SL Report 2007/08

REPORT ON THE SERIOUS INCIDENT AT OSLO AIRPORT GARDERMOEN ON 21 SEPTEMBER 2004 INVOLVING FLIGHT KAL520 BOEING 747-400F REGISTERED HL7467 OPERATED BY KOREAN AIR

This report has been written in English and published by the AIBN to facilitate access by international readers.

SUBMITTED
March 2007

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REPORT ON SERIOUS INCIDENT

Designation of type:	Boeing 747-400F
Registration:	HL7467
Owner:	Korean Air
Operator:	Korean Air
Crew:	3
Passengers:	None
Incident site:	Oslo Airport Gardermoen, Norway (ENGM), N60 12 10 E011 05 02
Incident time:	Tuesday, 21 September 2004, time 1302

All times given in this report are in local time (UTC + 1), unless otherwise stated.

NOTIFICATION

The Accident Investigation Board Norway (AIBN) was informed by the Civil Aviation Authority Norway (CAA-N) by letter dated 19 October 2004, of the air incident at Oslo Airport Gardermoen (ENGM) involving B747-400F, registered HL7467, taking off for a flight to Incheon International Airport (RKSI), Seoul, Republic of Korea. The Korean Accident Investigation Board (KAIB)[1] and Korean Air were informed by the AIBN that an investigation would be carried out in accordance with Annex 13 to the Convention of International Civil Aviation Organization. KAIB responded by appointing an Accredited Representative and offered any assistance required. KAIB had investigated the incident based on the landing at RKSI and AIBN was provided with a summary of the KAIB Aircraft Incident Report. Hence, this incident was investigated in two parts; KAIB investigation based on the landing incident in Korea and AIBN investigation based on the take off incident in Norway.

SUMMARY

On 21 September 2004, at time 1302, a B747-400F operated by Korean Air was taking off from Oslo Airport Gardermoen for a flight to Incheon International Airport, Seoul, Republic of Korea. During take-off run, the aircraft started to autorotate at approximately 120 Knots Calibrated Air Speed (KCAS) due to the actual Centre of Gravity (CG) being aft of the aft CG limit. The stabilizer remained steady as the aircraft continued to accelerate and became airborne at 165 KCAS and 11.5 degrees pitch attitude. After lift-off the nose attitude was increased to 12 degrees and then to 19 degrees. The Commander realised that the aircraft balance was wrong due to the far forward trim setting. The crew suspected a wrong CG location and contacted the company office through SATCOM. The crew was informed that the CG was out of limits for landing. A new CG location

[1] Korean Accident Investigation Board has later been changed to Korean Aviation-Railroad Accident Investigation Board.

was received and the flight crew relocated some load pallets during flight. However, the CG was still aft of the aft limit. During the approach briefing, the landing configuration and performance parameters were discussed to reduce the possibility of a tail strike during touchdown and landing rollout. Emergency equipment was requested to stand by. During the landing rollout at RKSI, the aircraft nose lifted at 60 knots and nose wheel steering was lost. The Commander stopped the aircraft on the runway and shut down all engines. The aircraft was subsequently towed to the parking stand.

The wrong CG location was caused by a mistake during loading. During load planning the Load Master mistook the Standard Operating Mass (SOM) Centre of Gravity (CG) Mean Aerodynamic Chord (MAC) percent number for the Index Unit (IU) number. Hence the aircraft was misloaded to a CG of 37.8% MAC, which was 4.8 % aft of the aft limit of 33 % MAC. The mistake was not discovered by the Load Master, SAS Cargo or Korean Air Supervisor. Nor was the mistake discovered by the Commander who accepted and signed the cargo loading manifest before take-off.

The aircraft took off from Oslo International Airport with the CG 4.8 % aft of the aft limit and landed at Incheon International Airport with the CG 7.2% aft of the certified aft limit.

The landing incident was investigated by the Korean Accident Investigation Board (KAIB) after the aircraft landed at RKSI.

AIBN is issuing two safety recommendations.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 A Korean Air (KAL) B747-400F cargo aircraft was prepared for a cargo flight from Oslo Airport Gardermoen (ENGM) to Incheon International Airport, Seoul (RKSI) on Tuesday 21 September 2004. The cargo loading was performed by SAS Cargo, while the load planning, mass and balance calculation was subcontracted to, and performed by, SAS Ground Services (SGS).

1.1.2 During load planning the Load Master mistook the Standard Operating Mass (SOM) Centre of Gravity (CG) Mean Aerodynamic Chord (MAC) percent number for the Index Unit (IU) number. Hence the aircraft was misloaded to a CG of 37.8% MAC, which was 4.8% aft of the aft limit of 33% MAC. The mistake was not discovered by the Load Master, SAS Cargo or Korean Air Supervisor. Nor was the mistake discovered by the Commander who accepted and signed the cargo loading manifest before take-off.

1.1.3 The Korean Air flight KAL520 departed ENGM runway 19R on 22 September 2004 at time 1302. During the take off roll, the aircraft was observed by an airport employee to rotate early, and then lowered the nose and continued the acceleration to lift off.

1.1.4 The FDR/QAR data showed that the control column was relaxed at approximately 50 knots. The column and pitch remained steady until the airplane autorotated at approximately 120 KCAS.The data further showed a lift-off speed of 165 KCAS and 11.5 degrees pitch attitude.

1.1.5 During the take-off phase the first officer, who was Pilot Monitoring (PM), observed excessive pitch-up of the aircraft. The PF controlled the pitch attitude by use of forward trim.

1.1.6 The pitch attitude was increased to 12° and then up to 19.5° at 200 ft radio altitude. The initial climb out was continued at a speed of 158 KCAS, well below the planned target value V_2 of 166 KCAS + 10 kt (176 KCAS).

1.1.7 Control Column Position (CCP) indicated values from -1.0 units during the take-off roll to -4.6 units during the climb.

1.1.8 During cruise flight the crew suspected wrong mass and balance calculation and contacted the company Operations Control Centre (OCC) via SATCOM. The OCC confirmed that the weight and balance manifest was wrong and that the landing CG would be 43% (estimated by AIBN at 43.7%).

1.1.9 After discussion with the OCC, the flight crew decided to adjust the CG by relocating some cargo pallets. Hence, the CG was adjusted to a landing CG of 40.2% MAC.

1.1.10 During the approach briefing, landing procedures were discussed and airport emergency equipment was requested.

1.1.11 The aircraft landed at RKSI with the CG 7.2% aft of the aft limit of 33%.

1.1.12 The nose gear steering function disengaged when the nose strut extended more than 18 inches. During landing at RKSI the nose gear strut extended 22 inches and activated the nose gear switch (Flight Ground Switch, FGS) at about 60 knots. This resulted in a loss of nose wheel steering and it was decided to stop and shut down the aircraft on the runway. The aircraft was then towed to the parking stand.

1.2 Injuries to persons

Injuries	Crew	Passengers	Other
Fatal			
Serious			
Minor/none	3		

1.3 Damage to aircraft

None.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Commander

1.5.1.1 Male, 53 years.

Flying experience hrs	All types	On type
Last 24 hours		11
Last 3 days		11
Last 30 days		88
Last 90 days		240
Total	17,086	5,104

Duration of his last rest period was 39 hrs. The duty period started at 1115 on the day of take off.

1.5.1.2 The commander was trained in the South Korean Navy. He started working for KAL on 25 February 1980. He received his Korean ATPL(A) in 1983. The Commander had type ratings on B727, MD-11, and B747 aircraft. He got his B747-400 type rating on 4 June 1996. He became a Commander on 18 October 1996.

1.5.1.3 His Class 1 medical was valid until 31 March 2005.

1.5.2 First Officer

1.5.2.1 Male, 35 years.

Flying experience hrs	All types	On type
Last 24 hours		11
Last 3 days		11
Last 30 days		60
Last 90 days		230
Total	2,279	2,113[2]

Duration of his last rest period was 39 hrs. The duty period started at 1115 on the day of take-off.

1.5.2.2 The first officer was trained at the Cheju Flying School in South Korea. He received his Korean CPL(A) on 20 April 1999 and started to work for KAL on 30 August 1999. The First Officer had type ratings on the Airbus 300-600 and Boeing 747 aircraft. He received his B747-400 type rating on September 2002 and became a First Officer on December 2002.

1.5.2.3 The First Officer's medical was valid until 30 September 2005.

1.5.3 Load Master

1.5.3.1 The Load Master had his basic load control training from Braathens domestic airline, where he started in 1995. In Braathens he received training in aircraft load control by Braathens, covering Braathens, KLM and British Airway's (BA) load control systems. The KLM training included widebody cargo handling.

[2] This leaves 166 hrs for basic training and type rating training on A300-600.

1.5.3.2 The Load Master was initially employed by Braathens where he was responsible for loading procedures. After the merger of SAS and Braathens, he worked for SGS in check in, gate and as a load controller.

1.5.3.3 The Load Master had been employed by SAS Ground Services (SGS) since 12 August 2002. After employment by SGS, the Load Master underwent a 3-day recurrent load control course at SGS and a 2-day course at KAL, where he received specialised B747-400F training. He also underwent a load control course provided Pakistan International Airways (PIA).

