AI2012-5

AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

JAPAN AIRLINES INTERNATIONAL CO., LTD.
J A 0 0 2 D

June 29, 2012

Japan Transport Safety Board

The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board (and with Annex 13 to the Convention on International Civil Aviation) is to prevent future accidents and incidents. It is not the purpose of the investigation to apportion blame or liability.

Norihiro Goto
Chairman,
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

ENGINE FIRE DURING TAKE OFF CLIMB
JAPAN AIRLINES INTERNATIONAL CO., LTD.
MCDONNELL DOUGLAS MD-90-30, JA002D
AN ALTITUDE OF ABOUT 5,500 FEET, ABOUT 11 KILOMETERS WEST OF SENDAI AIRPORT, JAPAN
AUGUST 15, 2010

June 8, 2012
Adopted by the Japan Transport Safety Board

Chairman	Norihiro Goto
Member	Shinsuke Endoh
Member	Toshiyuki Ishikawa
Member	Sadao Tamura
Member	Yuki Shuto
Member	Toshiaki Shinagawa

SYNOPSIS

〈Summary of the Serious Incident〉

On Sunday August 15, 2010, at 16:08 Japan Standard Time (JST: UTC+9hr, unless otherwise stated all times are indicated in JST on a 24-hour clock), a McDonnell Douglas MD-90-30, registered JA002D, operated by Japan Airlines International Co., Ltd. took off from Sendai Airport for Fukuoka Airport as a scheduled flight 3538. Around 16:10, while climbing, it declared a state of emergency upon the activation of the right engine fire warning alarm at about 5,500 ft. The right engine was shut down while the fire-extinguishing system was activated; consequently, the aircraft returned to Sendai Airport and it landed at 16:23. Heat damage inside the cowling of the right engine was confirmed after landing.

There were 111 people on board, consisting of the Pilot in Command (PIC), 4 other crewmembers, and 106 passengers, but no one was injured.

〈Probable Causes〉

It is probable that this serious incident occurred as follows: The Aircraft No. 4 Bearing Scavenge Tube of the right engine fractured during takeoff, resulted in the Tube breaking loose from the Diffuser Case letting the engine oil blow out through an opening where it broke loose, and subsequently the oil contact with the engine high temperature section developed into an engine fire.

It is highly probable that the repeated stress associated with engine operations generated the crack origins in the No.4 Scavenge Tube and the fatigue crack grew into the fracture of the tube.

〈Recommendations〉

In view of the result of this serious incident investigation, the JTSB recommends that the FAA urge the engine manufacturer to take the following measures:

In the serious incident, it is highly probable that the fatigue crack originating from the outer diameter of the No.4 Bearing Scavenge Tube progressed into the fracture, whereas the Tube is covered with the heat shield, making it impossible to have a direct inspection of the relevant spot during a regular maintenance work. Therefore, it is recommended that the manufacturer review the Tube design and overhaul inspection method thereof in order to prevent the recurrence of similar cases.

Abbreviations used in this report are as follows:

AAIB	: Air Accidents Investigation Branch
AMM	: Aircraft Maintenance Manual
CVR	: Cockpit Voice Recorder
DFDR	: Digital Flight Data Recorder
FAA	: Federal Aviation Administration
MWCC	: Master Warning and Caution Controller
NTSB	: National Transportation Safety Board
PF	: Pilot Flying
PM	: Pilot Monitoring
V1	: Takeoff decision speed
VHF	: Very High Frequency
VR	: Rotation speed

Unit Conversion Table

1 USqt	: 0.946 ℓ
1 USpt	: 0.473 ℓ
1 ft	: 0.3048 m
1 kt	: 1.852 km/h
1 psi	: 0.07031 kg/cm^2
1 in	: 25.4 mm

1. PROCESS AND PROGRESS OF THE INVESTIGATION

1.1 Summary of the Serious Incident

The occurrence covered by this report falls under the category of "Occurrence of fire within an engine fire-prevention area" as stipulated in Clause 10, Article 166-4 of the Civil Aeronautics Regulations of Japan, and is classified as an aircraft serious incident.

On Sunday August 15, 2010, at 16:08 Japan Standard Time (JST: UTC+9hr, unless otherwise stated all times are indicated in JST on a 24-hour clock), a McDonnell Douglas MD-90-30, registered JA002D, operated by Japan Airlines International Co., Ltd. took off from Sendai Airport for Fukuoka Airport as a scheduled flight 3538. Around 16:10, while climbing, it declared a state of emergency upon the activation of the right engine fire warning alarm at about 5,500 ft. The right engine was shut down while the fire-extinguishing system was activated; consequently, the aircraft returned to Sendai Airport and it landed at 16:23. Heat damage inside the cowling of the right engine was confirmed after landing.

There were 111 people on board, consisting of the Pilot in Command (PIC), 4 other crewmembers, and 106 passengers, but no one was injured.

1.2 Outline of the Serious Incident Investigation

1.2.1 Investigation Organization

On August 15, 2010, the Japan Transport Safety Board (JTSB) designated an investigator-in-charge and one other investigator to investigate this serious incident.

1.2.2 Representatives from Foreign Authorities

An accredited representative and an adviser of the United States of America, as the State of Design and Manufacture of the aircraft and the engine involved in this serious incident, participated in the investigation.

1.2.3 Implementation of the Investigation

August 16 and 17, 2010	Aircraft examination and interviews
August 20, 2010	Interviews
August 25, 2010	Teardown inspection of the engine
September 3, 2010	Review of maintenance records
October, 2010 to March, 2011	Functional test of the MWCC (the inspection was conducted with the cooperation of the United Kingdom)
November, 2010 to June, 2011	Detailed inspection of the No. 4 Bearing Scavenge Tube (the inspection was conducted with the cooperation of the USA)

1.2.4 Provision of Factual Information to the Civil Aviation Bureau (JCAB)

On August 27, 2010, the JTSB provided the JCAB with information regarding the fracture and crack of the No.4 Bearing Scavenge Tube of the right engine of the aircraft.

1.2.5 Comments from Parties Relevant to the Cause of the Serious Incident

Comments were invited from parties relevant to the cause of the serious incident.

1.2.6 Comments from the Related States

Comments on the draft report were invited from the related States.

2. FACTUAL INFORMATION

2.1 History of the Flight

On August 15, 2010, a McDonnell Douglas MD-90-30, registered JA002D (hereinafter referred to as "the Aircraft"), operated by Japan Airlines International Co., Ltd. (hereinafter referred to as "the Company"), took off from Sendai Airport at 16:08 for Fukuoka Airport as a scheduled flight 3538.

The outline of the flight plan for the Aircraft was as follows:

Flight rules: Instrument flight rules (IFR),
Departure aerodrome: Sendai Airport,
Estimated off-block time: 16:05,
Cruising speed: 440 kt,
Cruising altitude: FL320,
Route: DERBY (way point) – GTC (Niigata VORTAC) – V30 (airway) – JEC (Miho VORTAC) – Y14 (RNAV route) – TTE (Toyoda VOR/DME) – Y20 (RNAV route) – KIRIN (way point),
Destination aerodrome: Fukuoka Airport,
Alternate aerodrome: Nagasaki Airport,
Estimated elapsed time: 1 hr 34 min,
Fuel load expressed in endurance: 2 hrs 59 min

At the time of the occurrence of the serious incident, the PIC was in the left seat as the PM (pilot monitoring: pilot mainly in charge of duties other than flying) and the First Officer (FO) in the right seat as the PF (pilot flying: pilot mainly in charge of flying).

The history of the flight up to the time of occurrence is summarized below, based on the records of the Digital Flight Data Recorder (DFDR), the records of the Cockpit Voice Recorder (CVR), the records of air traffic control (ATC) communications, and the statements of the flight crewmembers.

2.1.1 History of the Flight Based on the DFDR Records, the CVR Records and the ATC Communications Records:

16:07:03 Sendai Aerodrome Control Station (hereinafter referred to as “Sendai Tower”) instructed the Aircraft to contact Sendai Departure Control Station (hereinafter referred to as “Sendai Departure”) after takeoff, and issued a takeoff clearance for the Aircraft.

16:07:19 Thrust levers for both engines of the Aircraft were advanced followed by the increased engine power output, and the takeoff roll commenced.

16:08:03 The Aircraft lifted off at an airspeed of about 160 kt.

16:08:39 Sendai Tower called the Aircraft after observing white smoke from the right engine, but there was no response.

16:09:07 Sendai Departure called the Aircraft to inform of the white smoke from the right engine observed during takeoff.

16:09:28	The autopilot was engaged.
16:10:01	Right engine fire warning alarm was activated.
16:10:16	Thrust levers of both engines were retarded.
16:10:19	The Aircraft declared a state of emergency to Sendai Departure and commenced gradual descent from about 6,150 ft.
16:11:47	Fuel flow to the right engine was shut off, and No.1 fire-extinguishing system was activated.
16:13:07	No.2 fire-extinguishing system was activated and the right engine fire warning alarm stopped.
16:23:26	The Aircraft landed on Runway 27 at Sendai Airport.

