L-1649 Lumer TAECC

File No. 1-0045

CIVIL AERONAUTICS BOARD

AIRCRAFT ACCIDENT REPORT

ADOPTED: November 15, 1960 **RELEASED:** November 1960

TRANS WORLD AIRLINES L-1649A, U.S. REGISTRY N-7313C
NEAR MILAN, ITALY, JUNE 26, 1959

English translation of the Report of Italian Republic Ministry of Defense Board of Inquiry Appointed to Investigate the Accident.

COMM-DC-27135

REPORT OF THE BOARD OF INQUIRY

on the crash of a TWA (U.S.A.) Super-Constellation plane, type 1649-A, N.7313/C, which took place in the vicinity of Olgiate Olona (Varese), Italy, on June 26, 1959

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I N D E X

C H A P T E R I

DETAILS OF THE CRASH

(a) Location

Olgiate Olona (Varese).

(b) Date and time

June 26, 1959, about 4:35 p.m. (time given is G.M.T. unless otherwise indicated).

(c) Nature of the flight

Regular scheduled flight.

		Actual take-off time
TWA Flight No. 891/26	(Athens	10:15 a.m.
	(Rome	2:00 p.m.
	(Milan	4:20 p.m.
	(Paris	-----

(d) Purpose of the flight

Public transportation of passengers, mail and cargo.

(e) Date on which the Board of Inquiry was notified

On June 26, 1959, on instructions from the Ministry of Defense, the Office of the Secretary General M.D.A. [Ministry of Defense - Aviation] appointed the following Board to investigate the crash:

Major General Duilio FANALI, Inspector of the Air Force Academy	Chairman
Col. Paris PERNAZZA, Air Force, Office of the Director General of Civil Aviation and Air Traffic	Member
Lt. Col. Piero ANDREOTTI, Air Force General Staff	Member
Lt. Col. Stefano CASTELLANI, Air Force, Office of the Inspector of Telecommunications and Aids to Air Navigation	"
Lt. Col. Enrico MIGLIO, G.A.r.i., Office of the Director of Aeronautical Construction, Milan	"

Lt. Col. Mauro BOCCASSINI, C.S.A., Director, Presidial Infirmary, 1st Z.A.T., Milan — Member

Adelio ZANASI, Engineer, Italian Air Registry, Milan Office — "

Domenico CASTAGNA, Engineer, Director of the Turin-Caselle Civil Airport — "

Commander Dino GONZADI, Representative of the National Association of Civil Aviation Pilots, [Italian abbreviation] A.N.P.A.C. — "

(NOTE: The representative of the A.N.P.A.C., Commander GONZADI, failed to appear and did not participate in the work of the Board.)

The Government of the United States appointed as its representative Mr. Martyn V. CLARKE of the Civil Aeronautics Board.

(f) Date and time of arrival of the Board of Inquiry at the scene of the crash

The first on-the-spot examination of the wreckage was made by the Board on June 27, 1959 at about 9:00 a.m.

CHAPTER II

SUMMARY DESCRIPTION OF THE CRASH

Reconstruction of the flight

The LOCKHEED aircraft 1649-A, No. 7313/C owned by Trans World Airlines, a U.S. airline, took off from the Malpensa airport at 4:20 p.m. on June 26, 1959 on a regular scheduled flight (flight 891/26) to Paris, Orly.

After being in the air about 15 minutes, still in the climbing stage on the prescribed route (Malpensa - NDB Saronno - NDB Biella), the plane crashed to the ground from an altitude of about 11,000 feet in the vicinity of Olgiate Olona (Varese) and was demolished

Consequences:

59 passengers and 9 crew members killed.

The aircraft was completely demolished.

Part of the cargo was recovered.

Damage at the point of impact: slight damage to objects, no injury to persons.

CHAPTER III

DATA ON THE AIRCRAFT

Lockheed Super Constellation mod. 1649-A- Serial No. 1015.

Built by the Lockheed Aircraft Corporation at Burbank, California, in 1957.

Owned by TWA (Trans World Airlines).

Registration markings and Certificate of Airworthiness: N 7313 C.

Type of engines: Wright 3350 EA2.

Type of propellers: Hamilton Standard Propellers, Model 43 H 60.

Total maximum weight authorized at take-off	160,000 lbs.
Total maximum weight authorized at landing	123,000 lbs.

At the take-off from Malpensa on June 26 the total weight of the aircraft was 122,175 lbs., distributed as follows:

Operating weight of the aircraft, including its normal crew and one extra member	93,370 lbs.
Fuel (635 gallons in each of tanks 1-2-3-4)	15,000
Passengers (59 in all, of which 5 were in first class and 54 in tourist class)	9,440
Baggage, mail and cargo (442 lbs. in the front compartment and 1,923 lbs. in the rear compartment)	2,365
	122,175 lbs.

Position of the barycenter at 21% of the m.a.c., that is, well within the limits allowed for the weight indicated above (the centering graph in the Flight Manual shows that the barycenter must be within 13% and 34% of the m.a.c.).

History of the aircraft

Total hours of flight (as of June 26, 1959)	6671.21'
Hours of flight since last overhaul	895.01'

The aircraft had flown 71 hrs. and 39' since the last Upkeep [and] Line Inspection and was considered to be in a normal condition of efficiency when it took off on June 26, 1959.

ENGINES

Position	1	2	3	4
Serial No.	705071	705043	705054	705094
Total hrs. in operation	4102.38'	4063.42'	4325.16'	4270.25'
Hrs. in operation since last overhaul	500.58'	514.11'	263.08'	244.12'

PROPELLERS

Position	1	2	3	4
Serial No.	202533	203119	199294	204879
Total hrs. in operation	5782.42'	5175.02'	5963.35'	3050.01'
Hrs. in operation since last overhaul	501.02'	1263.04'	746.27'	1598.13'

Operational limits of particular interest

(from the aircraft's Flight Manual)

Maximum permissible weight without fuel (W zero fuel), 117,000 lbs.
(At take-off at the Malpensa airport the aircraft without fuel weight 107,175 lbs.)

Design diving speed (V_D)	336	knots	(EAS)
Maximum permissible speed (V_{NE}) (up to 13,300 ft.)	294	"	"
Normal operating limit speed (V_{NO}) (up to 18,800 ft.)	261	"	"
Design manoeuvring speed (V_A)	195	"	"
Design (flap 80% extended) speed (take-off) (V_{FE})	185	"	"
Design (flap 100% extended) speed (landing) (V_{FE})	160	"	"
Optimum climbing airspeed ($\dot{V}$)	156	"	"

Limit of acceleration: flap up, 2.5 g; flap down 2 g.

Maximum differential pressure in fuselage: 10.92" Hg.
Also (from Lockheed's data on structural calculations):

Design speed for maximum gust intensity of 66 ft/sec. (V_B) 175 knots (EAS)

C H A P T E R I V

DATA ON THE CREW

(a) The crew was made up as follows:

Names of the crew members	Position	Age	Licences and qualifications (CAA)			Hours of flight		
			Type	No.	Date of latest physical examination	Total	On plane type 1649-A	Within the last 90 days
1. Paul S. Grade	/Aircraft/ Commander	50	ATR	18794	4/20/59	25514	682	212
2. Harry L. Stanton	Co-pilot	44	ATR	150600	5/29/59	12150	76	237
3. Frank W. Ellis	1st Officer	29	Comm. and Instr. Rating	1304387	12/23/58	3500	382	197
4. John V. Powell	Flight engineer	40	AAE Mechanic licence	413026	6/10/59	9200	609	232
5. Donald A. Lueke	Flight engineer	41	AAE Mechanic licence	171919	12/15/58	9606	658	188
6. Edmond Mouchnino	Flight steward	38						
7. Marguerite Fay	Hostess	28						
8. Jacqueline Janssen	Hostess	23						

(b) Addresses of all crew members:

Captain Jack Davis	1913 Portsmouth, Westchester, Ill.*
Captain Paul Grade	Brookfield, Conn.
Relief Pilot Harry Stanton	Seaford, L.I., N.Y.
First Off. Frank Ellis	Rowley, Mass.
Flight Eng. John Powell	Syosset, N.Y.
Flight Eng. Donald Leuke	Mission, Kans.