1.5.3.4 In April 2003 he underwent a Load Master course at SGS and became a Load Master for KAL B747-400F at ENGM in April 2004.

1.5.3.5 The Load Master was properly trained and fully qualified for his tasks.

1.6 Aircraft information

1.6.1 Aircraft general

1.6.1.1 The aircraft, a Boeing 747-4B5F, S/N 27073, registered HL7467, was manufactured in 2001. The Certificate of Airworthiness was valid until 12 November 2004.

1.6.1.2 The aircraft had accumulated 14,441 flight hours and the last A check was performed on 15 August 2004 at 13,883 flight hrs.

1.6.1.3 As far as AIBN has been able to verify, the aircraft was fully serviceable on the date of departure from Oslo airport.

1.6.2 B747-400 Weight and Balance System (WBS)

1.6.2.1 The B747-400F aircraft, including HL7467, was equipped with a WBS that automatically computed and displayed the mass and CG of the aircraft. The system was installed to provide verified information by comparing the CG and Trim units of the M & B Manifest. Part of the system included a Green Band stabiliser trim setting computed by the FMS. If the stabiliser trim value was set outside of the Green Band, a Take-off Warning horn would sound when the power levers were advanced.

1.6.2.2 The Take-off warning and Green band systems are designed to detect large mistrimmed stabilizer settings which could lead to insufficient control margin. It is not the purpose of these systems to detect mass and CG loadings outside the certified mass/CG envelope. The system may detect and alert the flight crew of misloaded situations within the certified loading envelope, but not necessarily.

1.6.2.3 The multiple green band system used for takeoff on the 747 does a rough check of whether the airplane is loaded heavy/forward or light/aft with respect to mass and CG. The check is based on nose gear pressure. The system check is to ensure a large mistrim stabilizer condition does not exist because of an incorrect green band being used. If the airplane nose up green band is displayed, the system verifies that the airplane is loaded heavy/forward. If the airplane nose down green band is displayed, the system verifies that the airplane is loaded light/aft. The system consists of a single nose gear pressure switch, which is only open or closed, and does not know how far forward or how far aft the airplane is loaded. The system only knows that the nose gear pressure is above or below the switch trip point. Therefore, the system only detects an incorrect green band, and thus a mistrimmed stabilizer, for a large loading error that extends across the switch trip point. A disagreement is displayed on EICAS as “STAB GREENBAND”.

1.6.2.4 Once the green band is selected, the system also checks that the actual stab trim position falls within that green band. A disagreement is displayed as “CONFIG STAB”.

1.6.2.5 With a take-off mass of 726,400 lbs at a CG of 37.8% MAC, the incorrect stabilizer trim setting of 4.5 units (corresponding to a CG of 27.0%) would fall within the airplane nose down green band which extends from 1.8 to 8.0 pilot units. Hence, the take off warning would not be triggered.

1.6.2.6 According to the Pilot Operating Manual (POM) the CG % MAC value from the M & B Manifest could be inserted manually by the crew, or the CG value calculated by the aircraft WBS could be selected (accepted) on the FLIGHT Management System (FMS). If the WBS calculated value was used, the SYSTEM had an error margin of ±3% MAC or ±0.5 unit Trim.

1.6.2.7 At the time of the incident the operating procedures of the aircraft’s WBS were not provided to the crew and the crew was not trained for their use. As a result of the Korean Air’s internal investigation report and recommendations, a revision to the B747-400F Pilot Operating Manual (POM) for proper use of the WBS was implemented.

1.6.2.8 At the time of the incident the flight crew inserted manually into the FMS the CG % MAC from the M & B Manifest. The FMS then calculated the proper stabiliser trim setting for the input CG. The wrong CG value of 27% MAC was put into the FMS which calculated the corresponding stabiliser trim setting to be 4.8. This was within the allowable ±0.5 unit tolerance of the trim setting of 4.5 on the M & B Manifest. Hence, the crew did not suspect anything wrong and no Take-off Warning would alarm the crew of the misloaded aircraft during the take off run.

1.6.3 KAL520 takeoff data

1.6.3.1 Aircraft HL7467 mass (AIBN uses mass in lieu of weight) data was as follows:

- SOM 350,100 lbs
- SOM CG percent MAC: 31.5%
- SOM IU 68.8

1.6.3.2 Aircraft HL7467 miscalculated takeoff data was:

- TOM 725,187 lbs
- TOM CG percent MAC: 27.0%
- SOM IU 73.7
- Stab trim 4.5

1.6.3.3 Aircraft HL7467 actual takeoff data:

- TOM 725,187 lbs
- CG percent MAC: 37.8%. Aft limit 33% (4.8% exceedance)
- TOM IU 111.0
- Stab trim 2.0

1.6.3.4 Aircraft HL7467 estimated landing data without in flight load adjustments:

- ELM 533,187 lbs
- CG percent MAC: 43.7%. Aft limit 33% (10.7% exceedance)
- ELM IU 109.7

1.6.3.5 Aircraft HL7467 actual landing data after in flight load adjustments:

- ELM 533,187 lbs
- CG percent MAC: 40.2%. Aft limit 33% (7.2% exceedance)
- ELM IU 101.0

1.6.3.6 Aircraft HL7467 planned takeoff speeds:

- V_1 143 knots
- Vr 154 knots
- V_2 166 knots

Boeing comments:

> *"The "planned" takeoff speeds V_1/Vr/V_2, as noted in Section 1.6.3.6 are 143, 154 and 166 knots. Boeing would like to note for conditions of a takeoff gross weight of 725187 pounds at flaps 20 in light winds, and the FDR outside temperature and pressure altitude values of 11 degrees C and 1550 feet, respectively at Gardermoen International airport, we determine V_1/Vr/V_2 to be* 139, 153 and 166 knots."

1.7 Meteorological information

1.7.1 TAF ENGM 210800Z 210918 21005KT 9999 –SHRA SCT 015 BKN030 TEMPO 0915 SHRA BKN007 SCT025CB

1.7.2 METAR ENGM 211050Z 21005KT 9999 –RA FEW010 SCT015 BKN050 10/08 Q0982 NOSIG

1.7.3 The general weather conditions were favourable for a take off on runway 19, with a headwind component of about 5 kt, temperature 10°C and QNH 982 hPa.

1.8 Aids to navigation

Not applicable.

1.9 Communications

Not applicable.

1.10 Aerodrome information

Runway in use was R19R which was 3,600 x 45 meters. R19R/01L is the western and longest runway of two runways at ENGM. See figure 1. The runway was dry.

AIP NORGE / NORWAY AD 2 ENGM 2 - 1

AERODROME CHART	60°12'10''N 011°05'02''E WGS84	AD ELEV 681 FT	TWR (W) 118.300 MHz TWR (E) 120.100 MHz GND (N) 121.925 MHz ATIS DER 127.150 MHz ATIS ARR 126.125 MHz	OSLO GARDERMOEN NORWAY

RWY	BRG (GEO)	THRESHOLD		BEARING STRENGTH	DECLARED DISTANCES				TAXIWAY
					TORA	ASDA	TODA	LDA	
01R	016.04	601032.72 N	0110628.01 E	PCN 75/F/A/W/T	2950	2950	2950	2950	TWY PCN 75/F/A/W/T EXC TWY C, C1, C2, C3 PCN 65/F/B/X/T
19L	196.06	601204.35 N	0110720.95 E	PCN 75/F/A/W/T	2950	2950	3350	2950	
01L	016.01	601106.00 N	0110425.48 E	PCN 75/F/A/W/T	3600	3600	3600	3600	
19R	196.03	601257.84 N	0110529.99 E	PCN 75/F/A/W/T	3600	3600	3600	3600	

Fig. 1 ENGM runway data

1.11 Flight recorders

1.11.1 The aircraft was equipped with the required FDR and CVR. However, the recorders were not downloaded.

1.11.2 The QAR (Quick Access Recorder) was downloaded by Korean Air and data made available to AIBN.

1.11.3 From Korean Air the AIBN has received the following information:

> "*The FDR/QAR data from the OSL takeoff was archived in accordance with KAL corporate document retention policies …*
>
> *Regarding the Vspeeds for the datum takeoff event, at a brake release weight of 726,400 lbs, ISA conditions, dry runway, 681' field elevation, -0,165 % average slope of R/W 19R, Flaps 20, TO1 reduced power settings, they are as follows:*
>
> V_1 *143 kts*
> *Vr 154 kts*
> V_2 *166 kts*
>
> *At Frame 9041-1, NSQS (Nose Gear Squat Switch) 1, 2, 3, and 4 parameters go from GND to AIR mode at a CAS of 53 kts. This indicates nose gear strut extension only, and should not be construed as to represent nose gear lift-off from the runway.*

Frame 9049-1 indicates movement of the left and right wing gear to the tilt position at a CAS of 163 kts.

Pitch attitudes after lift-off continuing through 1000 RA, do not indicate values over 19.5 degrees at the apex.