2.1.2 Statements of the Aircraft's Flight Crewmembers

(1) PIC

After the completion of the preflight inspection, the PIC had the Aircraft pushed back from Spot 6 and commenced taxiing to the runway. The PIC did not feel any signs of abnormality on the Aircraft as it continued to enter Runway 27. He handed the PF duty over to the FO, as the weather conditions were good, after Sendai Tower issued a takeoff clearance for the Aircraft while instructing it to contact Sendai Departure after takeoff.

The PIC kept monitoring the Air Speed Indicator while paying attention to engine instruments during the takeoff roll, but he observed no abnormalities, and the Aircraft made a normal takeoff.

The PIC retracted the landing gears. He switched the ATC frequency to contact Sendai Departure and received the notification of radar contact. While climbing through 3,000 ft, he was notified by Sendai Departure of the white smoke from the right engine.

He checked the instruments and found the illumination of amber and red lights on the engine system instruments, which indicate low oil pressure: the former illuminates when the pressure goes below 80 psi and the latter below 60 psi. The indicated oil pressure was 25 psi. The master caution lights in the front panel of the cockpit were not illuminating.

When he was requesting Sendai Departure to stop climbing at 6,000 ft and get a vector to the south of Sendai Airport to execute non-normal procedures for oil pressure low indication, the right engine fire warning alarm went off. He felt a minor sensation of right yawing motion, and he suspected the damage of the right engine. He called out "I have" to take over the PF duty from the FO and executed emergency procedures to respond to the engine fire.

While the Aircraft descended slowly at a descent rate of 500 ft per minute, the PM activated the No.1 fire-extinguishing system on the right engine. However, the engine fire alarm remained sounding after a prescribed period of time had elapsed; the No. 2 fire-extinguishing system was activated afterward and the alarm stopped. PIC notified Sendai Departure that he intended to return there although the right engine fire warning alarm stopped after the alarm activation, engine shut down and the fire extinguisher activation.

As the PIC spotted fire fighting vehicles when he landed on Runway 27 at Sendai Airport, he stopped the Aircraft momentarily on Taxiway B2, where the vehicles were standing by, to confirm that the fire had been extinguished and to prepare for possible evacuation. He requested Sendai Tower to check the status of the right engine, and received a report of no smoke observed. He resumed taxiing to Spot 7 without assistance.

(2) FO

The FO was monitoring the engine instruments while taxiing to have observed no abnormalities. After the PIC moved the Aircraft into the runway, the FO took over the PF duty.

The FO moved the thrust levers halfway forward to confirm the parameters of the left and right engines were stabilized. Then he commenced takeoff roll by advancing the thrust levers to the takeoff thrust using the autothrottle (automatic thrust control system). He checked the engine instruments and annunciator by the time of V1, but he found no abnormalities; he rotated the Aircraft at the PIC's call of VR. He then set the climbing thrust at an altitude of about 1,500 ft. He felt no abnormalities with engines even then.

Later, right after the Aircraft climbed through 3,000 ft, Sendai Departure informed them that Sendai Tower observed the white smoke from the right engine during takeoff. The FO then engaged the autopilot and checked the engine instruments with the PIC, and the low engine oil pressure lights were illuminating. The master caution lights were supposed to have been illuminating, but none of them were.

When the FO was leveling off to cope with the low engine oil pressure, the right engine fire warning alarm was activated. He later felt minor vibrations in the tail section of the fuselage. He handed over the control to the PIC at this point. The climb was stopped at about 6,000 ft, and a state of emergency was declared to Sendai Departure. The fire warning alarm stopped as the FO activated the fire-extinguishing system according to the emergency procedures.

2.1.3 Statements of Air Traffic Controllers at the Sendai Airport Office

According to the statements of the Air Traffic Controllers of the Sendai Airport Office who were controlling the Aircraft, the situation of the Aircraft from the time when it commenced takeoff roll, up to the time when the Aircraft declared the state of emergency after takeoff, is summarized as follows:

Sendai Tower instructed the Aircraft to contact Sendai Departure after takeoff and issued a takeoff clearance, as the Aircraft commenced uneventful taxiing from Spot 6 and entered Runway 27.

There was no abnormalities observed when the Aircraft commenced takeoff roll, but the white smoke was observed when it was about to lift off. Sendai Tower called the Aircraft, however, it was not available as the Aircraft was apparently switching the frequency. Sendai Tower explained the situation to Sendai Departure and requested that it check the situation of the Aircraft.

Sendai Departure, after receiving the information on the white smoke from Sendai Tower, informed the Aircraft of the situation during the takeoff. The Aircraft reported minor discrepancy on the engine parameter readouts on the engine instruments and the Aircraft requested for stopping the climb at 6,000 ft and a vector to the south of Sendai Airport, which were all approved. The Aircraft later declared a state of emergency due to engine fire.

The serious incident occurred around 16:10 on August 15, 2010, at about 5,500 ft, about 11

km (Latitude 38°06'49" N, Longitude 140°47'43" E) west of Sendai Airport.
(See Figure 1 Estimated Flight Route, Figure 2 DFDR Records, Photo 1 The Serious Incident Aircraft)

2.2 Injuries to Persons

No one was injured in this serious incident.

2.3 Damage to the Aircraft

2.3.1 Extent of Damage

The right engine was partially damaged, but there was no damage on the airframe.

2.3.2 Damage of the Right Engine

On the right engine cowling, the pressure relief door was open, from which the rear portion was heat-damaged and turned to brownish color. The No.4 Bearing Scavenge Tube (hereinafter referred to as "the Tube") which extends from the No.4 Bearing underneath the Diffuser Case (hereinafter referred to as "the Case") was found detached and the trace of oil leak was found. Inside of the lower cowl to which the oil adhered was partly burnt out, and soot was stretching upward from the lower part of the Case and the turbine module.
(See Photo 1 The Serious Incident Aircraft, Photo 2 The Damage to the Right Engine and the Tube)

2.4 Personnel Information

(1)	PIC Male, Age 52	
	Airline transport pilot certificate (Airplane)	August 26, 1992
	Type rating for Douglas DC-9	April 30, 1986
	Class 1 aviation medical certificate	
	Validity	January 22, 2011
	Total flight time	14,720 hrs 49 min
	Flight time in the last 30 days	31 hrs 54 min
	Total flight time on the type of aircraft	1,405 hrs 57 min
	Flight time in the last 30 days	31 hrs 54 min
(2)	FO Male, Age 41	
	Commercial Pilot Certificate (Airplane)	December 15, 1994
	Type rating for Douglas DC-9	June 29, 1998
	Instrument flight certificate	October 13, 1995
	Class 1 aviation medical certificate	
	Validity	February 14, 2011
	Total flight time	6,574 hrs 15 min
	Flight time in the last 30 days	48 hrs 32 min
	Total flight time on the type of aircraft	3,949 hrs 49 min
	Flight time in the last 30 days	48 hrs 32 min

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2.5 Aircraft Information

2.5.1 Aircraft

Type McDonnell Douglas MD-90-30

Serial number	53556
Date of manufacture	November 11, 1997
Certificate of airworthiness	No. 2009-222
Validity	For the period which the maintenance management manual (JAL Engineering Co., Ltd.) approved under the Article 113-2 of the Civil Aeronautics Act applies on and after October 1, 2009.
Category of airworthiness	Airplane, Transport T
Total flight time	26,813 hrs 19 min
Flight time since last periodical check (A maintenance on June 24, 2010)	328 hrs 02 min

(See Figure 3 Three Angle View of McDonnell Douglas MD-90-30)

2.5.2 Engines

(1) Left engine

Type	IAE V2525-D5
Serial number	V20148
Date of manufacture	August 6, 1997
Total time	24,297 hrs 04 min
Total cycles	22,367 cycles
Total time since last overhaul	8,012 hrs 05 min
Total cycles since last overhaul	7,389 cycles

(2) Right engine

Type	IAE V2525-D5
Serial number	V20034
Date of manufacture	September 16, 1995
Total time	26,163 hrs 33 min
Total cycles	23,933 cycles
Total time since last overhaul	4,567 hrs 33 min
Total cycles since last overhaul	4,153 cycles

2.5.3 Weight and Balance

When this serious incident occurred, the Aircraft's weight was estimated to have been 125,000 lb and the center of gravity (CG) was estimated to have been 17 % MAC, both of which were with the allowable range (maximum takeoff weight of 156,000 lb, and the CG range of -7.5 to 33.8 % MAC corresponding to the weight at the time of the serious incident).

2.5.4 Fuel and Lubricating Oil

Fuel onboard was Jet A-1 aviation fuel, and lubricating oil was Mobil Jet Oil 254 for jet engine (autogenous ignition temperature: 399 °C).