* Captain Davis was not a member of the crew.

(Cabin Attendants)

Purser Edmond Mouchnino	162 Rue Jeanne 'Arc, Paris 13-E, France
Hostess Jacqueline Janssen	114-bis Rue Ernest Renan, Bordeaux, Gironde, France
Hostess Marguerite Fay	Villa Alexiss, Blvd. de Strasburg, Vee Cannes, Alpes Maritimes, France

(c) Data on the members of the crew

1. Capt. Paul S. Grade, born March 13, 1909, was engaged by TWA on June 5, 1940 and was promoted to TWA Captain on July 17, 1942. He was the holder of CAA ATR-Certificate 18794 for DC-3, DC-4, and Lockheed Constellation C49, 749-A, 1049 and 1649-A aircraft.

He had undergone his last CAA physical examination on April 20, 1959, his last Line Check on September 20, 1958, and his last Instrument Check on April 13, 1959.

He had a total of 25,514 flight hours, 682 of which were on 1649-A aircraft. In 1958 he flew a total of 808 hours.

Flight hours in the last 90 days	212.29'
" " " " " 30 "	79.16'
" " " " " 7 "	22.27'

Rest period preceding the last flight: 12.00' hrs.

2. Co-pilot Harry L. Stanton, born October 26, 1915, was engaged by TWA on July 6, 1945 and was promoted to TWA Captain on June 7, 1956.

He was the holder of CAA ATR-Certificate 150600 (Martin and Lockheed Constellation).

His last CAA physical examination was on May 29, 1959, his last Line Check on June 25, 1958, and his last Instrument Check on February 10, 1959. He had a total of 12,150 flight hours, 76 of which were on 1649-A aircraft. In 1958 he flew a total of 790 hours.

Flight hours in the last 90 days	237.30'
" " " " " 30 "	97.28'
" " " " " 7 "	22.27'

Rest period preceding the last flight: 12:00 hrs.

3. First Officer Frank W. Ellis, born March 7, 1930, was engaged by TWA on May 2, 1955. He was the holder of CAA Certificate Commercial and Instr. Rating 1304387. His last CAA physical examination was on December 23, 1958. His last Line Check in February 1957. His last Instrument Check in January 1957.

He had a total of 3500 flight hours, 382 of which were on 1649-A aircraft. In 1958 he flew a total of 879 hours.

Flight hours in the last 90 days	197.15'
" " " " " 30 "	69.51'
" " " " " 7 "	22.57'

Rest period preceding the last flight: 12 hours.

4. Flight Engineer John W. Powell, born September 14, 1919, was engaged by TWA on March 19, 1943 and was rated a Flight Engineer on August 4, 1948.

He was the holder of A&E Mechanic Licence 413026, issued on June 27, 1949, F/E 1098300. His last CAA physical examination was on June 10, 1959. His last Line Check, on March 26, 1959.

He had a total of 9200 flight hours, 609 of which were on 1649-A aircraft. In 1959 he flew a total of 727 hours.

Flight hours in the last 90 days	231.54'
" " " " " 30 "	99.38'
" " " " " 7 "	22.27'

Rest period preceding the last flight: 12 hours.

5. Flight Engineer Donald A. Lucke, born January 9, 1918, engaged by TWA on February 16, 1940 and was rated a Flight Engineer on July 3, 1946. He was the holder of A&E Licence 171919 issued on October 28, 1944 F/E 3945. His last CAA physical examination was on February 15, 1958; his last Line Check, on February 19, 1959.

He had a total of 9606 flight hours, 658 of which were on 1649-A aircraft. In 1958 he flew a total of 821 hours.

Flight hours in the last 90 days	188.14'
" " " " " 30 "	35.35'
" " " " " 7 "	27.27'

Rest period preceding the last flight: 12 hours.

CHAPTER V

PASSENGER LIST

(a) Information

	Name and surname	Nationality	Address
1.	G. B. Albritton	U.S.A.	246 E. 46th St., New York, N.Y.
2.	Leonard Armanetti	U.S.A.	8042 North Enox, Skorie, Ill.
3.	Achille Belloni	Italian	Livraga (Milano)
4.	Mary Belknap	U.S.A.	5727 Kenwood St., Chicago, Ill.
5.	Augusta Benedetti	U.S.A.	2330 W. 32nd Place, Chicago, Ill.
6.	Jacob Binder	U.S.A.	1200 College Ave., New York 56, N.Y.
7.	Jean G. Brahamsha	Egyptian	c/o Boxall Co., Ltd., P.O. Box 1, Khartoum, Sudan
8.	William Buckley	U.S.A.	14 Kensington Rd., Arlington, Mass.
9.	Herman Carmely	Israeli	Piazza Sempione 3, Milan
10.	Pietro Castelnuovo	Italian	Via S. Martino 15, Bollate, Milan
11.	Franco Cavallanti	Italian	Via Roma 5, Livraga, Milan
12.	Gabriele Cavallanti	Italian	Via Risorgimento 9/3, Livraga (Milano)
13.	Celli Rinzieri	U.S.A.	1805 D St., Galveston, Tex.

14. Malfisa Celli Bertolucci	U.S.A.	1805 D St., Galveston, Tex.
15. Paolo Ciserani	Italian	Livraga (Milano)
16. Georgia Chicles	U.S.A.	6467 Riawatha St., Chicago, Ill.
17. Rafaele Cohen	Italian	Via Washington 89, Milan
18. Sophie Doumouras Nafpliotou	U.S.A.	4335 N. Hamlin Ave., Chicago, Ill.
19. George Ellis	British	23 Rue d'Annou, Boulogne, France
20. Marguerit Ellis	British	23 Rue d'Annou, Boulogne, France
21. Nora Fantoni-Sellon	Italian	Via Bolognese 51, Florence
22. Fernando Fratelli	Italian	5, Blvd. Jules Sandeau, Paris, France
23. Peter, Frohn	German	2957 Barbera Rd., Columbus, Ga., U.S.A.
24. Josephine Fuda	U.S.A.	7611 Peoria, Chicago, Ill.
25. Dominique Fuda	U.S.A.	7611 Peoria, Chicago, Ill.
26. Farid Geanoroura	French	23 rue St. Joseph, Le Chesnay S.-et-O., France
27. Katherine Germo	U.S.A.	21530 Occidental Blvd., Los Angeles, Calif.
28. Mary Germo	U.S.A.	21530 Occidental Blvd., Los Angeles, Calif.
29. Gianpietro Giordana	Italian	Viale Maino 17/a, Milan
30. Pasquale Graffeo	Italian	Via del Vespro 57, Palermo
31. Olivia Kammerer	U.S.A.	Crambury, N.J.
32. Syd Kave	U.S.A.	333 E. 43rd St., New York, N.Y.
33. Anna Korecky	U.S.A.	1809 So. Clarenge, Berwyn, Ill.
34. Chester Linsky	U.S.A.	State College, Pa.
35. Basil Lombardi	U.S.A.	4952 Downing Place, Chicago, Ill.
36. Anna Maga	U.S.A.	927 E. Angeleno, Burbank, Calif.
37. Michel Martino	U.S.A.	110 Linda Lane, Schenectady, N.Y.
38. Coriane Martino	U.S.A.	110 Linda Lane, Schenectady, N.Y.
39. Percy Nicholls	British	79 Marshead Mansions, London W. 9, England
40. F. Pellecchia Mariani	Italian	Via Umberto I 191, Ceglie del Campo, Bari
41. John A. Palmer	British	10/A Marshead Mansions, London W.9, England
42. Sonia Quinteros	Chilean	c/o Chilean Embassy, Tokyo, Japan
43. Pilar Quinteros	Chilean	c/o Chilean Embassy, Tokyo, Japan
44. Valerio Reggiani	Italian	Via Barzizza 8, Bergamo
45. Anna Rey	U.S.A.	1622 E. 79th St., Chicago, Ill.
46. Jasus Rey	U.S.A.	1622 E. 75th St., Chicago, Ill.
47. Manuel Rey	U.S.A.	1622 E. 75th St., Chicago, Ill.
48. Jacque Roch	French	41 rue Lenine, St. Oyr L'Ecole, S.-et-O., France
49. Janine Rousseau	French	18 rue Cignon, Paris, France
50. Ennie Rotter	French	12 rue Piccini, Paris, France
51. Maria Saccetti-Fermi	Italian	Via Monginevro 32, Rome
52. Antonio Salbego	U.S.A.	2797 No. Neva Ave., Chicago, Ill.
53. Emilio Sarchi	Italian	Via del Bollo 2/A, Milan
54. Ugo Sei	U.S.A.	2239 So. 47th St., Chicago, Ill.
55. George Sherman	U.S.A.	70 Margaret Ave., Lawrence, Ill.
56. Frank Sternes	U.S.A.	1835 So. Austin Blvd., Cicero, Ill.
57. Lillian Sternes	U.S.A.	1835 So. Austin Blvd., Cicero, Ill.
58. Sacchi Suardi	Italian	Via del Bollo 2/A, Milan
59. Mary Thompson	U.S.A.	215 W. 13th Way, Long Beach, N.Y.