However, climb out was accomplished below the target value of V_2+10, or CAS 176 kts, the lowest value of which occurred at Frame 9051-3 indicating a CAS value of 158 kts.

Control Column Position (CCP) values, ranging around -1.0 units, do not indicate that the flight crew was fighting to keep the aircraft on the ground. It is not until later in the climb out, Frame 9052-2, that forward CCP indicates -4.6 units."

1.11.4 From Boeing the AIBN has received the following information:

"Our analysis of the FDR (QAR) data shows that on the take off run, autorotation occurred at 120 knots followed by a commanded rotation at approximately the scheduled rotation speed (153 knots). Aborting the take off should be considered a viable option if a clear case of autorotation is perceived prior to V_1 (139knots)".

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

No blood samples were drawn from the crew.

1.14 Fire

None.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

None.

1.17 Organizational and management information

1.17.1 Korean Air (KAL)

1.17.1.1 The airline began operations in 1962 as Korean Air Lines, the state-owned airline of the Republic of Korea replacing the former Korean National Airlines. In 1969, it was privatized by the Korean government and purchased by the Hanjin Transport Group. The airline later changed its name to Korean Air and incorporated a blue-top aircraft livery in 1984.

1.17.1.2 Currently, the airline is performing scheduled and charter, international and domestic, passenger and cargo service to ninety-two (92) cities in thirty-one (31) countries. Its one hundred and eighteen passenger and cargo aircraft fleet consists of 42 B747-400, 2 B747-200F, 15 B777-200/300, 19 A330-200/300, 10 A300-600, and 30 B737-700/800 type aircraft. The average fleet age is 7.4 years. The airline has placed orders and options for A380 and B787 aircraft to be delivered beginning in 2008.

1.17.1.3 As of the end of 2005, Korean Air employed approximately 16,500 employees, consisting of 1,804 pilots, 3,338 flight attendants, 3,692 maintenance and engineering staff, 4,306 general administration staff, 1,508 regional station staff, and 1,896 staff engaged in miscellaneous airline functions.

1.17.1.4 Korean Air's Executive and Senior Management staff is centrally located within the Korean Air's World Headquarters Operations Control Building in Seoul, Republic of Korea. The airline's President/Chief Operating Officer is directly supported by the President of Cargo Sales and Traffic, the President of Passenger Sales and Traffic, and the Executive Vice President of Operations.

1.17.1.5 Korean Air had entered into a service contract with SAS Cargo to provide cargo ground handling services at the Oslo Gardermoen Airport. SAS Cargo had subcontracted the load handling and load calculation to SAS Ground Services (SGS). Oversight of SAS Cargo services was provided by a Copenhagen-based Korean Air supervisor who travelled to Oslo in accordance with the airline's cargo flight schedule. Oversight of Copenhagen Cargo Traffic activities was provided by Korean Air's Cargo Sales Regional Office in Frankfurt, Germany, who in turn, reported directly to the airline's Europe/Middle East Headquarters located in Paris, France.

1.17.1.6 At the time of the incident, the SAS Cargo/SAS Ground Services Load Master duties and responsibilities included, but were not limited to, the manual preparation and completion of the Weight and Balance Manifest and Load Planning Sheet.

1.17.1.7 Immediately after the incident, Korean Air placed a resident Korean Air Station Manager/ Supervisor at Oslo Airport Gardermoen to personally supervise all sub-contracted ground handling functions. He checked the aircraft loading documents before they were reviewed by the Commander. He was replacing the visiting Korean Air Danish representative who previously visited the ENGM cargo facility on a temporary basis in connection with the loading of Korean Air cargo aircraft.

1.17.2 SAS Cargo

1.17.2.1 At the time of the incident SAS Cargo Norway AS was contracted by Korean Air to perform loading operations at ENGM. SAS Cargo performed all load handling, but the load planning, mass and balance calculations and load control were subcontracted by SAS Cargo to SAS Ground Services (SGS), and performed by an SGS Load Master.

1.17.2.2 SAS Cargo had at the time a Cargo Operator Licence from Oslo Airport Gardermoen (OSL). This was not an aviation authority licence. At the time Norwegian regulations did not require a cargo terminal to be approved by CAA-N.

1.17.2.3 SAS Cargo personnel was properly trained and approved by Korean Air Cargo.

1.18 Additional information

1.18.1 SAS Cargo loading procedures

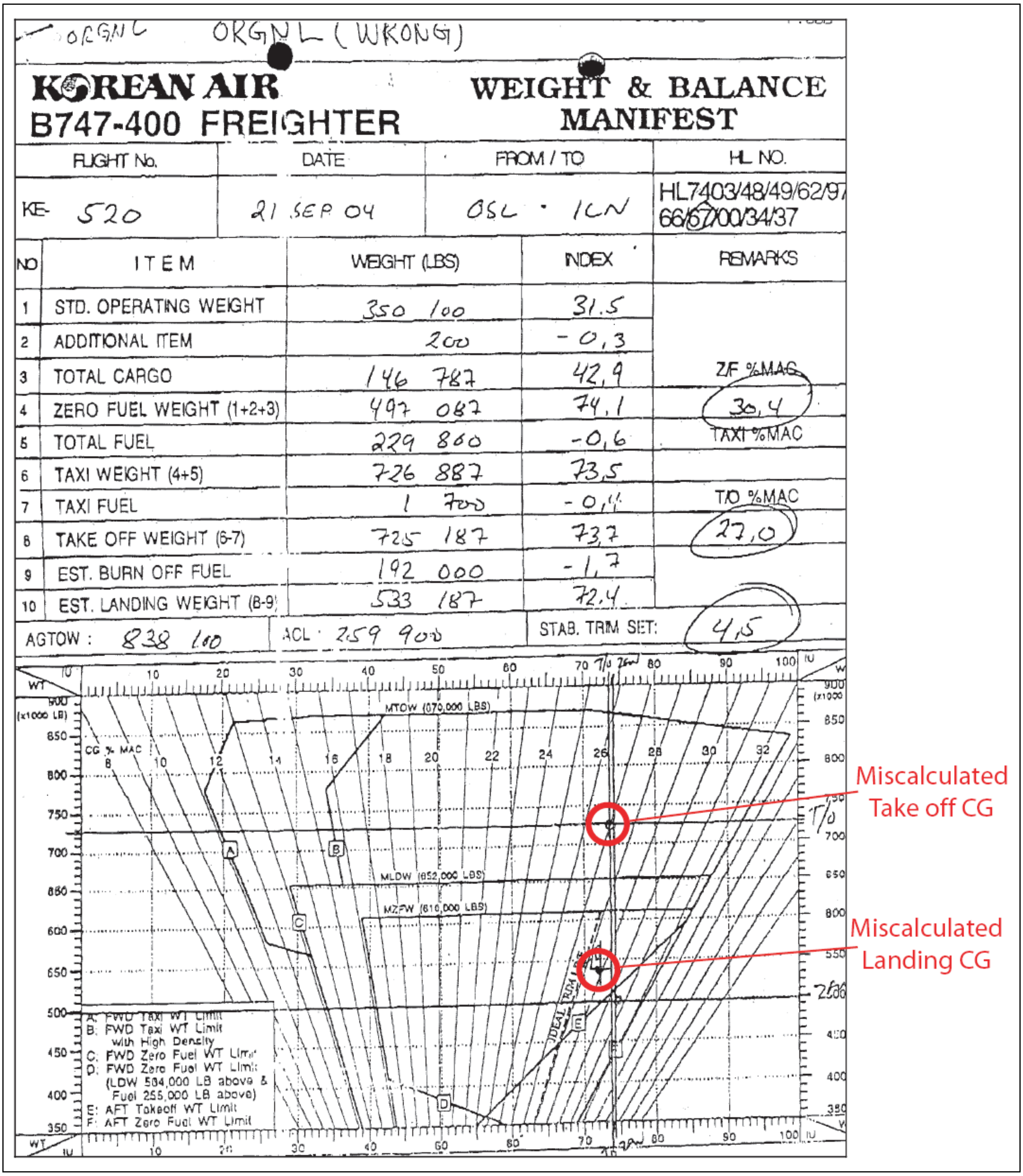
1.18.1.1 At the time of the incident, SAS Cargo/SGS was using manual load planning and Mass & Balance calculations. The Load Master used table values of the aircraft Standard Operating Mass (SOM) and SOM IU and filled these values into the Weight& Balance manifest. From these values he calculated and filled in the Zero Fuel Mass (ZFM) and IU, the Takeoff Mass (TOM) and IU, the Estimated Landing Mass (ELM) and IU, and the Stabilizer Trim Setting.

1) B747-400 CGO 351400,0 111,00 2004.9.9.