2.6 Meteorological Information

Aeronautical weather observations for Sendai Airport around the time of the serious incident were as follows:

16:22 Wind direction 100° Wind velocity 4 kt
Wind direction variable 050° to 130°

Visibility 15 km

Clouds	Amount 1/8	Type Cumulus	Cloud base 2,500 ft
	Amount 4/8	Type Cumulus	Cloud base 5,000 ft
	Amount 5/8	Type Altocumulus	Cloud base 8,000 ft

Temperature 27 °C Dew point 24 °C

Altimeter setting (QNH) 29.80 inHg

2.7 Information on DFDR and CVR

The Aircraft was equipped with a DFDR (part number: 980-4700-003) and CVR (part number: 980-6020-00), both of which made by Honeywell International Inc. of the United States of America and retained data at the time of the serious incident. Time calibration of the DFDR was determined by correlating the DFDR recorded VHF transmission keying signals with the NTT (Nippon Telegraph and Telephone Corporation) speaking clock recorded on the ATC communications records.

Data related to the illumination status of the master caution light in the front instrument panel of the cockpit and the engine oil pressure were not included as part of the data to be recorded by the DFDR.

2.8 Information on the Engines

2.8.1 No.4 Bearing and the Tube

No.4 Bearing is designed to support the rear section of the high-pressure shaft, and is attached in the Case near the combustion chamber and engine oil for the No. 4 Bearing is supplied through the Case and returns to an oil tank.

The Tube is a part of the piping to return the engine oil to the oil tank through the de-oiler after the lubrication and cooling of the No. 4 Bearing, and is located inside the Case. One end of the Tube is bolted to the No. 4 Bearing Compartment (housing), while the other end is fixed to an opening of the Case with a seal (a piston ring) to maintain airtight condition of the Case. The Tube is connected to the external pipe.

While the engine is in operation, the Case is filled with the compressed air from the 10th stage of the compressor (hereinafter referred to as "the 10th Stage Air". A part of the cooled compressed air from the 12th stage of the compressor also flows into the Case after cooling the No. 4 Bearing Compartment), and the temperature and the pressure inside the Case reach 560 ℃ and 270 psi, or higher, respectively, during takeoff.

(See Figure 4 The Tube)

2.8.2 Sensing of Engine Oil Pressure, etc.

The engine oil pressure is indicated by sensing the difference between the supply pressure and the scavenge pressure in the lower end of the Tube. The low oil pressure switch for warning and the oil pressure transmitter for pressure indication are installed in the engine oil system.

The low oil pressure switch displays the message on the overhead panel to notify the low engine oil pressure and illuminate the master caution lights in front of both pilot seats via the MWCC when the engine oil pressure goes below 60 psi.

The oil pressure transmitters indicate the engine oil pressure value on the engine system instruments. These also illuminate the amber lights when the pressure goes below 80 psi, and the red lights below 60 psi.

(See Figure 5 Engine Oil System Diagram (The relevant part))

2.9 Inspection of the Right Engine

2.9.1 Teardown Inspection of the Right Engine

The engine was delivered to the engine manufacturer's designated facility; accordingly, the fractured Tube was detached from the Case and visually examined. The examination discovered a circumferential fracture near the bend and straight cracks along the straight portion of the Tube. The fracture and the cracks extended along the weld beads that were formed in the process of manufacturing of the Tube. Oil was leaking at the circumferential fracture. There was no oil leak in other parts of the engine nor other defects relevant to the fire. There was no defect in the fuel system and in the combustion gas flow passage.

(See Photo 3 The Tube in the Case, Photo 4 Fractured Region of the Tube)

2.9.2 Detailed Examination on the Tube

Detailed examination on the fractured Tube was conducted with the cooperation of the NTSB of USA and the engine manufacturer. The results are summarized as follows:

(1) Binocular microscopic examination of the circumferential fracture at the bend part of the Tube showed the trace of fatigue crack progressed from the outer diameter to the inner diameter of the Tube, and conditions consistent with overload fracture were observed at outside of the fatigue crack region. The fatigue crack was 0.513 in in length, and two major origins of the crack were identified on the outer surface of the Tube along the circumferential weld bead.

Scanning electron microscope evaluation on the fracture surface also showed cyclic striations that were typically associated with low cycle mode of fatigue, and striation count was about 1900.

(2) There were three longitudinal cracks along the longitudinal weld bead on the Tube; the length of each crack was 2.10 in, 2.65 in and 3.70 in, respectively. Scanning electron microscope evaluation on the crack surfaces showed a number of small dimples, consistent with a overload, which were a trace that progressed crack rapidly from the inner diameter to the outer diameter through the Tube wall.

(3) The Tube conformed to the engineering drawing specification in thickness and the hardness, no material or processing abnormalities were detected, and no abnormalities were found in the welds.

(See Photo 5 Cracks in the Tube)

2.9.3 Examination on the Installation of the External Pipe of the Same Engine Type

The engine manufacturer examined six other engines of the same type on the installation of the external pipe assuming that the stress caused by the assembly of the Tube and the external pipe (assembly stress*[1]) was partly responsible for the fracture of the Tube. As a result, all the engines examined showed mismatched attachment of the Tubes. Of which five units had repair records on external pipe while the one engine had not enough repair information. The Aircraft's right engine had no repair record of the external pipe.

2.9.4 The Tube Inspection Methods during Overhaul

*[1] Assembly stress means a kind of stress which occurs at or after assembling multiple parts.

The engine was maintained by the on-condition procedure at the designated facility in accordance with the maintenance manual stipulated by the manufacturer, and three overhauls on the engine, including visual inspections on the Tube, had been performed between the period of manufacturing of the engine and the time of the serious incident. No abnormalities were found in the visual inspection on the Tube during the recent overhaul, and it was reassembled to the engine again.

The Tube was assembled into the engine when it was manufactured and had no records of replacement or repair.

2.9.5 Engine Oil Consumption Rate

The Aircraft's AMM sets out a guideline of the engine oil consumption rate as 0.3 USqt (US quart) or 0.6 USpt (US pint) per one flight hour.

The Company computes the engine oil consumption rate of the Aircraft by dividing the total amount of oil supply during the previous 30 flight hours from the last flight of the day by 30. The engine oil consumption rate of the right engine had never exceeded the guideline amount of 0.3 USqt per one flight hour, but it was showing a trend of slight increase of oil consumption rate during recent flights.

(See Figure 6 Chronicled Engine Oil Consumption Rate

2.10 Examination on the Detection of Low Engine Oil Pressure

2.10.1 Check of the Airframe Wiring

No abnormalities were found in the check of the wiring of the airframe and the engine regarding the detection of low engine oil pressure, as well as in the functional tests on the low oil pressure switch.

In addition to no abnormalities were found in the run-up of the right engine with the low oil pressure switch and the wiring assembled on the right engine during the final phase of the overhaul following the serious incident.

2.10.2 Functional Test on the MWCC

The MWCC is a device which receives warning or caution signals from the airframe and displays a message on the annunciator of the overhead panel in the cockpit, and illuminates master warning lights or master caution lights in front of both seats in the cockpit.

A functional test was conducted on the Aircraft's MWCC at a manufacture's facility thereof, with the cooperation of the AAIB of the United Kingdom. The test found no abnormalities related to the serious incident.

2.11 Information on Similar Cases of the Serious Incident and the correspondence

According to the engine manufacturer, there had been two similar cases where the identical Tube of the same engine type series fractured before the serious incident, but neither case caused fire, and incomplete welding was cited as the cause of the fracture:

(1) In December, 2004, because of oil leak was observed during a periodic overhaul, the engine was dismounted, and a fracture of the Tube was discovered.

(2) In November, 2009, an aircraft returned to the airport which it took off because low oil quantity was indicated after takeoff, and the fracture of the Tube was discovered during the post-landing inspection.

Following the review of the two cases, the engine manufacturer decided to conduct an X-ray inspection during the manufacturing of the Tube since April, 2010. Besides, the manufacturer issued a Service Bulletin (V2500-Eng-72-0617) on December 9, 2010, which recommended an X-ray inspection on the Tube manufactured before April, 2010, without disassembling the heat shield at the designated maintenance facility at the next maintenance work there.

The above Service Bulletin has been revised on September 28, 2011 to recommend an X-way inspection on the Tube without disassembling the heat shield, and additional X-ray inspection be conducted after disassembling the heat shield in case of the detected abnormalities on the Tube.

3. ANALYSIS

3.1 Qualification of Personnel

The PIC and The FO held both valid airman competence certificates and valid aviation medical certificates.

3.2 Airworthiness Certificate of the Aircraft

The Aircraft had a valid airworthiness certificate and had been maintained and inspected as prescribed.

3.3 Relation to Meteorological Phenomena

It is highly probable that conditions of the weather at the time of the serious incident had not any relation with the occurrence of this serious incident.