(b) Results of the medical examination of the [bodies of the] passengers and crew

(1) All the passengers and members of the crew died in the crash. The total number of deaths was 68.

The bodies were recovered on June 27, 1959 by personnel of the Italian Red Cross and the members of the Fire Department of Busto Arsizio.

The bodies, removed from the wreckage one by one, were numbered progressively from 1 to 68 in the same order in which they were removed; then, they were placed in zinc-lined coffins which were also numbered in the same order from 1 to 68 (see Annex V-1).

Dr. Lorenzo Fraonza, Health Officer of the Commune of Olgiate Olona, aged 59, born in Lorenzello, made out the death certificate for each of the 68 bodies as follows:

"Body partially dismembered. Shows general burns and fractures over its entire surface. Death was instantaneous and was due to crushing and combustion."

The 68 bodies were later identified by officials of the office of the Attorney for the Republic of Busto Ariszio, who made out for each of them a "Report of description, recognition, and dissection of a human body." The said office provided for an autopsy and coroner's inquiry into the death of the following crew members and passengers:

Capt. Paul Grade, aged 50
Co-pilot Harry Louis Stanton, born in the U.S.A. on October 26, 1915
Capt. Jack Davies, born in the U.S.A. on January 1, 1920

The autopsy and medical-legal investigation was performed by Prof. Desiderio Cavallazzi of the University of Milan.

In carrying out his task, Prof. Cavallazzi was requested by the office of the Attorney for the Republic at Busto Arsizio to consider these questions:

[1] what caused the death;

[2] what were the circumstances in which the injuries were suffered;

[3] whether the bodies showed any intrinsic or extrinsic evidence which might suggest the concurrence of several injurious effects in the causes of death.

With respect to the third question, the investigator took under examination the following hypotheses of non-traumatic death:

[1] concurrence of burning action;

[2] possible organic alterations;

[3] presence of carbon monoxide;

[4] concurrence of alcoholic factors.

On July 30 Prof. Cavallazzio submitted the following conclusions:

"The causes of the death of Messrs. Stanton, Davies and Grade are to be identified with a complex traumatism which produced multiple fractures (skull, ribs, limbs, pelvis, etc.) and injuries to internal organs (brain, heart, lungs, liver, kidneys, etc.); the traumatologic view suggests injuries from precipitation from a high altitude and subsequent burning of the aircraft; the autopsy did not disclose any intrinsic or extrinsic elements in the bodies which might suggest the concurrence of other injurious factors in causing death (see Annex V-2)."

(2) All bodies were found in the plane's fuselage, with the exception of one which lay in the immediate vicinity of the aircraft and, its clothes burned by the flames, showed burns over the entire surface, wounds, fractures, and multiple injuries, all of which leads to the assumption that this body was ejected from the plane at the time of the impact and as a result of it.

The bodies were found bunched together; in fact, some of them seemed to be embracing each other as if, while still alive, they had realized the impending great danger and imminent death.

The members of the crew, located in the front section of the plane, showed traumatic injuries more severe than those suffered by the passengers because, by reason of their position, they had taken the brunt of the impact. The passengers showed evidence of injuries from combustion and carbonization greater than those suffered by the members of the crew because, by reason of their position, they had been more exposed to the action of the flames. Both the members of the crew and the passengers showed complex mortal injuries of such gravity as is rarely seen in air crashes.

The statements of those who were first in bringing help to the scene of the crash were to the effect that, although it was virtually impossible to get close to the burning plane, they did not see or hear any sign of life coming from it.

At the time of recovery of the bodies the passengers as well as those of the crew members were still wearing the safety belts, for which reason many of them suffered injuries to the groin, the lower abdomen, and the perineum.

(3) The injuries suffered by the passengers and the members of the crew consisted of:

[1] Deformation of various kind of all, or almost all, sections of the body, partly by carbonization and destruction of the soft parts and partly by fragmentation of the skull, ribs, pelvis, limbs, etc.

[2] Traumatic collapse, in various degrees but always very considerable, of the brain, heart, lungs, spleen, liver, kidneys, etc.

It is presumed that, in the case of all victims, the injuries from burning came after those of a traumatic nature.

It is presumed also that the members of the crew as well as the passengers were still alive when the plane came in contact with land.

It is not possible either to state definitely whether some of the persons on the plane may have suffered injuries while the plane was still in the air but falling. The cause of the almost instantaneous death of both the passengers and the crew was a complex traumatism which produced multiple internal fractures and injuries (traumatic death), followed immediately by carbonization caused by the flames of the burning wreckage of the plane.

In this specific case it is likely that death occurred, for all persons, instantaneously, on the ground.

The conclusions of the autopsies and pertinent medical-legal examination may be considered valid also for the other members of the crew.

The autopsies showed no evidence whatsoever of any intrinsic or extrinsic elements in the bodies, such as the presence of pre-existing organic changes, or the presence of carbon monoxide, or a sudden illness of the pilots followed by immediate death, or the alcoholic [intoxication] factor with resulting erroneous handling of the plane, etc., which might lead to the belief that, in so far as the crew is concerned, there were other causes of death besides the aforementioned complex traumatism.

CHAPTER VI

WEATHER CONDITIONS

(a) General weather conditions

At 12:00 noon on June 26, 1959, the situation over land showed the following features:

(1) A high-pressure zone, with peak around 74° North and 05° East, extending from the Scandinavian regions to East Germany, Poland and the Carpatian zones;

(2) A high-pressure zone (anticyclon from the Azores) with peak around 33° North and 30° West, extending up to the French-Iberian Peninsula Atlantic zone and, to the South, extending over North Africa as far as Tunisia;

(3) A wide low-pressure zone on the North Atlantic with lowest around 55° North and 20° West;

(4) Another low-pressure zone over the Eastern Mediterranean and Asia Minor;

(5) A band of relatively low and more or less leveled-off pressure, connecting the two low-pressure zones mentioned above through the British Isles, the Benelux countries, North-Eastern France, West Germany, the Italian peninsula and its surrounding waters, Greece and the central Mediterranean.

(6) A disturbance over the Atlantic connected with the low mentioned in (3) above and located between the 10° and the 15° Meridian West, still too far away to affect our regions;

(7) A disturbance featuring a cold front and extending from the Spanish Mediterranean shores to the French side of the Western Alps, the Rhineland, the Benelux countries, and the North Sea;

NOTE: This disturbance, which was held back during the entire morning by the Alps, in the early afternoon overcame the obstacle and penetrated the Po Valley, veering toward the East and remaining active; the passage of the disturbance was accompanied by the usual phenomena connected with a cold front, namely vast and imposing formations of cumulus clouds, heavy showers, storm activity; at 6:00 p.m. the front, in so far as our regions were concerned, was located along a line running approximately from La Spezia to Piacenza and thence to Bolzano.