REG NO.	PORTION	SOW-LB	% MAC	IU	BW-KG	BI	PW-KG	PI	BW_adj	BI_Adj
HL7403 '04.4.7	ALL CGO B.E.W	351600 350232	30,3 30,6	67,0	159164 ARM : 1358,26	67,9 MOMENT : 475705926	129	-0,3	-1567	-0,7
HL7448 '04.4.7	ALL CGO B.E.W	351100 349737	30,8 31,1	67,8	158940 ARM : 1359,88	68,7 MOMENT : 475598806	129	-0,3	-1792	0,0
HL7449 '04.4.7	ALL CGO B.E.W	352700 351357	30,5 30,7	67,3	159675 ARM : 1358,70	68,2 MOMENT : 477388541	129	-0,3	-1057	-0,5
HL7462 '04.4.7	ALL CGO B.E.W	351800 350382	31,7 31,9	69,2	159232 ARM : 1362,63	70,1 MOMENT : 477440976	129	-0,3	-1499	1,4
HL7466 '04.9.7	ALL CGO B.E.W	350600 349272	30,6 30,9	67,4	158729 ARM : 1359,19	68,3 MOMENT : 474728101	129	-0,3	-2003	-0,3
HL7467 '04.4.7	ALL CGO B.E.W	350100 348776	31,5 31,7	68,8	158504 ARM : 1362,07	69,7 MOMENT : 475058812	129	-0,3	-2228	1,1
HL7497 '04.8.10	ALL CGO 0 B.E.W	355100 0 353687	30,7 0,0 30,9	67,8 0,0	160732 ARM : 1359,40	68,6 MOMENT : 480800836	129 0 0	-0,3 0,0 0,0	0	0,0
HL7400 '04.4.27	ALL CGO B.E.W	349400 348039	30,6 30,9	67,4	158170 ARM : 1359,21	68,2 MOMENT : 473058866	129	-0,3	-2562	-0,4
HL7434 '04.4.7	ALL CGO B.E.W	350500 349134	31,4 31,6	68,7	158666 ARM : 1361,68	69,5 MOMENT : 475408559	129	-0,3	-2065	0,9
HL7437 '04.4.7	ALL CGO B.E.W	351100 349719	31,2 31,5	68,4	158932 ARM : 1361,16	69,3 MOMENT : 476024631	129	-0,3	-1800	0,7

Fig. 2. Fleet SOM and IU

1.18.1.2 After completion of the loading and balance calculations, the Load Master signed the Manifest and brought it to the visiting KAL cargo representative (ref. 1.17.1.5) who checked the loading manifest before it was brought to the Commander for review. This procedure was not always adhered to, and, in this incident, the KAL representative did not look at or reviewed the manifest. After verifying that the mass and CG was within limits, the Commander countersigned the load manifest. In this incident, the deviation was missed both by the Load Master and the Commander.


ORGNL (WRONG)

KOREAN AIR B747-400 FREIGHTER

WEIGHT & BALANCE MANIFEST

FLIGHT No.	DATE	FROM / TO	HL NO.
KE- 520	21 SEP 04	OSL · ICN	HL7403/48/49/62/97 66/67/00/34/37

NO	ITEM	WEIGHT (LBS)	INDEX	REMARKS
1	STD. OPERATING WEIGHT	350 100	31.5	
2	ADDITIONAL ITEM	200	-0,3	
3	TOTAL CARGO	146 787	42,9	Z/F %MAC
4	ZERO FUEL WEIGHT (1+2+3)	497 087	74,1	30,4
5	TOTAL FUEL	229 800	-0,6	TAXI %MAC
6	TAXI WEIGHT (4+5)	726 887	73,5	
7	TAXI FUEL	1 700	-0,4	T/O %MAC
8	TAKE OFF WEIGHT (6-7)	725 187	73,7	27,0
9	EST. BURN OFF FUEL	192 000	-1,7	
10	EST. LANDING WEIGHT (8-9)	533 187	72,4	

AGTOW : 838 100 ACL : 259 900 STAB. TRIM SET: 4,5

Fig. 3. M & B Manifest of 21 Sep 2004

1.18.1.3 The above procedure was based on three levels of control. First the Load Master himself checked the calculations. Then a Korean Air Supervisor from Korean Air Denmark visiting SAS Cargo/SGS at ENGM checked the loading calculations. Finally the Commander verified that the mass and balance of the aircraft was within limitations.

1.18.1.4 After the incident SAS Cargo implemented a temporary fourth level check by introducing a check between the Load Master and the Korean representative before the Commander received the manual M & B calculations for verification.

1.18.1.5 In addition, the individual aircraft data sheet columns for Index Units were coded yellow. Hence the critical IU numbers were highlighted. This reduced the possibility of taking the MAC value instead of the IU value. Further, SAS Cargo faxed the completed weight and balance manifest to Korean Air Operational Control Centre in Seoul, South Korea, for verification.

1.18.1.6 Later KAL implemented a computerized Automated Load Planning (ALP) system, where the Load Master works on an online M & B computer containing the individual aircraft's SOM data. If wrong entries are made, this will be recognised automatically by the computer and subsequently rejected.

1.18.1.7 With ALP the Load Planning Sheet is created by the Load Master and delivered to the loading duty person at the aircraft in order to record final pallet weight and location. The finalized Mass and Balance Manifest and Load Planning Sheet are then reviewed by the Korean Air Supervisor prior to being delivered to the Aircraft Commander. The Commander is then responsible for ensuring that the loading and mass/balance calculations contained within the Mass and Balance Manifest are accurate and comply with the aircraft's limitations.

NEW CORR.

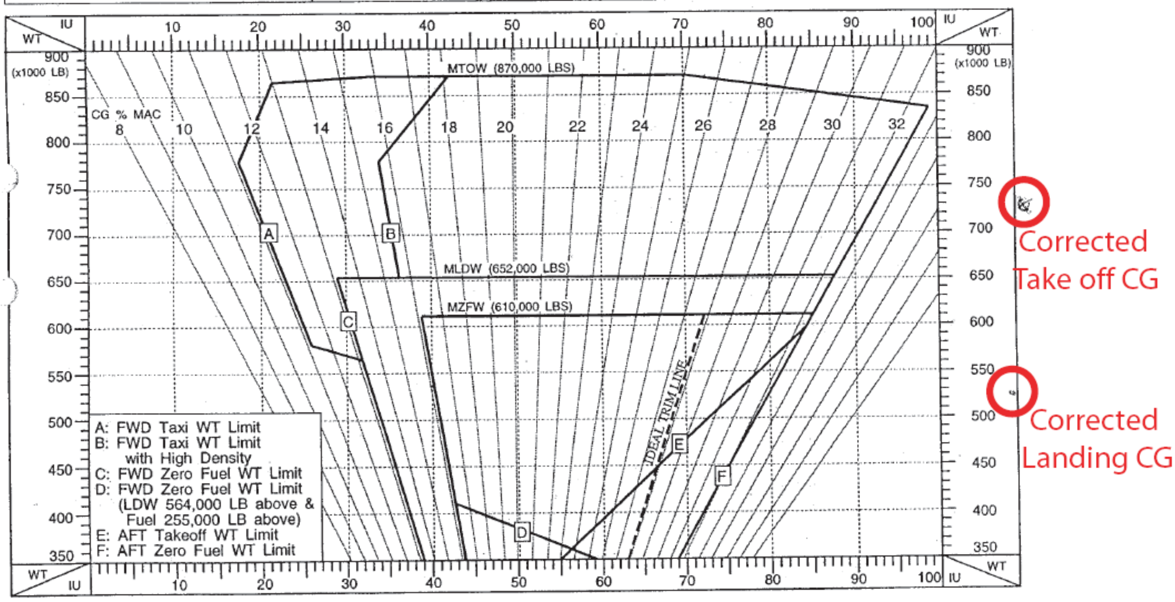
KOREAN AIR
B747-400 FREIGHTER

WEIGHT & BALANCE MANIFEST

FLIGHT No.	DATE	FROM / TO	HL NO.
KE- 520	21 SEP 04	OSL - ICN	HL7403/48/49/62/97/ 66/67/00/34/37

NO	ITEM	WEIGHT (LBS)	INDEX	REMARKS
1	STD. OPERATING WEIGHT	350100	68,8	
2	ADDITIONAL ITEM	200	-0,3	
3	TOTAL CARGO	146787	42.9	Z/F %MAC
4	ZERO FUEL WEIGHT (1+2+3)	497087	111,4	46,4
5	TOTAL FUEL	229800	-0,6	TAXI %MAC
6	TAXI WEIGHT (4+5)	726887	110,8	
7	TAXI FUEL	1700	-0,4	T/O %MAC
8	TAKE OFF WEIGHT (6-7)	725187	111,0	38
9	EST. BURN OFF FUEL	192000	-1,7	
10	EST. LANDING WEIGHT (8-9)	533187	109,7	

AGTOW : ACL : STAB. TRIM SET:



FORM NO	KAL-FT-C004
EFF	2004. 5. 1

SIGNATURE Dispatcher or Agent :

SIGNATURE Captain :

Fig. 4. Corrected M & B Manifest of 21 Sep 2004

1.18.2 Korean Air M & B procedures

1.18.2.1 At the time of the incident, manual load control was in effect. The Load Master manually calculated the mass and balance of the aircraft on the Korean Air Mass & Balance Manifest (see figure 3). In doing so, he mistook the MAC value of 31.5% for the Index Unit of 68.8.