3.4 History of the Occurrence of the Fire

3.4.1 Fracture of the Tube

As described in 2.8.1, the Tube is in the Case, one end of it is bolted to the No. 4 Bearing Compartment (housing), while the other end is fixed to an opening of the Case with a seal (a piston ring) to maintain airtight condition of the Case. Because of this, it is highly probable that the region around the bend of the Tube gets repeated stress associated with engine operation when the sealed end is pushed outwards as the pressure and the temperature inside the Case rise in proportion to the engine thrust. Also, as described in 2.9.2 (1), origins of the fracture were found on the outer diameter of the Tube along the circumferential weld bead at the bend, and the trace of the progress of fatigue crack from the outer diameter to the inner diameter was observed on the fracture surface. Therefore, it is highly probable that the repeated stress associated with engine operations generated the fracture origins; from which further repeated stress caused the progress of the fatigue crack followed by the final fracture.

It is probable that because the Tube fractured at the bend, the straight portion lost its support; broke loose from the Case to make an opening, and from which the engine oil blew out into the high temperature section of the engine to get ignited.

As described in 2.9.3, the engine manufacturer suspects that the assembly stress associated with assembling the Tube and the external pipe was a part of the probable reasons for the fracture of the Tube. However, it could not be determined whether there had been the assembly stress on the right engine because the external piping was deformed as the Tube broke loose.

3.4.2 Longitudinal Cracks on the Tube

As described in 2.9.2 (2), there were traces on the longitudinal crack surfaces of the Tube that showed the rapid occurrence of cracks from the inner diameter to the outer diameter of the Tube. Also, as described in 2.8.1, the Case is filled with the 10th Stage Air which exceeds the flash point of the engine oil during takeoff. Therefore, it is possible that the longitudinal cracks on the straight portion were caused by the rapid increase of the inner pressure which resulted from the ignition of the oil upon touching the 10th Stage Air which entered from the fracture.

3.5 Detecting of the Low Engine Oil Pressure

As described in 2.1.2, the flight crewmembers stated that the amber and red lights, which illuminate receiving the signals from the oil pressure transmitters, were already illuminating to indicate the low engine oil pressure on the engine system instruments when the white smoke on the right engine was reported by Sendai Departure; however, the master caution lights, which illuminate receiving the signals from the low oil pressure switch, were not. Therefore, it is possible that the master caution lights were not illuminating at the time of the serious incident.

However, as described in 2.10, the check of the wiring of the airframe and the engine, functional tests on the low oil pressure switch and MWCC revealed no abnormalities, so that it was not possible to determine why the master caution lights did not illuminate at the time of the serious incident.

3.6 Possibility of Early Detections of the Problem

As described in 2.9.4, three overhauls on the right engine, including visual inspections on the Tube, had been performed at the designated facility in accordance with the maintenance manual stipulated by the engine manufacturer between the period of manufacturing of the engine and the time of the serious incident. As the Tube was covered with the heat shield, it is highly probable that it was difficult to find the trace of fatigue crack by the visual inspections.

Also, as described in 2.9.5, the Company was monitoring the engine oil consumption rate; however, it never exceeded 0.3 USqt per one flight hour as set out in the guideline of the AMM. Therefore, it is highly probable that it was difficult to find the signs of the fracture on the Tube by checking the engine oil consumption rate.

4. PROBABLE CAUSES

It is probable that this serious incident occurred as follows: The Aircraft No. 4 Bearing Scavenge Tube of the right engine fractured during takeoff, resulted in the Tube breaking loose from the Diffuser Case letting the engine oil blow out through an opening where it broke loose, and subsequently the oil contact with the engine high temperature section developed into an engine fire.

It is highly probable that the repeated stress associated with engine operations generated the crack origins in the No.4 Scavenge Tube and the fatigue crack grew into the fracture of the tube.

5. SAFETY RECOMMENDATIONS

In view of the result of this serious incident investigation, the JTSB recommends that the

FAA urge the engine manufacturer to take the following measures:

In the serious incident, it is highly probable that the fatigue crack originating from the outer diameter of the No.4 Bearing Scavenge Tube progressed into the fracture, whereas the Tube is covered with the heat shield, making it impossible to have a direct inspection of the relevant spot during a regular maintenance work. Therefore, it is recommended that the manufacturer review the Tube design and overhaul inspection method thereof in order to prevent the recurrence of similar cases.

6. ACTIONS TAKEN

6.1 Actions Taken by the Company

The Company implemented a measure to check the Tube region for the leak of engine oil in case of supplying 2 USqt or more of engine oil during the inspection after the last flight of the day in order to prevent the occurrence of similar cases. Another measure has been implemented in which the information of more than 0.1 USqt of the engine oil consumption rate per one flight hour is reported to the maintenance job support section, and the section will take necessary measures after verifying the situation.

6.2 Actions Taken by the Engine Manufacturer

The engine manufacturer considers that the possible assembly stress caused by assembling the Tube and the external pipe is partly responsible for the fracture of the Tube, and it has temporarily revised the engine manual as follows:

Temporary Revised Date	Contents of Revision
November 4, 2011	Addition of the alignment check.
November 11, 2011	Deletion of repair items on the external pipe.
December 9, 2011	Change of installation procedures of the Tube.