(8) Another rather weak and uncertain disturbance was located on a line running from Tunisia to Sardinia, and thence to Latium, Dalmatia and Hungary.

(b) Actual conditions (cloud formations, wind and temperature) over the area at the time of the crash

While a study of the general situation affords a quite clear identification of the cold front mentioned in (7) above, which at 12:00 noon seemed still to be hovering over the French side of the Alps, an analysis of the behavior of this front on the afternoon of the 26th in the Po Valley, after it had crossed the Alps, becomes a particularly difficult and uncertain problem.

The baric and thermic fields associated with the front were very weak and spread-out and the slight differences between the pre-frontal and post-frontal air masses were not apparent through a clear-cut frontal area but through a zone that was rather large and difficult to identify.

The mountain chain to the west and north of the Po Valley tends to slow down the front systems advancing from the west and the sheltering effect of the mountains themselves tends to disperse the frontal characteristics of the system, making analysis uncertain. If the differences in pressure and temperature pertaining to the front are slight, as they were in this case, often the front passes by at a great height and does not reach the ground in the Po Valley until it has passed over numerous weather stations in the westernmost part.

Many of the weather reports issued by the Po Valley stations in the afternoon of the 26th do not correspond to the concept of a cold front, as it is usually understood. For example, the weak storm activity which began at the Malpensa airport immediately before 5:00 p.m. or soon thereafter, when the front in all probability had already passed by, is not in strict conformity with the normal passage of a cold front, but neither is it out of the ordinary in this region during bad frontal situations. It is also difficult to explain the prolonged storm activity in the Turin area. It is possible that the weak low building up northwest of Genoa contributed to accentuating the southern currents at high altitudes and the consequent effects due to orographic factors. Another possibility is that this [condition] is associated with the front at a high altitude, or it may be more readily explained by assuming that a large storm nucleus remained at that place because of its size and nature, abetted by the action of cooler air from above.

Reports from pilots [flying in the area] show that the storms hovering over the Malpensa airport, which was hit about 5:00 p.m., came from Cameri and Vercelli, that is, from the southwest, since they were reported by those weather stations a little earlier in the afternoon. Instead, in the opinion of those who saw it, the storm on the Malpensa airport at about 5:00 seemed to be coming from the east.

Taking into consideration the slight winds blowing in the zone at that time and the lack of more recent observations of winds at high altitude, it may very well be that the storm activity reached the Malpensa airport from the east, although the high-altitude charts show a slight circulation from the southwest.

The storm activity which had its beginning to the southwest of Milan and then extended rapidly eastward through the Po Valley, may be explained as indicating a cyclonic impulse, or a wave motion in the front. The exact determination of the successive positions of the front both over land and at high altitude will never be possible since it seems unlikely that there will ever be full agreement as to the front's precise positions and its shifting course through Northern Italy. Nevertheless, a careful examination of the data gathered by the weather stations of the Western Po Valley and of the information supplied by the pilots who flew in the Milan area on the afternoon of the 26th, all within the framework of a general analysis of conditions on land and at high altitude, will permit us to arrive at a precise enough and reliable description of the weather prevailing in the zone at the time of the crash.

At 12:00 noon on June 26, 1959, Western Europe was under the influence of a weak westerly influx of Atlantic air slightly cooler than the existing air, advancing from the West behind a relatively weak cold front which, upon reaching the Alps in the morning, settled against them, being held in check by the mountain chain and forming a wave motion along the Franco-Swiss side of the chain. Not until early afternoon did the front succeed in overcoming the obstacle and spreading over the Po Valley. Surface winds were very weak during the entire day over most of Europe. At an altitude of 700 MB there is noted a weak gradient wind of about 15 knots pushing the front forward.

As we have already said, it is very difficult to establish the exact surface position of the front in the Po Valley, but its existence is ascertained by an analysis of the general charts at various altitudes. The air masses preceding the front system are potentially unstable (on the afternoon and evening of the 25th places located at high altitudes had showers and scattered storms). Later, the passing of the front through Southern France touched off notable vertical developments and at 12:00 noon on the 26th the western Alps and Southern Germany were hit by showers and storms.

Radio-soundings made by the Milan-Linate station at 12:00 noon on the 26th showed unstable conditions over the Po Valley. Any cause that would raise the surface air would result in condensation at about 3000 ft. by forced up-draft and at about 4000 ft. by convective up-draft, while a further rise to about 6000 ft. would end the instability. From this point up the rising particles remain on the positive side of the curva di stato and the clouds may exist up to about 35,000 ft. The greatest humidity in the air (85-95%) is found in the strata between 7000 and 14000 ft. It is therefore likely that above 14,000 ft. the cumulus clouds under development will absorb a considerable quantity of drier air and this fact will tend to reduce the additional developments above into less numerous but more extensive scattered cells. The small systems probably will be dissolved toward other locations between 14,000 and 20,000 ft.

The thermic zero level is found at about 11,000 ft., above which there is to be expected some ice formation in the clouds.

In the area of the Malpensa airfield, at 00:00 hr. on the 26th, the wind in the upper air was from the west. As it advanced from the west, it turned to the southwest and struck the chain of the Alps, causing showers and rain, especially in the mountains. Rain became more general and hit the Malpensa zone at 1:00 p.m. Although the situation in the upper air shows that a frontal system was affecting the Po Valley at the time under examination, establishing the exact location of the front is made difficult and uncertain by the many storms striking the zone and causing local variations in surface winds and atmospheric pressure. The greatest storm activity was noted at Vercelli and Govone, in the neighborhood of which might have been located the crest of the front's wave correlated with the formation there of a barely noticeable low-pressure center. Later this center moved toward the northeast, drawing along in that direction, and apparently ahead of the system, the major storm activity. Some large storm cells remained active after the front had passed by, such as at Turin and at Malpensa. However, at 6:00 p.m. most of the storm had moved over the eastern Po Valley and its hills.

Winds over Northern Italy at 850 MB were lightest over Turn at 12:00 noon, while a small sacca was barely noticeable at 700 MB. This minimum was [then] later reflected by the higher altitudes and from midnight on it was reported at 500 MB. Hence, the wind over the Milan zone, at between 5,000 and 10,000 ft., was from the south with a southwest rotating motion at higher altitudes; the speed was 10 knots, going up to 20 knots at higher altitudes.

There was no evidence of strong shears in the high-altitude winds. It is to be assumed that the storm cells moved about in conformity with the winds described above.

In view of the small rise in the surface temperature during the day because of the dense clouds, the scattered storms hitting the Po Valley in the afternoon seem to have been due to phenomena of forced updraft, caused by infiltration of cold air from the Alps, rather than to thermo-convective phenomena.

The calculation of the available energy for the phenomena of forced updraft, as the maximum estimate of the rising vertical currents in the storm cell at the presumed height of the crash, namely between 10,000 and 11,000 ft., comes out to about 12 M/s, a figure which may go up to about 19 M/s if we consider the thermic instability also as being active.

Because of the aforesaid possible speeds of the rising currents, in contrast with the downward currents which, although weaker, were always present about the storm cell, we can admit outright the existence of the turbulence with strong accelerations.

Within the same cell there is also a maximum probability for the production of very strong and localized electric charges, with a wide difference of potential even between adjacent points and, therefore, a high probability of discharges.

Weather conditions at the place where TWA Flight 891/26 crashed, about 12.5 km. from the Malpensa airport, may be presumed to have been similar to those reported by the weather stations of Malpensa and Linate. In fact, dense cloud formations covered the Milan zone at altitudes of from 2,000-4,000 to 14,000-20,000 ft. At higher altitudes, towering cumulo-nimbus formations, in large cells, existed at up to 35,000 ft.

Below the 2,000-4,000 ft. the cloud ceiling may for short periods have dropped to 600-1,000 ft. during the showers. More-or-less steady rain and shower activities existed over the Alps and in the Po Valley until the system moved on toward the Adriatic Sea, permitting the entry of northerly winds, after which the skies became clear.