1.18.2.2 The Load Master signed the Manifest and then took the M & B Manifest to the Commander who was responsible for verifying that the mass and CG was within limits. The Commander signed for the verification.

1.18.2.3 The Pilot Operating Manual at that time lacked specific Aircraft Mass and Balance information containing detailed information regarding the aircraft's Standard Operating Mass, Standard Operating Index Unit, and Standard Operating percent MAC. Further, the crew did not have available Minimum and/or Maximum Allowable Values for Standard Operating Mass, Standard Operating Mass Index Units, Zero Fuel Mass, Takeoff Gross Mass, Percent MAC, and Stabilizer Trim Settings. Hence , the Commander did not have available the aircraft specifics to check against the M & B Manifest and he did not discover that the IU value read 31.5 instead of the correct IU value of 68.8.

1.18.2.4 After the incident, Korean Air implemented Automated (computer) Load Planning (ALP) and Departure Control System at ENGM and other off-line cargo stations. During ALP conditions, the flight crew does not have SOM/IU source document info available in the cockpit, but relies upon the computer generated info.

1.18.2.5 For manual M & B & Load Planning, the flight crew will be provided computer generated tail-number specific SOM/IU values.

1.18.2.6 Korean Air is implementing an Engineering Order (EO) to install cockpit placards indicating aircraft specific SOM & IU values. These values would be changed subsequent to aircraft re-weighing which occurs at KAL once every 3 years.

1.18.2.7 When the flight crew enter data from the weight and balance manifest provided by ground crew into the FMS, most flight crew enter the data without comparing the data with the FMS basic data.

1.18.2.8 According to Pilot Operating Manual (POM) 5.4.2, the CG value should be selected or manually inserted into the FMS. This could be an effective method to determine an exceedance error resulting from manual calculations. The allowable error range was ± 3% of take off CG expressed in MAC, compared to the mass and balance manifest.

1.18.2.9 According to the Korean Flight Operations Manual (FOM) 6.8.7, Operations Control for manual weight and balance, the flight crew should confirm the weight and balance manifest. Further, the flight crew should be well aware of the full contents so far as to prepare it, if necessary. The flight crew did not find any errors associated with the SOM and IU.

1.18.2.10 The weight and balance manifest in use at the time did not include any "range of acceptable value" criteria for SOM and IU, which created difficulty in identifying data errors.

1.18.3 Korean Air investigation report

Korean Air performed an internal investigation after the incident. The investigation report listed 7 safety recommendations, all of which have been implemented:

"4.1 Cargo Division

-Ensure that all Korean Air and contracted ground handling employees engaging in the acceptance, load planning, loading/securing, weight and balance and aircraft performance calculations, and unloading of cargo be provided with adequate training and certification prior to beginning their duties. Such training should be in accordance with applicable internationally accepted standards (IATA and ICAO), Republic of Korea Flight Safety Regulations (FSR), and Korean Air company regulations. After the completion of such training they should be issued appropriate validation of training completion in the form of a Weight and Balance Diploma or other such officially recognized certificate of achievement.

Status: Implemented.

-Ensure that all Korean Air and contracted ground handling supervisory personnel receive specialized training, in addition to the training specified in Recommendation 4.1 (A) above, in effective oversight and supervision of cargo traffic functions. After the completion of such training, these personnel should be issued appropriate validation of supervisory training completion in the form of a Cargo Traffic Diploma or other such officially recognized certificate of achievement.

Status: Implemented

-Ensure that the Cargo Ground Handling Company Service Evaluation System for overseas stations includes specific items regarding operational safety.

Status: Implemented

4.2 Flight Operations Division

-Ensure that all flight crew receive initial, transition, upgrade, and recurrent training in the fundamentals of aircraft performance and weight and balance theory and related calculations with specific focus on the accurate preparation of manual weight and balance forms. Such training completion should be validated through either oral or written testing procedures.

Status: Implemented.

-Ensure that accurate information regarding specific aircraft standard operating weight (or range of weights) and standard operating weight index unit (or range of index unit values) is provided on the aircraft flight deck either in the form of a placard or other such notification method as found appropriate for flight crew awareness.

Status: Implemented.

-Ensure that appropriate training is provided to applicable flight crews regarding the proper operation and utilization of the WBS in accordance with established operation specifications.

Status: Implemented.

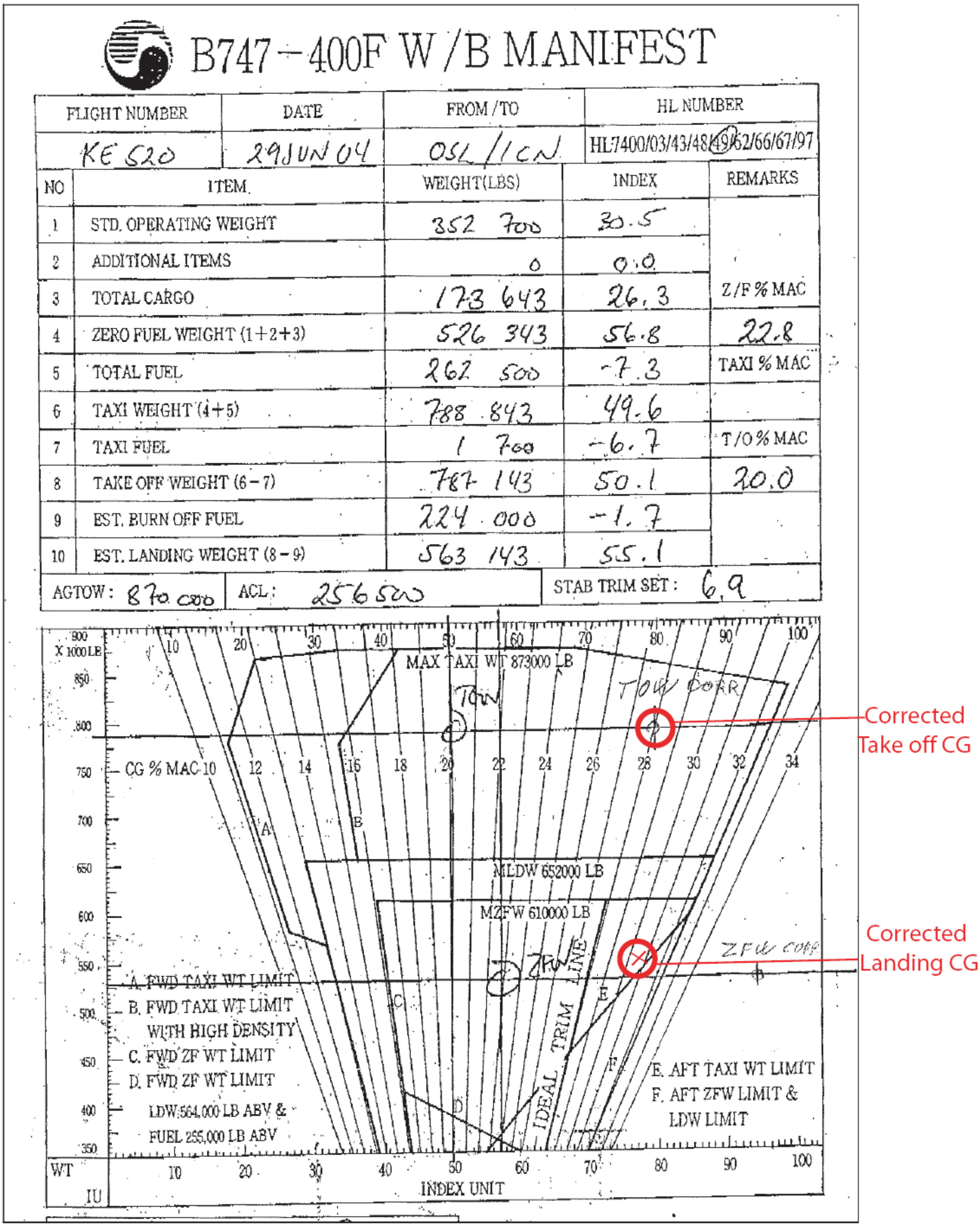
4.3 Operations Control Division

- Establish situational and comprehensive support procedures (including emergency contact points) in order to ensure timely and appropriate response to irregular operations.

Status: Implemented.

1.18.4 Similar, but less serious incident at SAS Cargo/SGS at ENGM

1.18.4.1 During the investigation following the KAL520 incident, SAS Cargo checked through the previous mass and balance manifests. It was then discovered that the same mistake had been made by the same Load Master on 29 June 2004. See M & B Manifest, figure 5.