Figure 1 Estimated Flight Route

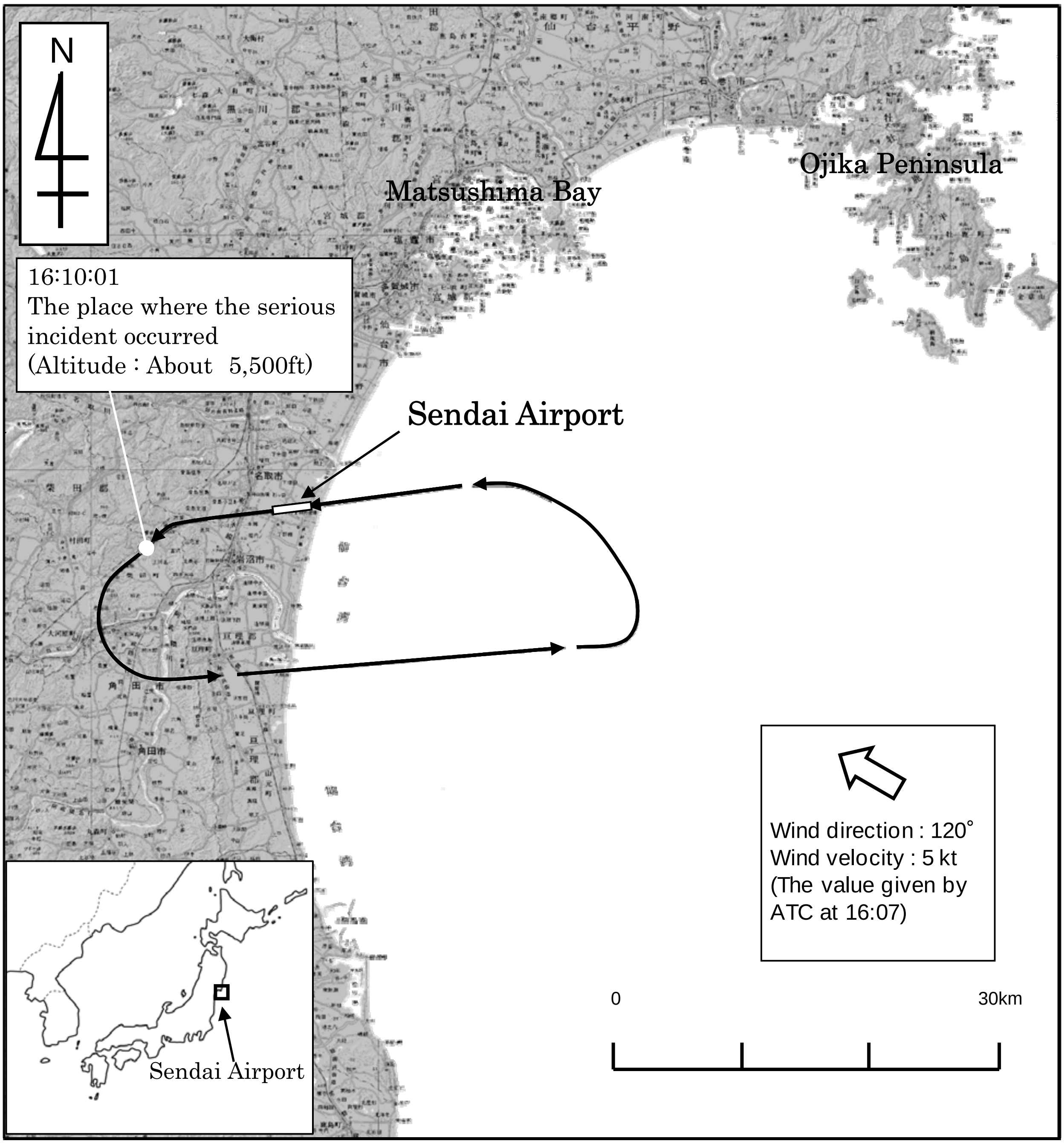
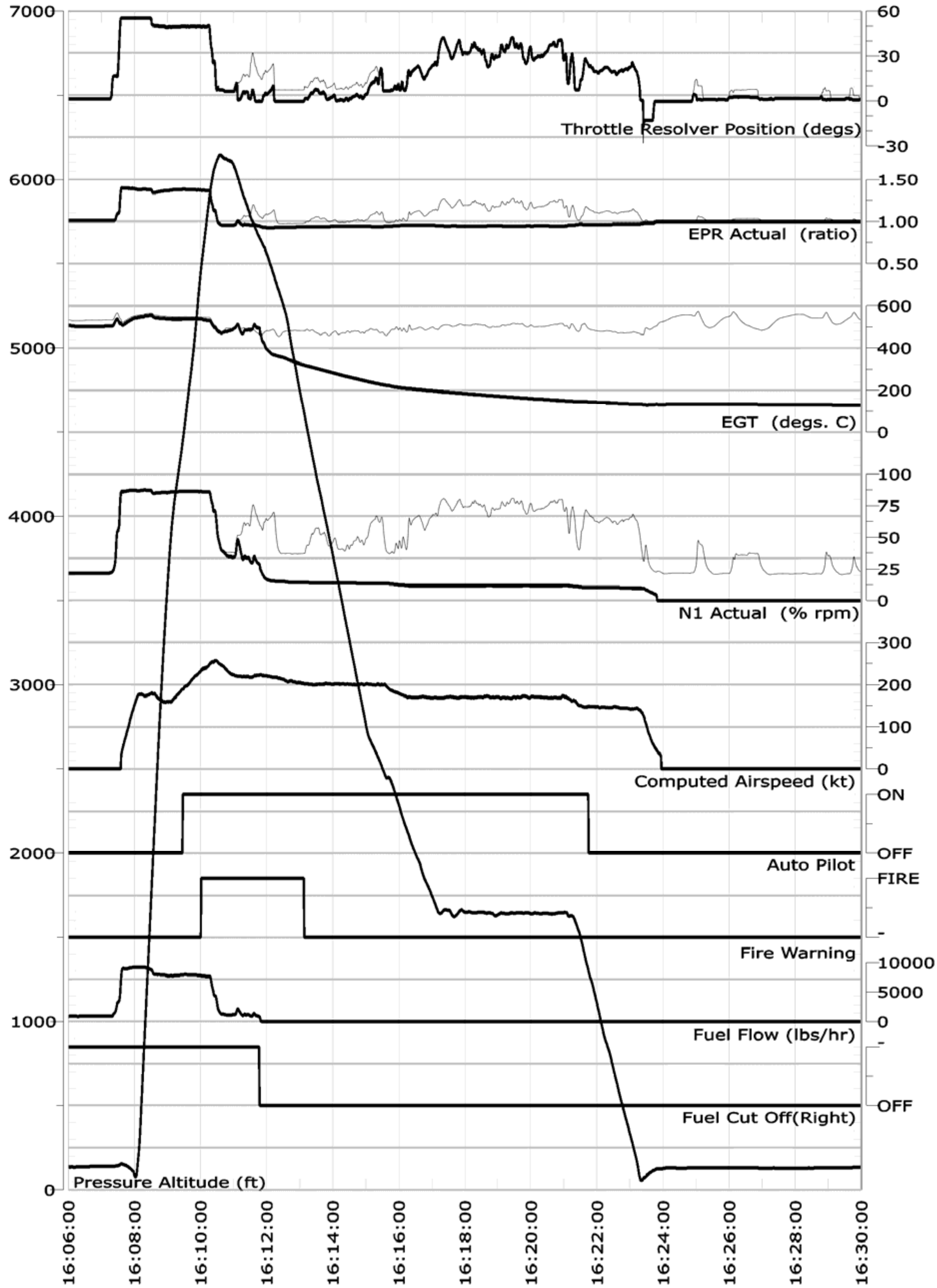


Figure 2　DFDR Records

The fine lines show the value of the left engine.



Time (JST)

