuel tank vent light alloy spider is located on the outboard side of number 4 nacelle, separated from the jet pipe muff and the engine breather pipe by the light alloy nacelle side wall and light alloy heat shield only. One of the flexible couplings incorporated in the breather pipe is located near the spider.

It is considered that the external fire exposure to the upper parts of number 3 nacelle and the aircraft rear fuselage and empennage can only have resulted from the in-flight release of fuel in bulk associated with abnormal aircraft manoeuvres and attitudes. This would be entirely consistent with the loss of control and the breaching of number 4 fuel tank, both these events following detachment of the right-hand wing outboard of number 4 nacelle. However there is no direct evidence to support this. Ignition of fuel during dumping, whether or not the dump chutes were deployed, could possibly produce the torching damage to the rear fuselage and empennage but not to the upper surface of number 3 nacelle.

3. Conclusions

3.1 Findings

(i) The aircraft had been maintained to an approved schedule and its documentation was in order.

(ii) The crew were properly licensed and sufficiently experienced to carry out the intended flight. They had enjoyed an adequate period of rest before coming on duty for the flight.

(iii) The aircraft was properly loaded, the weight at take-off was below the maximum authorized for the ambient conditions, and the Centre of Gravity was within the prescribed limits.

(iv) Number 4 propeller was feathered shortly after rotation and the engine was shut down.

(v) Although the crew had intended to dump fuel it is considered improbable that the dump procedure was initiated.

(vi) The evidence indicated that number 4 engine experienced an internal fire resulting in jet pipe and breather pipe overheat.

(vii) Flexible couplings in the engine oil breather duct were not Fireproof although certification requirements required them to be so.

(viii) Number 4 nacelle protected area and number 4 fuel tank both experienced an internal fire.

(ix) It was not possible to establish the cause of the number 4 engine fire or how it apparently propagated.

(x) There had been several previous cases of uncontained engine fires in CL44 aircraft, usually associated with increased engine oil consumption prior to engine failure. There was no evidence in the subject case of a high oil consumption prior to the accident flight.

(xi) The number 4 engine and right-hand wing outboard of it became detached as a result of fire damage. This resulted in a loss of control.

3.2 Cause

The accident was caused by a loss of control following in-flight separation of the right-hand outboard wing section and the number 4 engine. These failures followed a number 4 engine failure, an internal engine fire and a fire in the aircraft fuel system eventually resulting in a massive external fire.

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