An examination of the weather bulletins shows that at the time the TWA Flight 891/26 to Paris took off (4:20 p.m.) the weather over the airport was not good but neither was it prohibitive, even though the rumble of thunder, already audible at 4:00 p.m., announced the approach of a storm. It was not until 4:50 p.m. that storm activity of moderate intensity reached the airport. According to statements made by reasonably reliable witnesses, at the time of the crash, 4:35 p.m., it was raining slightly in the vicinity of Olgiate Olona and the ceiling was estimated at 600-700 meters (SABENA's flight 648 entered from the clouds at about 2,600 ft. QNH, more or less in the same area and at approximately the same time, with a variation of plus or minus 30 seconds). Visibility was described as good enough: about 3-4 km. There had been a very heavy shower 5-10 minutes before the crash and it rained quite hard again, briefly, some time later. Some witnesses heard thunder and saw flashes of lightning just before and after the crash.

The absence of a weather station in the vicinity of Saronno does not permit ascertainment of any further data.

(c) Conditions likely to cause disturbances, electric discharges and ice formations

Because of the frequency of strong upward and downward vertical air currents that accompany them, formations of storm clouds are always accompanied by disturbances, even of great violence, and the existence of strong electric charges with wide differences in potential and consequent discharges. Inside these formations, icing will occur at heights above the level of the thermic zero, which according to the soundings made by the Linate station at 12:00 noon was in the neighborhood of 11,500 ft. However, this altitude may vary inside the storm cloud; hence it is permissible to assume that in our case ice might have formed immediately above 10,000 ft. As to the highest limit for ice formation, still on the basis of the Linate soundings, we may assume a height of about 20,000 ft.

Documents and weather information supplied to the crew before departure

The documents and the weather information supplied by the Malpensa airport weather station to the crew of TWA Flight 891 on June 26, 1959 before taking off were the following:

(1) Routing papers, including:

[a] (Annex VI-1) Forecast chart of significant weather - ICAO Form SW, valid from 2:00 p.m. to 8:00 p.m. of June 26, 1959 (weather conditions plus position and type of fronts or meteorological phenomena of particular interest);

[b] (Annex VI-2) Prognostic charts for 700, 500, 400 MB levels - ICAO Form P, with validity as above (winds and temperatures at the levels indicated);

[c] (Annex VI-3) Landing forecasts covering airports along the route, the terminal point and alternate airports (Aerodrome Forecasts, ICAO Form A).

(2) Verbal explanations of the documents mentioned above and information on general and local weather conditions based on latest available data.

[a] (Annex VI-4) Excerpts from conversations between aircraft in flight and Milan Control relating to requests for route changes in order to avoid storm zones;

[b] (Annex VI-5) Statement by the SABENA Co. and their Capt. Caughan who took off from the Malpensa airport on a DC-6B plane at 4:33 p.m.

CHAPTER VII

AIDS TO NAVIGATION

(a) The radio-electrical aids available on Italian territory are those listed in the publication AIP Italy. Specifically, the Terminal Region of Milan is served by the following radio-electrical aids:

VOR	MORTARA
VOR	POIRINO
NDB/APP	MALPENSA
NDB/NAV	SARONNO
"	BIELLA
"	LINATE
NDB/APP	ORIO AL SERIO
NDB/NAV	PAVIA
"	PARMA
"	GENOA
NDB/APP	TURIN
"	CAMERI
VDF/NAV/SAR/MET	TURIN
"	MILAN
VDF/APP	MALPENSA

(b) Navigational equipment on the aircraft:

(A) 1 Magnetic Compass
(B) 1 Weather Radar Control
(C) 2 Radio Magnetic Indicators
(D) 2 Omni Magnetic Indicators
(E) 2 Omni Bearing Indicators
(F) 1 ILS set complete with "Marker" receiver
(G) 2 VHF receiver-transmitter sets
(H) 2 HF " " "

The inquiry as to the aids utilized by the aircraft included, besides the communications exchanged between the plane, the Malpensa control tower and the Milan Area Control Center, also the radio-compass stations mentioned in the preceding paragraph. There is no evidence that assistance from such stations was requested. From the authorizations issued by the Milan ACC and the communications exchanged between the aircraft and that control office, it appears that the plane plotted its navigation by utilizing first the Saronno and then the Biella radio beams. During the flight of the Super Constellation, those navigational aids were in uninterrupted operation.

CHAPTER VIII

FIREFIGHTING EQUIPMENT

It does not appear that the firefighting equipment carried on board the plane was used.

CHAPTER IX

TESTIMONY

(See Annex IX)

Written statements were secured from the following persons who were eye-witnesses to the crash:

NAME	ADDRESS	NOTATIONS
1 Tulio ADOBATI	OLGIATE OLONA Via per Marnate 2	Annex IX-1
2 Olga ADOBATI	OLGIATE OLONA Via per Marnate 2	" IX-2
3 Davide BARBIERI and son Ugo	OLGIATE OLONA Via per Marnate 2	" IX-3
4 Davide BARBIERI	OLGIATE OLONA Via per Marnate 2	" IX-4
5 Ugo BARBIERI	OLGIATE OLONA Via per Marnate 2	" IX-5
6 Adele BARBIERI	OLGIATE OLONA Via per Marnate 2	" IX-6
7 Franco BELLINI	CASTELLANZA Comando Carabinieri	" IX-7
8 Severino BENETTI	CASTELLANZA Via Venezia 14	" IX-8
9 Gabriela BIANCA	BUSTO ARSIZIO Via Ugo Mara 12	" IX-9
10 Daniele BIANCHI	CASTELLANZA Ditta Mancini	" IX-10
11 Oreste BOTTINI	GALLARATE Via Venegoni 2	" IX-11
12 Giovanni CAMPANELLI	BUSTO ARSIZIO Palazzo Comunale	" IX-12
13 Angelo CRANNA	CASTELLANZA Via Stelvio 6	" IX-13
14 Michele LA ROCCA	MARNATE Via Valle 2	" IX-14
15 Arturo LUCCHI Umberto MINA	GALLARATE 2° Deposito A.M.	" IX-15
16 Ettore MICHELUZZI	CASTELLANZA	" IX-16
17 Franco MOTTA	IERAGO Via Indipendenza 7	" IX-17
18 Alfonso PASCARELLA	CASTELLANZA Comando Stazione CC.	" IX-18
19 Carmen PAVARINI	OLGIATE OLONA Via per Marnate 2	" IX-19
20 Giuseppe PIANTANIDA	FERNO Via Marconi 2	" IX-20

21	Gioacchino POLIZZI	BUSTO ARSIZIO 2° Rep. Mobile di P.S.	Annex IX-21
22	Giorgio PONTI	LEGNANO Via 29 Maggio 43	" IX-22
23	Giorgio PORRINO	OLGIATE OLONA Via Marnate 3	" IX-23
24	Luigia ROSSETTI	OLGIATE OLONA Via Roma	" IX-24
25	Mariangelo SACCONE	OLGIATE OLONA Stazione C.A. di Busto	" IX-25
26	Leonardo TANZARELLA	BUSTO ARSIZIO 2° Rep. Mobile di P.S.	" IX-26
27	Ambrosio VOLONTE	MARNATE Via Silvio Pellico 3	" IX-27
28	Mario ZANARDI	MARNATE Via Tagliamento 1	" IX-28
29	Fiorino BELLINI	CASTELLANZA Comando Stazione CC.	" IX-29
30	Ettore CAREMOLI	BUSTO ARSIZIO Ospedale di Circolo	" IX-30
31	Ettore CAREMOLI and Mario FANCHINI	BUSTO ARSIZIO Ospedale di Circolo	" IX-31
32	Cornelio COLOMBO	CASTELLANZA Via Venezia 6	" IX-32
33	Renato CRENNA	GORLA MINORE Frazione Prospiano 70	" IX-33
34	Italo LECIS	BUSTO ARSIZIO 2° Rep. Mobile di P.S.	" IX-34
35	Pietro MARCORA	CASTELLANZA Corso Matteotti 17	" IX-35
36	Angelo MAZZA	GARATTOLA MARNATE Ditta Borri	" IX-36
37	Alfonso PASCARELLA	CASTELLANZA Stazione CC.	" IX-37
38	Giorgio PORRINO	COSSATO (Vercelli) Via Martiri Libertà 84	" IX-38
39	Giovanni ROSSINI	BUSTO ARSIZIO Municipio	" IX-39
40	Benedetto BANFI	RESCALDINA Stazione FF.SS.	" IX-40
41	Giancarlo BIENATI	CASTELLANZA Via Nizzolina	" IX-41
42	Carlo CARLI	RESCALDINA Via Milano	" IX-42
43	Gino CERINI	RESCALDINA Via Repubblica	" IX-43
44	Gaetano COLARUOTOLO	SOLBIATE OLONA 3° Batt. Bersaglieri	" IX-44
45	Michele COLOMBO	BUSTO ARSIZIO Viale Alfieri 25	" IX-45
46	Ampelia COLOMBO	MARNATE Via Rizzolina 34	" IX-46