Figure 3 Three Angle View of McDonnell Douglas MD-90-30

Unit : m

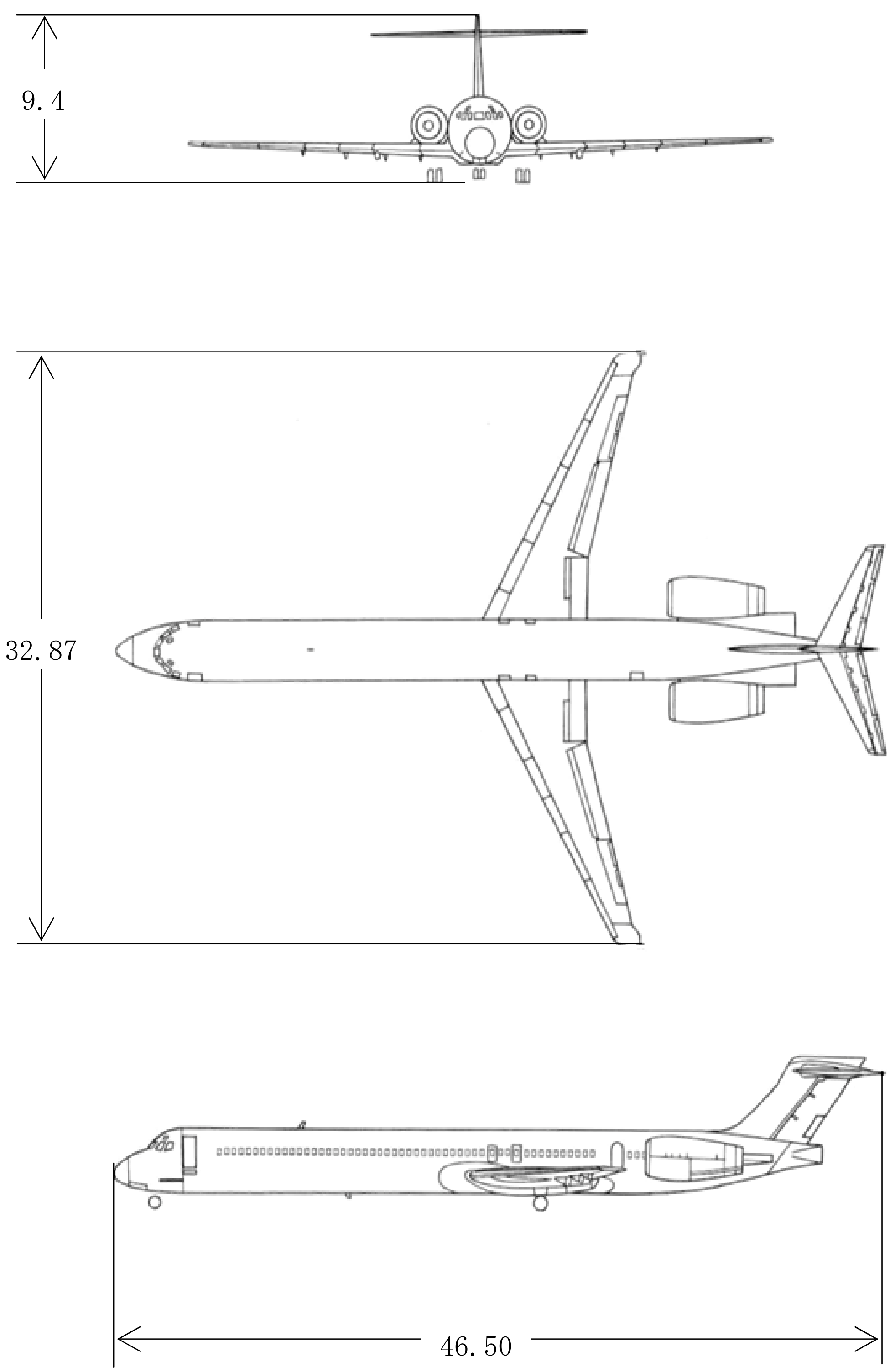


Figure 4　The Tube

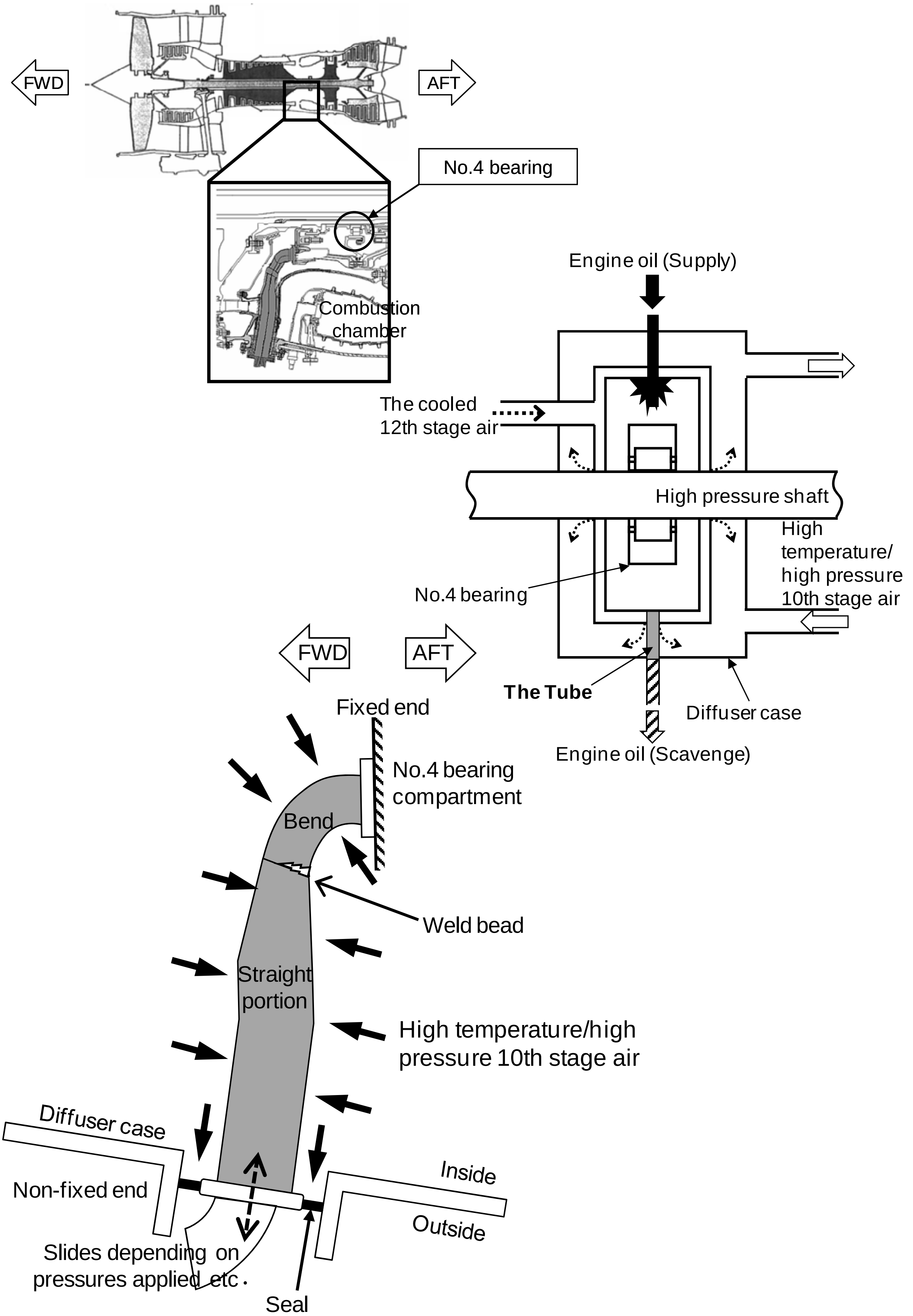


Figure 5　Engine Oil System Diagram (The relevant part)