B747−400F W/B MANIFEST

FLIGHT NUMBER	DATE	FROM/TO	HL NUMBER
KE 520	29JUN04	OSL/ICN	HL7400/03/43/48/49/62/66/67/97

NO	ITEM	WEIGHT(LBS)	INDEX	REMARKS
1	STD. OPERATING WEIGHT	352 700	30.5	
2	ADDITIONAL ITEMS	0	0.0	
3	TOTAL CARGO	173 643	26.3	Z/F % MAC
4	ZERO FUEL WEIGHT (1+2+3)	526 343	56.8	22.8
5	TOTAL FUEL	262 500	-7.3	TAXI % MAC
6	TAXI WEIGHT (4+5)	788 843	49.6	
7	TAXI FUEL	1 700	-6.7	T/O % MAC
8	TAKE OFF WEIGHT (6−7)	787 143	50.1	20.0
9	EST. BURN OFF FUEL	224 000	-1.7	
10	EST. LANDING WEIGHT (8−9)	563 143	55.1	

AGTOW: 870 000 ACL: 256 500 STAB TRIM SET: 6.9

Fig. 5. M & B Manifest of 29 June 2004

1.18.4.2 In this incident the Load Master mistook the 30.5% MAC value for the correct UI of 67.3.

1.18.4.3 The error was overlooked by the Load Master himself and by the aircraft Commander.

1.18.4.4 The aircraft took off from ENGM with an actual CG at 28% MAC instead of the calculated 20% MAC, and landed in Korea without incident. In this case the CG was still within limits.

1.18.5 Longitudinal static stability

1.18.5.1 A review of the longitudinal static stability:

The distance between the CG and Aerodynamic Centre (AC) of the aircraft (normally referred to as the Neutral Point) expressed in percent Mean Aerodynamic Chord (% MAC) is called Static Margin. The Static Margin is numerically equal to the negative slope of the C_m versus C_L curve and indicates the longitudinal static stability of an aircraft.

1.18.5.2 If the CG is moved back to the Neutral Point, the aircraft becomes neutrally stable. The required Static Margin (i.e. the negative slope of the C_m vs C_L curve) is established during certification testing. It is not a certification requirement for a minimum Static Margin, but it is based on acceptable handling qualities. Normally the minimum Static Margin is in the order of 10% MAC.

1.18.5.3 A reduced Static Margin may result in running out of longitudinal trim in flight and possible tail strike and/or nose pitch up and loss of nose wheel steering on the ground.

An examination of Figure 5–18 shows that as the c.g. is moved aft the slope of the pitching moment curve (dC_m/dC_L) for the assumed airplane becomes more positive. When a c.g. position of 30 per cent is reached, the slope becomes zero. At this point the airplane is neutrally stable ($dC_m/dC_L = 0$), and this c.g. position is called the stick-fixed neutral point and is denoted by the symbol (N_0). Equations (5–32) and (5–34) can be used to solve for this neutral point.

$$N_0 = x_{cg(dC_m/dC_L=0)} = x_{ac} - \left(\frac{dC_m}{dC_L}\right)_{\substack{Fus\\Nac}} + \frac{a_t}{a_w}\bar{V}\eta_t\left(1 - \frac{d\epsilon}{d\alpha}\right) \quad (5\text{–}35)$$

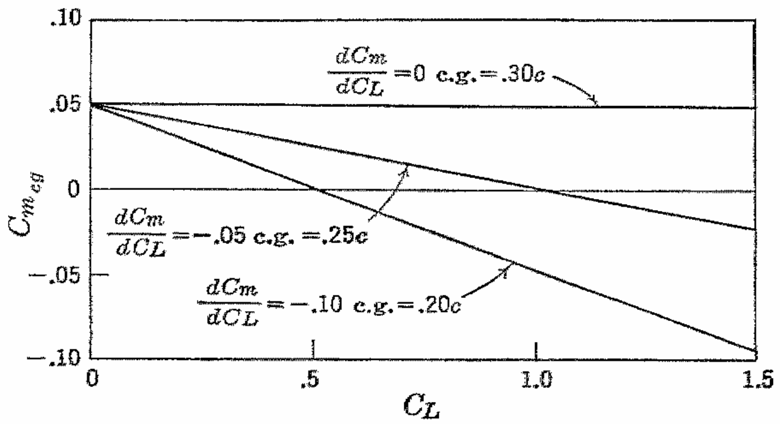


FIGURE 5–18. Typical effect of c.g. shift on pitching moments.

The neutral point gives the most aft location at which the c.g. can be placed before making the airplane unstable. It therefore places one limit on the airplane's permissible c.g. travel, for the airplane should never be balanced aft of this point if a stable airplane is desired.

The neutral point is also very convenient to obtain, for once the neutral point is known, the stability at any other c.g. position may be obtained with good accuracy from the following relation:

$$\frac{dC_m}{dC_L} = x_{cg} - N_0 \quad (5\text{–}36)$$

In other words, the slope of the pitching moment coefficient versus C_L is numerically equal to the difference between the c.g. location and the neutral point, both expressed in percentage of the mean aerodynamic chord.

Fig. 6. Effect of CG shift on Static Margin [3]

[3] C. D. Perkins and R. E. Hage, Airplane Performance, Stability and Control, John Wiley & Sons, USA 1949.

1.18.6 Boeing information

AIBN has received the following information from Boeing regarding the expected stability and control characteristics for a B747-400F loaded to an out of tolerance aft CG location:

1.18.6.1 *"For the typical cruise condition of this flight (M=0.85, Alt.=35,000 ft, Wt=600,000 lbs), and a maximum aft cg of approximately 42%, our analysis shows a Static Margin of 5% and a Maneuver Point Margin of 9%. For reference, the mid point of the main gear is approximately 44%.*

1.18.6.2 *Regulations do not require certification of margins with regard to the aft center of gravity, either a Static Margin or margin to Maneuver Point. Certification is accomplished by demonstrating that the airplane meets all handling qualities regulations at the aft limit. Typical handling qualities demonstrations include stick force characteristics with changing load factor and airspeed.*

1.18.6.3 *Takeoffs conducted beyond the aft CG limit may experience reduced directional control via nose gear steering during the initial takeoff roll, auto-rotation at speeds below normal rotation speeds, light control column force for rotation, increased potential for tail strikes, increased potential to overshoot target pitch attitude after liftoff and an accompanying potential to exceed stick shaker angle of attack, and may require trim on elevator if the stabilizer reaches its travel limit.*

1.18.6.4 *The flight crew should respond to an autorotation with a nose down elevator input. Beyond the aft cg limit, enough nose down elevator to counter the auto-rotation may not exist. They should reject the takeoff and perform an RTO maneuver. The FCTM section on Rejected Takeoff Decision says "At low speeds (up to approximately 80 knots), the energy level is low. Hence the airplane should be stopped if an event occurs that would be considered undesirable for continued takeoff roll or flight." The crew at this point does not know if the airplane is misloaded or mistrimmed or other, and continued safe flight is unknown. In the Non Normal Maneuver section of the QRH both prior to 80 knots and above 80 knots a reject should be initiated if "the airplane is unsafe or unable to fly". Aborting the take off should be considered a viable option if a clear case of autorotation is perceived prior to V_1 (139 knots). This would be consistent with the Boeing Flight Crew Operations Manual guidance for non-normal maneuvers (rejected take off).*

1.18.6.5 *For flight beyond the aft CG limit the autopilot performance has not been evaluated, and may reach authority limits, and may be unacceptable under failure conditions. In manual flight, the airplane may require trim on elevator, would be more sensitive to control inputs and a lighter application of control forces would be necessary. A greater potential for over-controlling the airplane, structural damage and loss of control would exist. Under normal fuel burn procedures, the CG will move further aft over time, increasing the potential for adverse characteristics.*

1.18.6.6 *Approach issues would be the same as cruise.*

1.18.6.7 *Landings beyond the aft CG limit may experience light control column force for flare, increased potential for tail strikes, reduced directional control via nose gear steering and the possibility for tip up onto the tail.*

1.18.6.8 *Go-around issues would be the same as cruise, with the increased potential to overshoot go-around target pitch attitude and an accompanying potential to exceed stick shaker angle of attack. We have completed our assessment of elevator control margins, and our analysis shows that sufficient elevator is available during a go-round in manual flight at this condition. Autopilot performance has not been evaluated.*

1.18.6.9 *The center-of-gravity limits on the certified gross weight vs. cg envelope should be considered as the ultimate cg locations. The verification of this envelope is shown to meet the minimum safety requirements of the regulatory agencies and Boeing. Flight beyond these limits may critically compromise many longitudinal and lateral-directional flight conditions and design criteria, and may significantly reduce the safety margins for subsequent failures and/or MEL/CDL dispatches.*

<u>1.18.7 Observation from airport employee</u>

The AIBN was informed of the incident by CAA-N who had received a call from an airport employee. He had informed CAA-N that he had observed a B747 which rotated to a nose high attitude early during the take-off run. The aircraft continued the take-off run and lifted off near the end of the runway.

<u>1.18.8 Crew training</u>

1.18.8.1 The flight crew training syllabus of Korean Air was based on standard Boeing training recommendations. Training in aborted take-offs were mainly based on engine failures before V_1 and any serious warning lights. It was not a training requirement to train for out of limits CG situations.