47 Eleonora DAMETTO	MARNATE Via Rizzolina 328	Annex IX-47
48 Piero GALLI	MARNATE Via Legnano 25	" IX-48
49 Renzo VANETTI	MARNATE Via Legnano 15	" IX-49
50 Carlo VANZULLI	RESCALDINA Stazione FF.SS.	" IX-50
51 C.R.I.	BUSTO ARSIZIO Croce Rossa Italiana	" IX-51
52 Egidio ZECCHINI	OLGIATE OLONA Via G. Tovo	" IX-52
53 Aristi RE FRASCHINI	BUSTO ARSIZIO Via Ugo Foscolo 6	" IX-53
54 Giuseppe TOMASSINI	VARESE 88° Corpo V.F.	" IX-54
55 Bruno DOLCINI	BUSTO ARSIZIO - Gallar. Distaccamento V.F.	" IX-55

CHAPTER X

OTHER STATEMENTS

None.

CHAPTER XI

EXAMINATION OF THE WRECKAGE AND TECHNICAL INVESTIGATION

11.0 Forword

The technical investigations of the crash on June 26, 1959 of a Super Constellation plane type 1649-A, serial No. 7313, were conducted during the period July 26, 1959 to December 1, 1959.

Specifically:

[1] The inquiries described in paragraphs 11.1, 11.2 and 11.3 were made in Italy, at the A.M.I. 2nd Central Depot in Gallarate and at industrial establishments in the Milan area in the period from June 27, 1959 to December 1, 1959;

[2] The inquiries described in paragraph 11.4 were made in the United States under the direct supervision of the C.A.B. at plants of the aircraft industry, plane maintenance shops and specialized organizations in the period August-December 1959.

For purposes of a clearer understanding of the subject matter, the following documents are to be taken as integral parts of this Chapter:

Annex XI-1

Chart showing the position of each piece of wreckage at the place of the crash and pertinent legend.

Annex XI-2

Set of photographs of each piece of wreckage, taken at the crash site immediately after the crash.

Annex XI-3

Set of photographs taken at the 2nd Central Depot in Gallarate in the course of the inquiries described in paragraph 11.2.

Annex XI-4

List of materials sent to the U.S.A. for tests.

Annex XI-5

Descriptive sketch of fuel tanks Nos. 5, 6 and 7.

Annex XI-6

Diagram of the fuel system of the Super Constellation plane type 1649-A.

Annex XI-7

Accessories of the fuel tanks.

11.1 Position of the wreckage

In the course of the events which ended with the structural disintegration, in flight, of the aircraft while it was following the prescribed route Saronno NDB-Biella NDB, many parts of the wreckage became separated from the plane and were scattered over an area of about 3 square kilometers.

The crash area is located at about 30 km. to the NW of Milan and includes the towns of Olgiate Olona, Prospiano, Gorla Minore, Nizzolina, Marnate and Castellanza, all of them to the NE of Busto Arsizio in the province of Varese.

Proceeding into the said zone, in an east-west direction corresponding more or less to the plane's route, the scattering of the wreckage on the ground extended for about three kilometers within a wide and irregular lane which began at the Celora farm (about 1 km. to the NE of Nizzolina) and ended at the town of Olgiate Olona.

Along this lane, starting from the aforesaid Celora farm and proceeding in the direction of Olgiate Olona, the following most significant and principal parts and pieces of wreckage of the plane were found in the order in which they are listed:

1. The upper plate, in perfect condition, of fuel tank cap P.N. 750438-13; by process of elimination, it was later ascertained that the cap belonged to tank No. 6 or No. 7.

2. Upper and lower panels, wing ribs, bulkheads, inlet pipe P.N. 478301 and other structural parts, belonging to tank No. 6 and the right side of tank No. 7.

   These parts were scattered along the lane of fall of the wreckage, up-course from the main wreckage (fuselage and left wing) and the right wing.

   The surfaces of several of the panels and bulkheads, of quite large dimensions, belonging to tank No. 6 and the right side of tank No. 7, were bent outward, as if they had been subjected to great internal pressure.

   Likewise, intake pipe (P.N. 478301) of tank No. 7 was literally split open by the obvious effect of great internal pressure. All these articles were extraordinarily clean and bore no sign of damage from fire.

3. The engines in the right wing, numbered 3 and 4, became detached from the wing in flight. They fell at a distance of some 1,100 meters to the SE of the main wreckage (fuselage-left wing) in a field facing the C.R.M. plant at Castellanza, digging two holes in the ground.

   Both engines suffered considerable damage from the impact with the ground, especially the propeller of engine No. 4, which became detached from the engine.

4. The right wing, complete with its cowlings and semicarriage, was broken off at a point along the semicarriage housing.

   The wing fell in a field facing the Galli sawmill, in the township of Marnate, some 650 meters to the SE of the spot where the main wreckage (fuselage and left wing) fell. It suffered considerable damage from the impact with the ground and from fire.

5. The main wreckage included the fuselage, the left wing, the left semicarriage, the fore carriage and the inner engine, No. 2.

   This wreckage fell in the township of Olgiate Olona a few meters from the Agnesi farm, striking the ground almost vertically: it was found with the nose pointing to the SE in such a position that the axis of the fuselage formed with the North an angle of about 140°. The entire wreckage was badly damaged, warped and broken in many places as the result of disintegration in the air, the impact with the ground and fire.

6. The tail assembly, with part of the tail cone but minus the greater portion of the elevators and the lower end of the left rudder.

This group fell close by a fencing wall about 450 meters south of the main wreckage.

Of the three rudders, the two outer ones were attached to their respective fins, excepting the lower end of the left rudder which was missing; part of the central rudder was still attached to its fin and the rest of it (the upper portion) was lying on the ground.

The entire tail assembly suffered considerable damage from the impact with the ground and showed ample evidence of burns.

7. Left-side outer engine, No. 1.

This engine, which became detached from the left wing in flight, fell in a field about 250 meters to the SW of the main wreckage, digging a deep hole in the ground; as a result of the impact, the propeller became detached from the engine but was found with it in the hole. The entire assembly was badly damaged by the impact with the ground.

11.2 Condition of the wreckage and technical examination of the same

11.2.1 All the pieces of the aircraft, including the smallest ones, found after a long and meticulous search of the crash site, constituting together the most important and significant parts of the plane, were recovered and brought to the 2nd A.M.I. Central Depot at Gallarate. Here, a group of more than 15 technicians spent about 40 days making a minute and accurate examination of every single piece of wreckage.

Specifically, the examination was conducted along these lines:

1. To the extent necessary, it included:

[a] Reconstruction, by means of suitable metal trellis and pipe work, of the entire right wing and the entire central portion of the wing housing tanks Nos. 6 and 7 and reconstruction, alongside the central portion, of the left wing by rearranging its parts, in the proper order, on the floor;

[b] Careful reconstruction of the fuselage, by arranging all available parts, in the proper order, on the floor;

[c] Reconstruction of the engines by placing each of them in front of the two wings, in its numerical order;

[d] Reconstruction, separately, of other groups of materials of particular importance (front compartment of the hydraulic system, etc.).