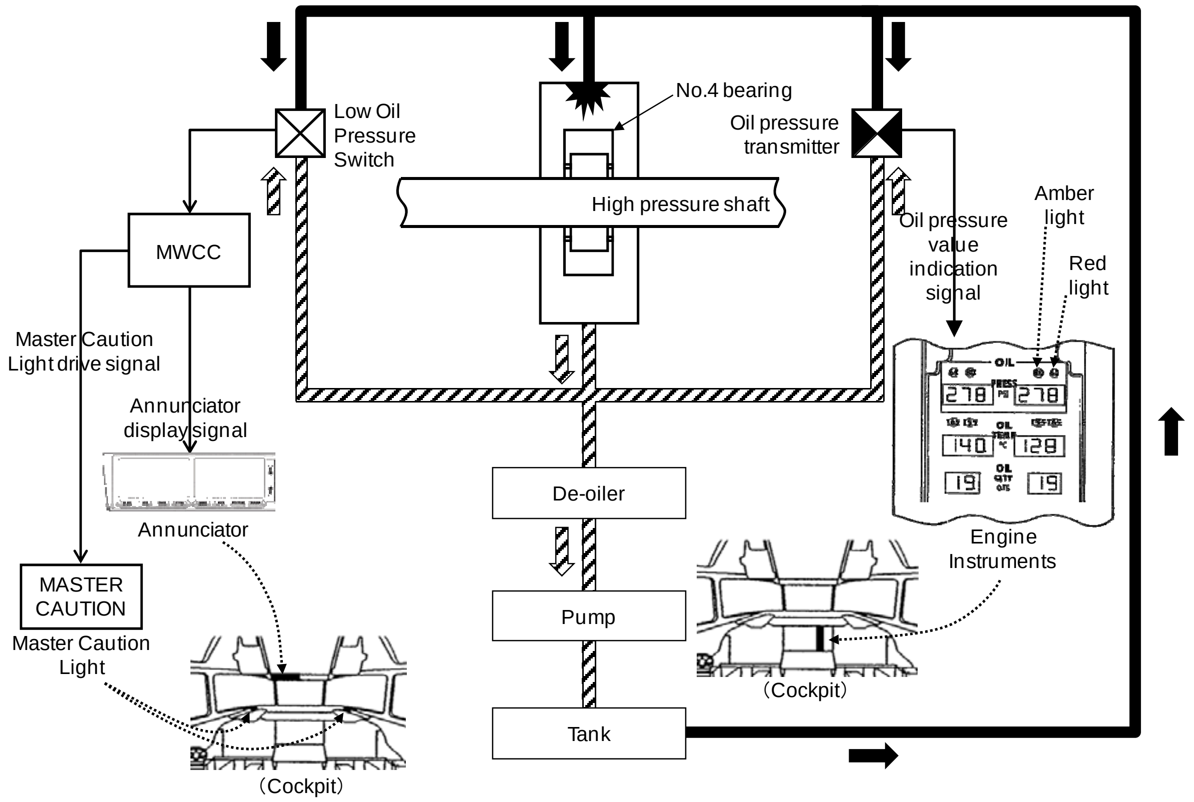


Figure 6　Chronicled Engine Oil Consumption Rate

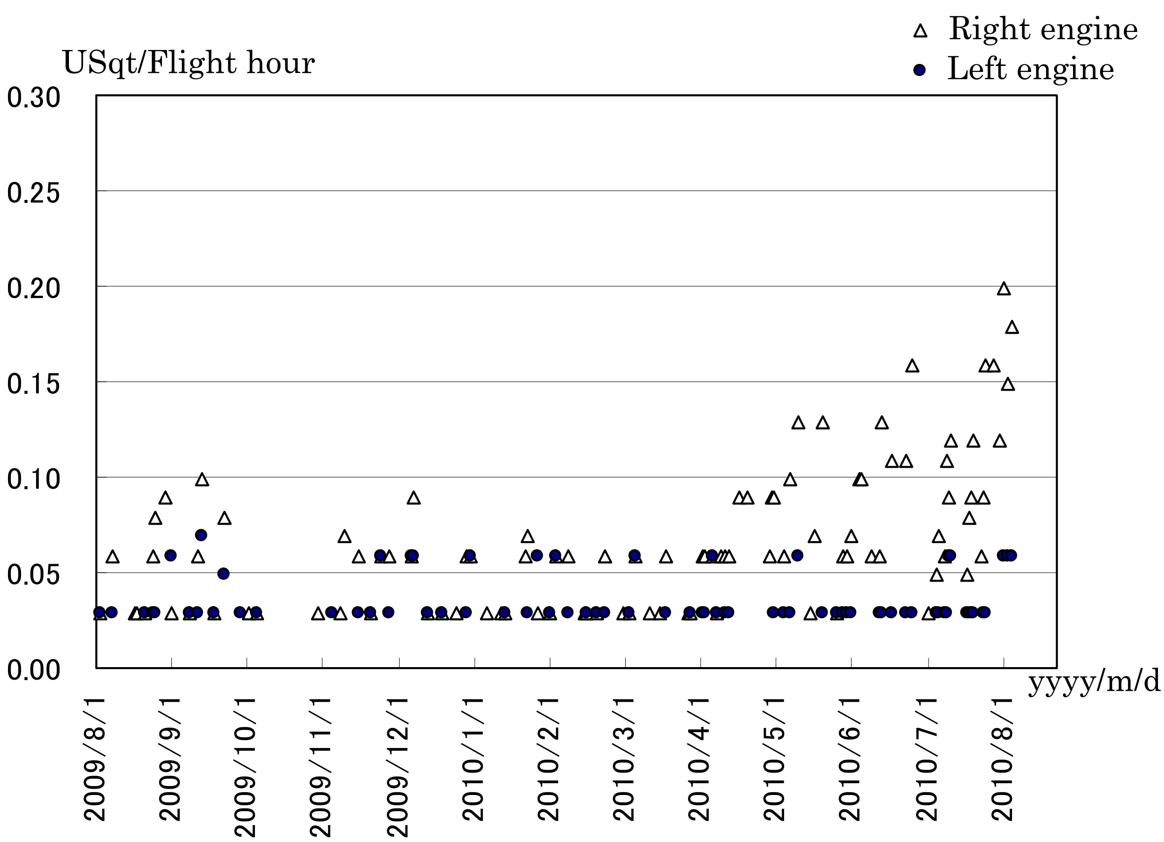


Photo 1　The Serious Incident Aircraft

Whole View

Right Engine Exterior

Photo 2　The Damage to the Right Engine and the Tube

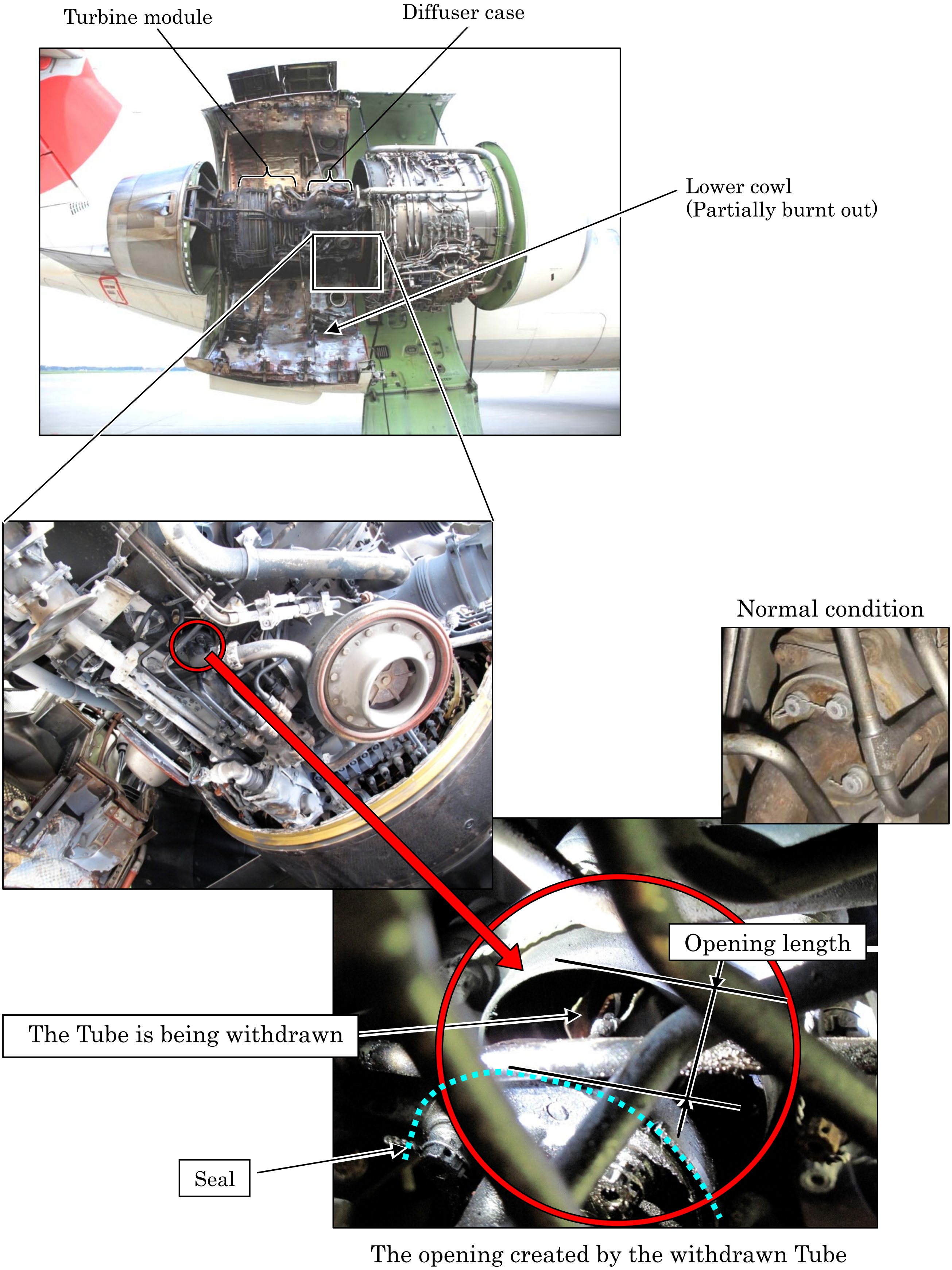
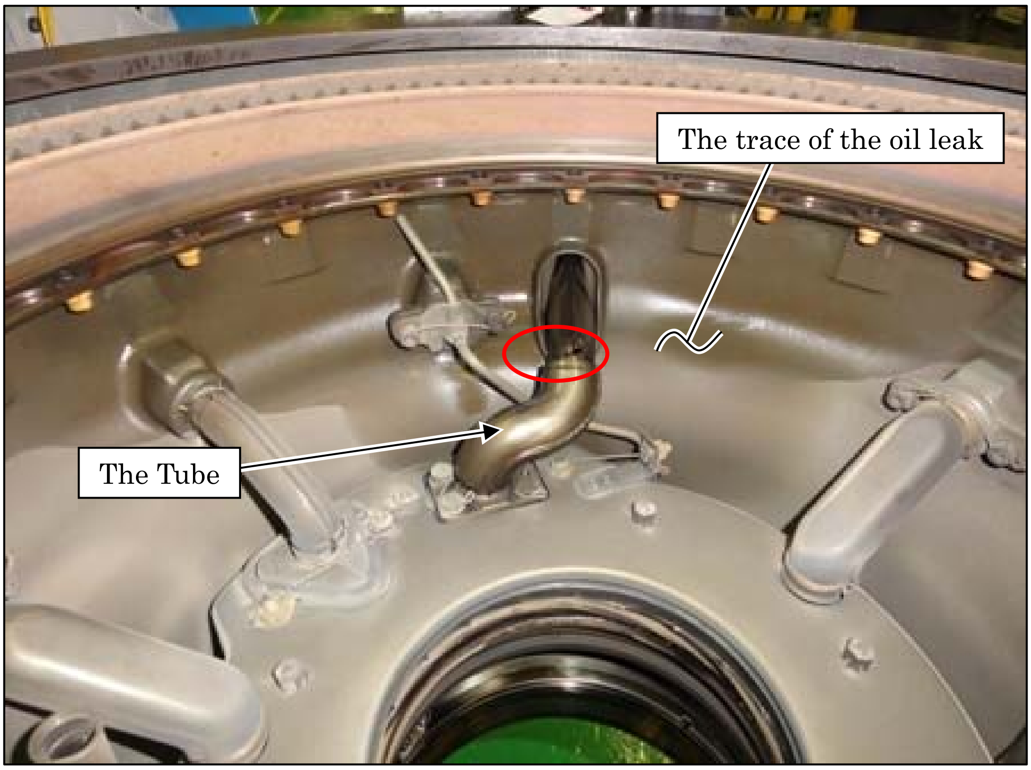