1.18.8.2 The aircraft HL7467 was equipped with a Green Band trim tolerance system. If the aircraft CG, as sensed by the nose wheel pressure switch, was out of tolerance with the trim setting, a take-off warning horn would sound. Crew training did not include such anomaly.

1.18.8.3 The flight crew was trained in weight and balance for 9 hrs during initial training, 3 hrs during fleet transition, and 1 hr during recurrent training. Flight crews assigned to cargo operations were not required to maintain proficiency on a recurrent basis in regard to performing manual weight and balance calculations.

1.19 Useful or effective investigation techniques

In this investigation no methods have been used which qualify for any specific reporting.

2. ANALYSIS

2.1 A probable sequence of events during takeoff.

2.1.1 AIBN considers it important to understand the crew's observations and reactions during the take-off run with a misloaded aircraft. The purpose for this is to evaluate the crew's actions seen in the right context of the incident.

2.1.2 The AIBN has not been able to interview the flight crew and this evaluation is based on the available reports from the Commander, First Officer, KAL and KAIB.

2.1.3 The flight crew followed normal company procedures during the take-off preparations. The CG % MAC and stabiliser trim was set manually according to the M & B Manifest. There was no discrepancy between the CG % MAC and the Stabiliser Trim setting, which was within the Green Band. There were no other warnings or cautions indicated.

2.1.4 During the take-off roll the PF was concentrated on the runway and was prepared for a possible immediate rejected take-off (RTO) normally associated with engine fire, engine failure or warnings indicating that the aircraft was unsafe for flight. No such warnings were indicated.

2.1.5 The aircraft started to accelerate. The FDR data shows that during takeoff the column was held relatively steady at -1 degree as the airplane accelerated to approximately 50 knots. In this period the airplane pitched from approximately 0.5 degree to a 1 degree pitch attitude due to thrust application. Thereafter, both pitch attitude and column deflection remained relatively steady until the airplane started autorotating at approximately 120 knots. The stabilizer remained steady until the airplane was airborne and only then was it retrimmed nose-down. Lift-off occurred at 165 knots and 11.5 degrees pitch attitude.

2.1.6 As the aircraft mass was relatively light, its acceleration rate was quite high. The QAR data indicates that the airplane autorotated at 120 knots (ref. Boeing, paragraph 1.11.4). This was controlled by the PF and the planned V_1 was reached quickly. The crew had still not received any warning and/or caution indications to indicate that an RTO was in order. The aircraft was quickly accelerating toward V_1 where a "GO" decision is generally the most prudent course of action. At that point in time, they did not feel they had positive reason to believe that the aircraft was unsafe for flight. Further, industry training preferences (including that of KAL) are skewed against high-energy RTO maneuvers.

2.1.7 Too late, the Commander may have realised that something was wrong. The speed approached V_1 and he could see the end of the runway coming close. He then may have realised that the early “automatic” rotation was caused by misloading of the aircraft.

2.1.8 It was too late to reject the take-off as the aircraft was about to leave the runway. His remaining option was to adjust the pitch attitude to approximately 11 degrees nose up, in order to avoid a tail strike and gain more speed for a safe departure. He controlled the pitch attitude and eventually got the required speed and regained full control of the aircraft. He had saved the situation and managed to avoid an accident.

2.1.9 In retrospect, it is easy to see that the takeoff should have been rejected. However, as a result of the relatively light weight of the aircraft and associated high acceleration rate, the flight crew found themselves within a speed range in which the normal RTO requirements include an engine fire, engine failure, or a perception that the aircraft is unsafe for flight. V_1 was quickly reached and the commander determined that to continue the takeoff was a safer course of action than a high-speed RTO.

2.2 SAS Cargo personnel

2.2.1 The Load Master was properly trained in weight and balance calculations. When performing manual weight and balance calculations he was required to transfer the SOM and IU from aircraft tables for the correct aircraft registration. In the tables were values for both IU and percent MAC. The IU values were not highlighted in the columns and it was possible to mistake one value for the other. After the incident, the IU column was coloured yellow to distinguish the values from the percent MAC values.

2.2.2 The B747F Operating Mass CG is typically near the aft limit. The miscalculated CG was very unusual as it was forward of the forward CG limit. This anomaly was not detected by the Load Master or the Commander.

2.2.3 Once the mistake had occurred, the AIBN considers this type of error would have been difficult to discover without a specific check of the IU values against the individual aircraft specific data. This difficulty is further indicated by the fact that the error was also overlooked by the Commander.

2.2.4 During the SAS Cargo incident investigation it was discovered that the Load Master had made the same mistake once before. In that case, the miscalculation was not discovered and the aircraft took off and landed without anyone reporting any anomaly.

2.2.5 At the time of the incident, there were three levels of control of the loading calculations. However, before this flight, the Korean Air's supervisor who visited from Denmark did not verify the calculations. The Load Master checked the calculations himself before handing the Load Manifest to the Commander. The AIBN considers this to be a weak link in the quality assurance of flight preparation. It is considered easy to pick the wrong number as long as there is no distinct colour or identification highlighting the units.

2.2.6 After the incident, SAS Cargo introduced a fourth level of verification by having a local KAL load Supervisor check the weight and balance calculations. Further, the completed load manifest is then faxed to the Korean Air Operations Control Centre in Seoul for verification. Hence, a verification of the load calculations is received before the manifest is presented to the Commander. In this way the possibility of overlooking errors was reduced.

2.3 Korean Air personnel

2.3.1 Flight Crew

2.3.1.1 The flight crew was properly trained and certified. Their training in weight and balance included the preparation of manual mass and balance calculations, but they were not required to maintain proficiency in this discipline on a recurrent basis. This reduced the crew's capability to discover critical errors made by the Load Master in the mass and balance manifest. AIBN suggests that KAL include a review of manual mass and balance during recurrent training.

2.3.1.2 The KAL training curriculum included aborted take-offs. This however is mainly focused on engine fire, engine failure and serious warnings. AIBN suggests that KAL review the training curriculum to include CG out of tolerance and include this in the simulator training.

2.3.1.3 It is the duty of the Commander to verify that the aircraft mass and CG are within limits. In order to check the values of the mass and balance manifest, the flight crew must have access to individual aircraft data, like the SOM and IU values. These numbers are critical for the rest of the mass and balance calculations. The mass and balance manifest in use at the time of incident did not include any "range of acceptable value" criteria for SOM and

IU. This made it difficult for the Commander to identify data errors. In reality, the Commander was merely checking that the mass and CG values were within limits for takeoff and landing.

2.3.1.4 The flight crew had adequate rest during the layover in Oslo. Flight and duty time limits and rest requirements were within the requirements. There is no data to indicate that crew fatigue was a factor in the incident.

2.3.2 Supervisor

2.3.2.1 At the time of the incident, a Korean Air Supervisor from Korean Air Denmark travelled to ENGM and supervised the cargo loading operation. Normally, after the Load Master had completed and checked the M & B Manifest, the Supervisor checked the calculations before the manifest was handed over to the Commander, who reviewed and signed the manifest. In this incident this procedure was not followed. However, the AIBN considers this procedure of limited value. In order to discover such calculation errors the Supervisor would have to perform a full load calculation himself, and that was not practised at the time. After the KAL520 incident, Korean Air based a permanent local Supervisor at ENGM to oversee the cargo operations.

2.4 Aircraft handling

2.4.1 Take-off

2.4.1.1 At the time of take-off, the CG was at 37.8% MAC. The midpoint of the main gear was at 44% MAC. Hence, the margin for aircraft on ground static stability (to prevent static pitch-up) was 6.2%. This is considered a small margin and explains why the aircraft autorotated at 120 KCAS during take-off with the elevator trim set for a CG of 27% MAC.

2.4.1.2 Generally, the stick fixed minimum stability margin is in the order of 10%. In this case the aircraft took of with the CG 4.8% aft of the aft limit. Hence the stability margin was about half of the normal value and the aircraft would feel quite tail heavy. This will have the effect of requiring more forward trim than normally used.

2.4.1.3 Information AIBN has received about the incident, includes an airport employee observing the take-off. He has explained that he saw the aircraft rotate early during the take-off run. The aircraft was observed to continue the take-off towards the runway end and lift-off normally. Paragraph 1.18.6 includes Boeing's assessment of the take-off anomaly. According to Boeing, the proper way of handling such an anomaly is to abort the take-off.

2.4.1.4 The FDR/QAR data shows that the airplane autorotated at 120 knots. The low rotation speed may have caused the aircraft to use longer runway than normal, with the lift-off as the runway end was approaching. The QAR data indicates that the only substantial column pull occurred at approximately the rotation speed. This assessment is consistent with the witness report.

2.4.1.5 It is considered possible that the aircraft autorotated due to the tail heaviness and wrong trim setting for the aft CG. Based on the Commanders statement, the initial pitch attitude was excessive. Initially the pitch attitude was 10-11° (FDR data 11.5°), then 12°, and finally reached a maximum of 19.5° at 200 ft radio altitude.

2.4.1.6 Based on the QAR data, Commander's and First Officer's statements, witness report, and other information, the AIBN considers that the takeoff phase and aircraft behaviour was in line with Boeing's assessment of the flight characteristics of the B747-400F with the CG aft of the aft limit (paragraph 1.18.6).