2. The pieces of wreckage mentioned under point 1 were systematically and carefully examined by specialized technicians after being subdivided into three principal groups, namely: structure of the aircraft, engines, various inboard installations.

3. In the examination of the materials mentioned under point 1 and in the evaluation of the damage suffered by them, consideration was given to all those hypotheses which, directly or indirectly, might relate to the possible causes of the accident and to all uses previously made of the plane (see par. 11.2.3.7).

11.2.2 Examination of the engines

11.2.2.1 Condition of each engine assembly at the spot where it fell

Assembly No. 1

This assembly became detached from the left wing at the firewall and struck the ground almost vertically with its front portion, embedding itself in the ground almost 2 meters deep; the result was considerable damage and breakage, especially to the front and rear ("power egg") areas.

Specifically, the force of the impact caused the front portion of the assembly, including part of the reduction gear housing, the propeller, and part of the propeller shaft, to break off and separate; two propeller blades broke off near the hub. All these parts were found together with the engine in the hole. The assembly showed no visible signs of fire or damage from fire.

The pitch of blades 1, 2 and 3 was found to be, respectively, 33°, 34° and 27°.

Assembly No. 2

This assembly remained attached to the main wreckage and, on striking the ground, penetrated into the front part of the fuselage.

The rear part of the engine suffered very severe damage from the fire that followed the crash; the propeller remained attached to the engine, with the exception of one of the blades, which broke off at the hub and was buried under the wreckage.

The pitch of blades 1, 2 and 3 was found to be, respectively, 28°, 25°, and 27°.

Assembly No. 3

This assembly became detached from the right wing at the firewall, after the wing had broken off from the plane, and its rear portion struck the ground. The empact caused considerable damage; one of the propeller's three blades broke off and was buried under the engine.

The group showed no visible signs of fire or damage from fire.

The pitch of blades 1, 2 and 3 was found to be, respectively, 17° /21°, 22°, and 19°.

Assembly No. 4

This assembly became detached from the right wing at the firewall, after the wing had broken off from the plane, and struck the ground with cylinder No. 17 undermost; the assembly suffered considerable damage from the impact.

The propeller, as the result of first striking a high tension wire and then of hitting the ground, became separated from the engine together with the dome and part of the propeller shaft and was hurled about 15 meters away. Of the three blades, one remained attached to the hub, one broke off in two and the third broke off near the hub; these parts were found on the ground near the main wreckage of the propeller.

The examination of the rear part of the engine disclosed that a small fire had developed in the "power egg"; the pattern of the smoke traces and the flow of the metal melted by the flames showed that the fire started after the plane had crashed.

The pitch of blades 1, 2 and 3 was found to be, respectively, $15^{\circ}/21^{\circ}$, $16^{\circ}/20^{\circ}$, and $17^{\circ}/19^{\circ}$.

11.2.2.2. Result of the technical findings on the engine assemblies

Propellers

Nothing abnormal was revealed by the examination of the propellers; particularly, the differences in the pitch of the various blades were caused by impact with the ground, as was found upon inspection of the parts.

The checking, done in the U.S.A., of the calibrations shown by the governors of engines 1, 3 and 4 revealed that they were set for the following speeds:

propeller No. 1 - 2,611 rev.
" " 3 - 1,949 "
" " 4 - 2,502 "

which are indicative, at least for engines 1 and 4, of a climbing speed.

Governor No. 2 was destroyed by the fire on the ground.

Engines

The careful examination of the 4 engines made, after a checking of their respective operational records, which involved partial disassembling or stripping of the more significant parts for the purpose of looking for evidence of breakdowns, failures, or fire while the plane was still in the air, disclosed the following:

Engines Nos. 1, 3 and 4: No breakdowns, failures or fire while the plane was still in the air.

Engine No. 2: No signs of breakdowns or failure in flight; because of the severe damage suffered by the engine from fire after the crash, it was not possible to ascertain whether it had caught fire in the air. However, an examination of all the parts and the pertinent areas of the left wing failed to bring to light any physical evidence that it had.

11.2.3 Examination of the structures

11.2.3.1 Right wing (from the wing tip to the nacelle of engine No. 3)

The right wing, complete with its cowlings, part of the landing gear, flaps, and aileron, broke up in flight, with an upward motion, near nacelle No. 3 and fell to the ground in flames, near the town of Marnate.

It struck the ground with the part where the breakage had occurred, namely part of the landing gear, and suffered severe damage, especially in that area. Further damage was caused by the fire, which continued for a short time to burn both the outside and the inside of the wing, after it had struck the ground.

The wing was meticulously inspected in order to determine whether some of the damage caused by fire had taken place before it became separated from the plane. It was decided that such was not the case. The examination of all the areas of breakage showed no evidence of breakages due to stress or metal fatigue.

The lower covering of the wing, outside engine No. 4, was torn off, beginning from the tip, into long and narrow panels, some of which became detached from the wing and fell separately to the ground.

The wing tip, with its counterweight, was found near the wing but detached from it because the couplings had broken, this

separation was found to be a direct consequence of the impact with the ground.

The landing gear was found in a partially lowered position (see par. 11.2.3.5 - Hydraulic system).

The flaps were in the retracted position; the outer one was in its seat, the inner one was broken into two main parts.

The aileron was broken into two parts: the smaller one was found about 150 feet away from the wing; the other part was still attached to the wing.

Right wing: from the nacelle of engine No. 3 to the plane's center line (area of tanks Nos. 6 and 7)

The wing structure from reference point 196.D. (outer bulkhead of tank No. 6) to reference point zero (plane's center line), including tank No. 6 and the right half of tank No. 7, disintegrated in flight into many pieces, which were found scattered over the path of fall of the wreckage, but at a distance up-course from the main wreckage and the right wing.

In the area of tank No. 6 included between reference points 196.D. (outer bulkhead), 65.D. (bulkhead-partition between tank No. 6 and tank No. 7), the upper wing structure and the front spar (constituting, with the rear spar and the two bulkhead-partitions, tank No. 6) showed clear signs of having been bent outward, manifestly the result of strong pressures.

In particular, the wing panels, on both the upper and lower sides, constituting the top and the bottom of tank No. 6, showed a curvature of about 25 centimeters.

Likewise:

[1] Several pieces of the outer bulkhead, reference point 196.D., showed signs of stress from pressure coming from the interior of tank No. 6;

[2] The examination of two intact ribs, inside tank No. 6, showed that they had become detached from the upper and lower wing covering following the shearing, in a vertical direction, of the junction rivets.

In the area of tank No. 7 right side (comprised between reference points 65.D.0.), the wing structure, recovered in several pieces, had also been bent outward, but somewhat less than tank No. 6.

These structural pieces - namely, those of the right side of tank No. 7 - were found, as has already been stated, together with those of tank No. 6 scattered over the path of fall of the wreckage, up course from the main wreckage and right wing;

in particular, the partitioning bulkhead between tanks 6 and 7 was found, in pieces of considerable size, at the beginning of the path of fall. The structural parts of the left side of tank No. 7 (reference points 0-65.S) were, however, found in several pieces, damaged by the impact and by fire, under the fuselage at Olgiate Olona.

Of particular significance was the examination of the intake pipe (P.N. 478301) of tank No. 7, which was found about one kilometer away, up course and NE of the right wing (see Annexes XI-5).

This pipe had been literally split open by great internal pressure; the examination of the ends of the pipe and of the corresponding connection points on the partition bulkhead between tanks 6 and 7 and on the wing panel constituting the top of tank No. 6, disclosed that the pipe had been subject to outward stress and that, before that stress was exerted, both the partition bulkhead and the wing panel were at their proper places and in a normal position.

All parts listed above, without exception, belonging to the area of tank No. 6 and the right side of tank No. 7, were found along the path of fall of the wreckage, perfectly clean and free from traces or indications of fire. A careful examination of these parts did not disclose any trace of electric discharges.

11.2. .2 Fuselage

The main wreckage (fuselage, left wing and engine No. 3) fell to the ground in flames, the nose and the stump of the right wing striking the ground first as indicated by the very considerable crushing of the entire right side of the fuselage, especially in the front area, near the nose of the plane.