Photo 3　The Tube in the Case



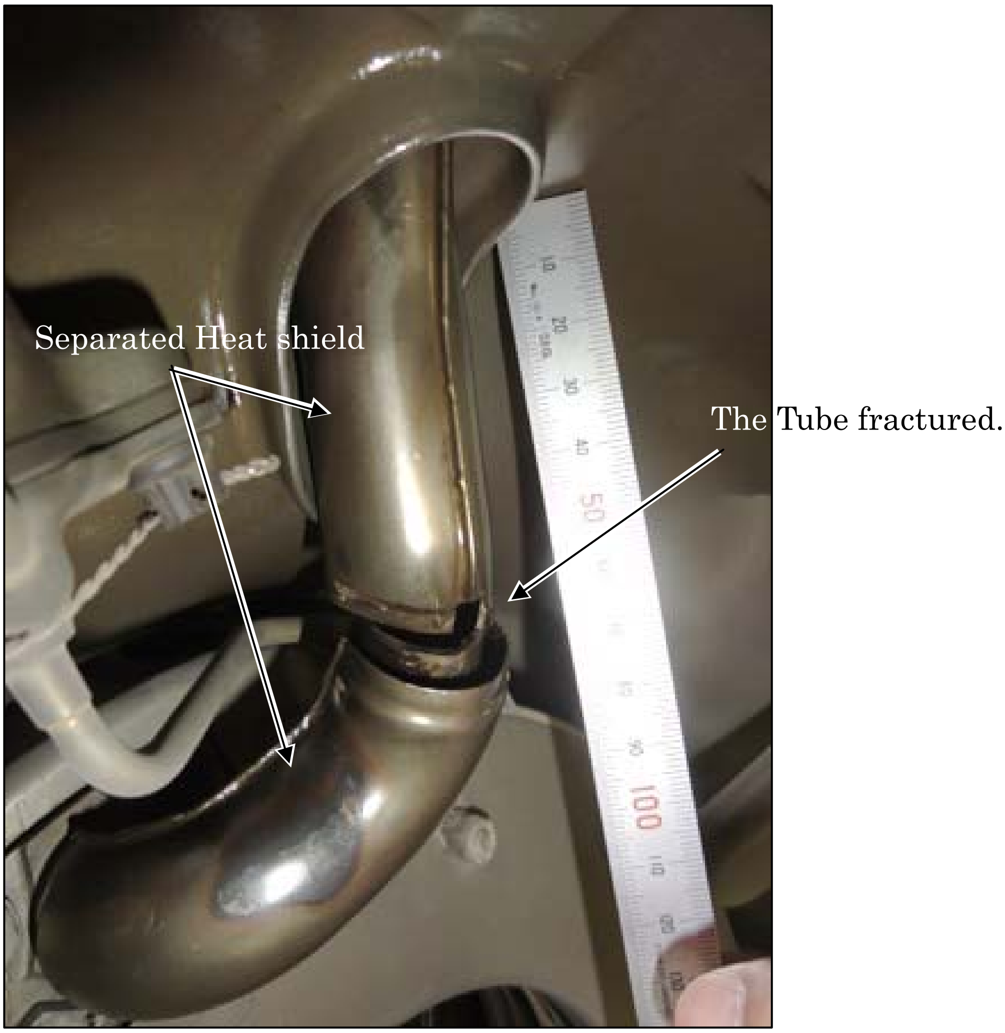


Photo 4　Fractured Region of the Tube

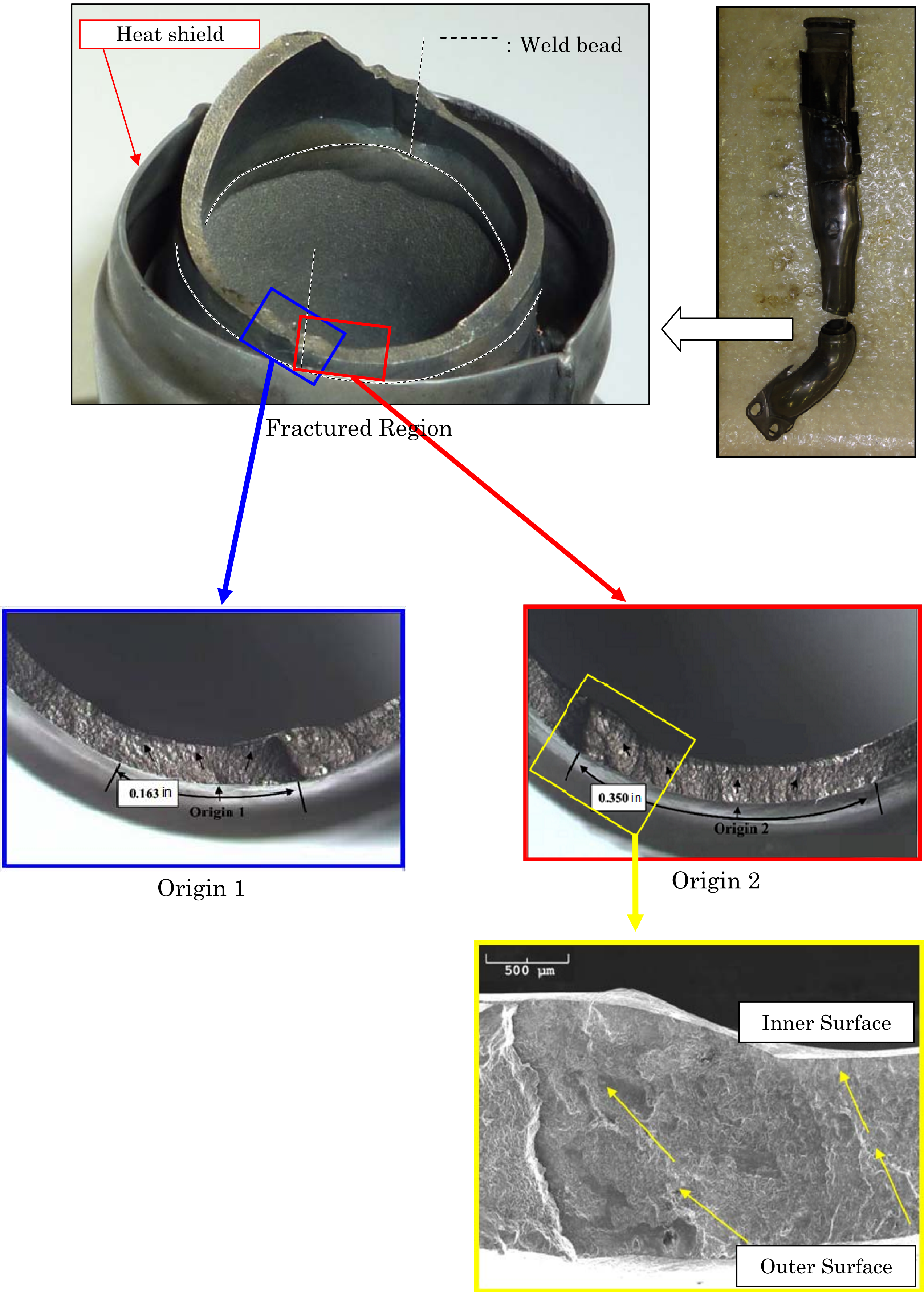
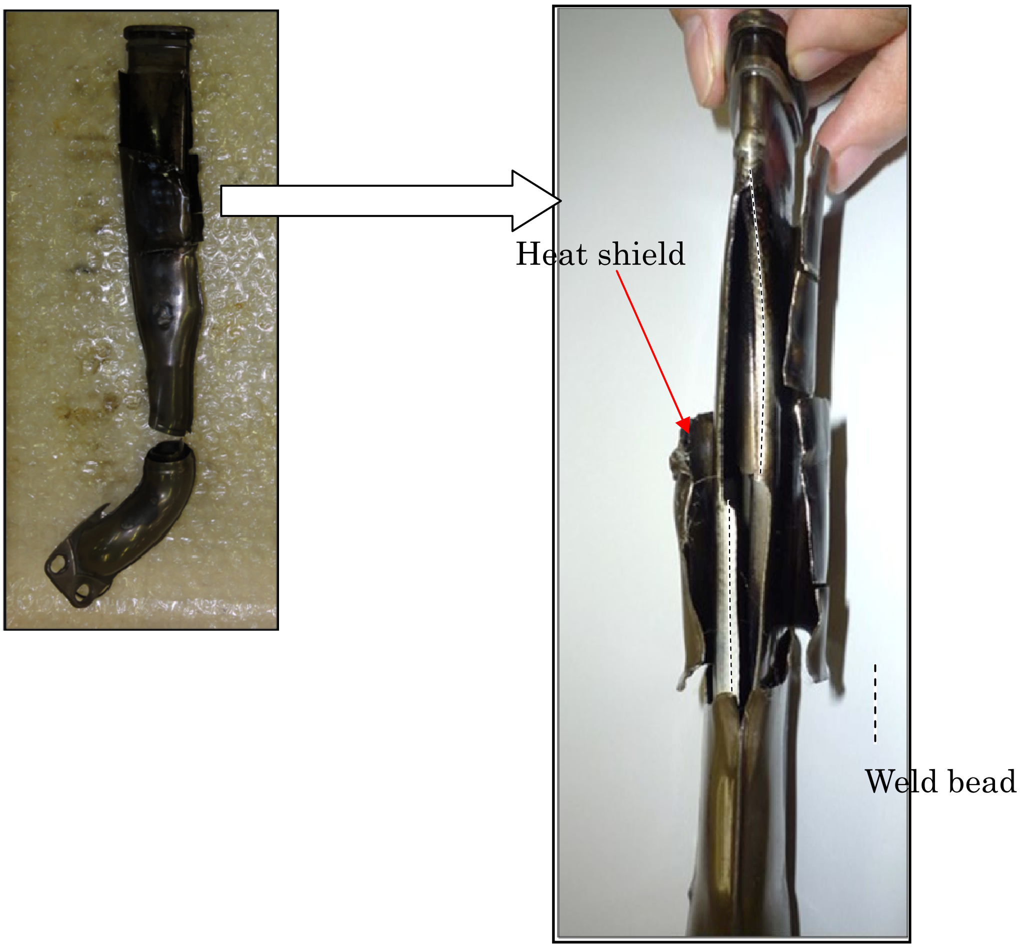


Photo 5　Cracks in the Tube



Overall images of the Tube (the heat shield being removed)