2.4.2 Climb

2.4.2.1 The planned V_2 was 166 knots with a target speed of V_2+10 kts, or 176 knots, The QAR data indicate that the speed was clearly lower, with the lowest recorded value of 158 KCAS. This was 18 knots below the planned value.

2.4.2.2 The recorded QAR data (paragraph 1.11) is in line with Boeing's assessment of the aircraft characteristics during climb with a reduced static stability.

2.4.3 Cruise

2.4.3.1 During cruise, the crew realized that the aircraft was misloaded with reduced static stability due to the required forward trim. After contact with KAL OCC, they were informed about the correct CG position and that the CG would be 10.7% aft of the aft limit during approach and landing at the Incheon Airport (RKSI) in South Korea.

2.4.3.2 It was decided to relocate some load pallets in the aircraft to increase the static margin. Hence, two crew members were able to shift the CG to a final value of 7.2% aft of the aft limit.

2.4.4 Approach and landing

2.4.4.1 The crew briefed and flew the approach based on the knowledge of reduced longitudinal stability. They also requested airport safety equipment to stand by. The approach and landing went as planned. However, during the landing rollout the nose wheel steering was lost due to the extension of the nose strut beyond limit. This was caused by the loss of stabilizer control moment and the aircraft nose started to lift.

2.4.4.2 The incident shows that the aircraft autorotated at 120 knots during take-off with the CG 4.8% aft of the aft limit. During landing with the CG 7.2% aft of the aft limit, the nose pitched up at about 60 knots, causing loss of the nose gear steering.

2.4.4.3 Without the load shifting during flight the CG would have been located at 43.7% MAC, or 10.7% aft of the aft limit. This could at best have caused a loss of control or a tail strike during landing. This is an indication of the dangers associated with misloading of aircraft.

2.5 Human errors and weak safety barriers

2.5.1 This incident demonstrates a clear example of the weakness in using humans checking other humans' performance without the proper reference material. In this case it was natural to check that the mass and balance was within limits. This was verified by two individuals. However, no one was able to see that the initial IU value was wrong. Further, a similar incident had occurred at least once before.

2.5.2 After the incident, for manual mass and balance and load planning, the flight crew is provided with computer generated aircraft tail number specific SOM and IU values. Hence, the human safety barriers are enhanced. Further, KAL is implementing an EO to install cockpit placards indicating specific SOM and IU values. This will reduce the possibility of similar errors in the future.

2.5.3 A significant improvement in human safety barriers is KAL's implementation of Automated Load Planning at all cargo stations. Hence, the flight crew can rely on computer generated data in addition to having aircraft specific SOM data in the cockpit.

2.5.4 Another safety barrier is the faxing of the load manifest to the KAL OCC in Seoul for verification before the aircraft takes off. Previously this was done after take-off. The AIBN considers this a positive action and an additional safety barrier.

2.6 Korean Air Internal Investigation Board

2.6.1 Korean Air performed an internal investigation after the incident. The report listed 7 safety recommendations. AIBN support these recommendations and considers them to strengthen the safety barriers.

2.7 Korean Air crew training

2.7.1 Korean Air training curriculum did not require recurrent training in manual mass and balance calculations. Nor did it include simulator training in out of tolerance CG recognition. AIBN considers these aspects important for cargo operations. Based on this incident AIBN is recommending a review of the company training curriculum.

2.8 SAS Cargo operating licence

2.8.1 SAS Cargo is a registered air cargo operating company in Norway, and has an operating licence issued by Oslo Airport Administration (OSL). SAS Cargo has no official licence issued by CAA-N. There are no international requirements for official licensing of air freight terminals, even though some countries (like Sweden) have introduced such regulation.

2.8.2 AIBN considers that air cargo operating companies should have an operating licence issued by CAA-N and is making a safety recommendation to this effect.

3. CONCLUSIONS

3.1 Findings

3.1.1 Korean Air/SAS Cargo did not have available Auto Load Planning and Departure Control System at ENGM Airport.

3.1.2 The SAS Cargo Load Master mistook the percent MAC value for the IU value as a basis for the balance calculation.

3.1.3 The Load Master did not discover the error when reviewing his own calculations.

3.1.4 The Commander verified that the mass and CG values were within limits and did not discover the error regarding the wrong IU value when reviewing the calculations.

3.1.5 The Commander did not have available in the Pilot Operating Manual aircraft weight and balance information containing detailed information about the aircraft's Standard Operating Mass, Standard Operating Index Unit, or Standard Operating percent MAC.

3.1.6 The Commander did not have available in the cockpit information regarding Minimum and/or Maximum Allowable Values for Standard Operating Mass, Standard Operating Weight Index Units, Zero Fuel Mass, Take-off Gross Mass, Percent MAC, and Stabilizer Trim Settings.

3.1.7 The aircraft took off with the CG 4.8% MAC aft of the aft limit. This resulted in an early autorotation at 120 knots.

3.1.8 The commander chose to continue the takeoff and subsequently experienced excessive nose pitch up during take-off and climb.

3.1.9 The crew realized that the aircraft was tail heavy and contacted KAL OCC. Correct CG data was received and cargo was relocated to reduce the tail heaviness of the aircraft before landing.

3.1.10 The aircraft landed with the CG 7.2% MAC aft of the aft limit. At approximately 60 knots the nose wheel steering was lost due to nose pitch up.

3.1.11 The aircraft engines were shut down on the runway and towed to parking.

3.1.12 Korean Air established an internal investigation group. In their report were listed seven (7) safety recommendations which addressed the weak safety barriers (paragraph 1.18.3). All safety recommendations have been implemented.

3.1.13 Korean Air's pilot training curriculum does not include recurrent training in manual mass and balance calculations or simulator training for misloaded aircraft out of CG limits.

3.1.14 SAS Cargo had no official operating licence issued by CAA-N and there was no Norwegian requirement for such a licence.

4. SAFETY RECOMMENDATIONS[4]

SL recommendation no. 2007/02T

The flight crew did not recognise the out of limit CG situation.

The AIBN recommends that Korean Air use this incident as a basis for reviewing the pilot training curriculum, including recurrent manual mass and balance calculation and simulator flight training with aircraft CG outside of limits, to enhance the awareness of out of limits CG conditions and early recognition of such anomalies.

[4] The Ministry of Transport and Communications forwards safety recommendations to the Norwegian Civil Aviation Authority and/or other involved ministries for evaluation and monitoring, see Norwegian Regulations regarding public investigations of accidents and incidents in civil aviation, § 17.

SL recommendation no. 2007/03T

SAS Cargo did not have an operating licence issued by CAA-N for operating a freight terminal, nor was such licence required.

AIBN recommends that CAA-N evaluates the requirement for a Norwegian regulation for air cargo terminals.

REFERENCES

C. D. Perkins and R. E. Hage, Airplane Performance, Stability and Control, John Wiley & Sons, USA 1949.

Accident Investigation Board Norway

Lillestrøm, 19 March 2007

APPENDIX

ABBREVIATIONS

AC	Aerodynamic Centre
AIBN	Accident Investigation Board Norway
ALP	Automated Load Planning
ATPL(A)	Airline Transport Pilot Licence Airplane
BA	British Airways
CAA-N	Civil Aviation Authority – Norway
CAS	Calibrated Air Speed
CASA	Civil Aviation Safety Authority of the Republic of Korea
CCP	Control Column Position
CDL	Configuration Difference List
CG	Centre of Gravity
CGO	Cargo
CPL(A)	Commercial Pilot Licence Airplane
CVR	Cockpit Voice Recorder
ELW	Estimated Landing Weight
ENGM	Oslo Airport Gardermoen, Norway
EO	Engineering Order
FDR	Flight Data Recorder
FGS	Flight Ground Switch
FMS	Flight Management System
FOM	Flight Operations Manual
GND	Ground
ICAO	International Civil Aviation Organization

ISA	International Standard Atmosphere
IU	Index Unit
KAL	Korean Air
KAIB	Korean Aviation Accident Investigation Board
KCAS	Knots Calibrated Air Speed
LM	Load Master
MAC	Mean Aerodynamic Chord
MEL	Minimum Equipment List
METAR	Meteorological Aerodrome Report
NP	Neutral Point
OCC	Operations Control Centre
OSL	Oslo Airport
PF	Pilot Flying
PIA	Pakistan International Airways
PM	Pilot Monitoring
POM	Pilot Operating Manual
QAR	Quick Access Recorder
QRH	Quick Reference Handbook
RA	Radio Altitude
RKSI	Seoul Airport Incheon, Republic of Korea
RTO	Rejected Take Off
R/W	Runway
SAS	Scandinavian Air Lines System
SATCOM	Satellite Communication
SGS	Scandinavian Ground Services
SOM	Standard Operating Mass
SOW	Standard Operating Weight

S/N	Serial Number
TOW	Take Off Weight
TOM	Take Off Mass
W&B	Weight and Balance
ZFW	Zero Fuel Weight