All the structural parts of the fuselage and the left wing, which were found and recovered, had been badly crushed, twisted and torn by the impact with the ground and most of them had also suffered damage of varying degree from fire, both in flight and on the ground.

As we have already said, the fuselage was carefully reconstructed, on the ground, at the Gallarate Central Depot, where the various pieces were first identified and then arranged in their proper order. At the time of their identification the various pieces were closely examined with a view to finding evidence of breakdowns, loss of parts in flight, damage from fire, or from collision, or from explosion of devices, etc., which might in any manner have happened during the planes flight prior to its disintegration.

Particular care was exercised in inspecting the cargo compartments in order to ascertain whether any fire or explosion from explosive devices had occurred there.

Within the degree of reliability commensurate with the conditions and quantity of the structural parts that were recovered, the inspection failed to disclose any concrete and significant evidence which might support the existence, or the development during the plane's normal flight, of abnormal conditions which could have been either the direct or the indirect cause of the accident.

Of the three main doors giving access to the plane, only the crew entrance door was found intact; the front entrance door was found broken into two parts; the rear door was almost completely destroyed by the fire. The lock on each of them was in the closed position.

Of the five emergency exit doors, three were recovered; because of their condition, it could not be ascertained whether they had been properly blocked. The other two were destroyed by the fire. The outer door of the rear service area, having become separated from the plane following the disintegration of tank No. 7, was found along the path of fall of the wreckage; it showed no sign of fire.

Of the six inspection ports beneath tank No. 7, two were found together with the fuselage; the other four became separated from the plane in flight following the disintegration of the tank No. 7 above them and fell to the ground up course from the main wreckage. None of these four doors showed any sign of fire.

Most of the window frames were recovered; those missing were destroyed by the flames. All the glass was shattered and none of it was recovered.

The front landing wheel assembly was found in a retracted position. As to the front compartment of the hydraulic system, see par. 11.2.3.5 - "Hydraulic system."

11.2.3.3. Left wing

The left wing was recovered in two large sections and numerous medium- and small-size pieces, all of them damaged by the impact with the ground and by fire.

The largest section, comprised between stations 266S. [and] 487S., consisted primarily of cowling No. 1, the rear spar and the trailing edge, complete with its flap in the retracted position, and several panels of various sizes.

The second section, smaller than and fitting against that described above, extended up to station No. 109.S.; the trailing edge was complete, with its flap in the retracted position.

Part of the carrying structure of the landing gear was still in its housing, with the landing gear attached to it. In general, all the structural parts ahead of the back spar were twisted and broken into small pieces.

Outward from station No. 487.S., that is, toward the tip, the wing was broken into several parts.

Many of these parts (including the aileron, which was broken into four pieces and torn from its fastenings) were recovered in the immediate vicinity of the fuselage and were found to be free from damage from fire, since they were lying beyond the zone where the fire broke out following the crash. Some small panels of wing covering became detached in flight and fell, down course from the main wreckage, in the town of Olgiate Olona.

The wing tip and its counterweight became detached prior to the impact with the ground and was found near the fuselage. The landing gear was found in the "lowered" position (see par. 11.2.3.5. - "Hydraulic system").

11.2.3.4 Tail assembly

The entire assembly became separated from the plane, in flight at a point beyond the pressurization bulkhead and fell on a fencing wall, coming to rest upside down on the wall. It suffered considerable damage from the impact.

Five pieces of the two elevators, the lower part of the left rudder, and part of the terminal stern cone and fairing were found in other places distant from the tail assembly, which indicates that these parts broke off while the plane was still in the air.

The examination of the breakage area of the tail assembly failed to disclose any trace of metal fatigue and showed that the assembly became separated from the end of the fuselage as a result of static overloads, directed to the left and downwards. Extensive and evident traces and signs of lapping flames and smoke deposits were distributed continuously and in a longitudinal and transversal direction, on several areas of the stabilizers, elevators, and rudders; particularly, the de-icer sheathing of the stabilizer's leading edge showed evidence of searing. This circumstance showed that the tail assembly was structurally in its proper when, during flight, a fire broke out on the front part of the plane; specifically, it showed that the fire enveloped the tail assembly from its right side.

11.2.3.5. Installations and equipment on the plane

A thorough examination was made of all the plane's installations and equipment in order to establish whether they had suffered

breakdowns, failures, etc., and, consequently, might have been the direct cause, or a contributing cause, of the crash.

The condition in which several of the individual parts were found, the particular nature of certain installations, the damage caused by the impact, by the fire, and by the recovery operations, the virtual destruction of many control panels, the fact that the force of the impact moved many levers and switches to the "on" or "of" position, the changes caused by the breaking off in flight, of part of the aircraft--all these things rendered the examination extremely laborious. Hence, in some cases the conclusions derived from the examination were not so much the result of concrete and specific physical evidence as they were of careful and logical interpretation and of indirect but interesting indications.

Whenever necessary and considered useful, in order to determine whether certain individual parts and accessories of the installations were in good working order, such parts were subjected to bench tasts and partially or totally disassembled.

We wish to explain that the term "abnormality" employed below means any failure or breakdown which, having occurred before or at the time of the accident, might have been the direct or indirect cause of it. Having given that explanation, we can proceed to sum up hereunder the results of the various examinations.

Air conditioning system

Pressurization. No abnormality. It was not possible to determine whether the plane was pressurized at the time of the impact. As to the automatic control of the pressurizing system, see par. 11.2.3.7.

Heating, refrigeration and air circulation. No abnormality: specifically, the two heaters bore no signs of explosion. It was not possible to determine whether the system was in operation when the plane struck the ground.

Automatic pilot system

No abnormality. It was not possible to determine with certainty whether the automatic pilot was on at the time of the crash. However, a concurrence of considerations leads to the belief that, in all probability, it was not.

A checking of the Air Data Sensor's calibration, in the condition in which it was recovered, showed the following data:

Altitude: between 2,685 and 7,000 feet
Speed: between 145 and 195 MPH

Communications and navigation

No abnormality was found which might suggest a malfunctioning of the respective devices.

Specifically, it was established that the weather radar, AVQ-10, was operating: this was shown by the fact that the inverter serving the radar as well as the antenna carried on the plane's nose were in rotation at the time of the impact. However, the retractable viewing screen, mounted behind the control panel in the pilot's cabin, was so badly crushed that it was not possible to determine with certainty whether it had been used by the crew.

Fire-fighting equipment

No abnormality. Specifically, it was found that the fire-fighting equipment was not used, either for the engines or for the heaters.

Flight controls

Following a long series of checking and searching operations, it was concluded that the various controls of the plane (ailerons, flaps, rudders, etc.) were in normal operating condition at the time of the crash. In particular, it was deduced that the flap controls were in the "retracted" position.

Fuel system

This system was examined with extreme care in view of the evidence that tanks Nos. 6 and 7 had disintegrated in flight.

With the exception of tank No. 6 and the right side of tank No. 7 (see par. 11.2.3.1), the tanks showed no signs of damage from fire. All tank caps P.N. 750438-13 were recovered. In the case of one of them, of which only the upper plate had been left (see par. 11.1, point 1), it was established, by a process of elimination, that it must have belonged either to tank No. 6 or tank No. 7.

The level-indicating rods (P.N. 481741-1) for tanks Nos. 1 and 6 were not found because they had been removed, very likely by unauthorized visitors, at the crash site.

This was shown by the direct examination of their respective seats located on the top surface of the wing.

All the metallic mesh filters (P.N. 480909-1) with which the fuel intake ports (on the top surface of the wings) were equipped were found, with the exception of the one belonging to tank No. 5. Specifically, the filter of tank No. 7 was found at the spot where the wreckage was lying; that of tank

No. 6 was found to the north of Nizzolina, along the path of fall of the wreckage. A careful examination of these latter two filters and their respective seats in the wing did not disclose anything abnormal.

The fuel-dumping controls were found in the closed position.

The vent outlets of the fuel tanks were located: the right-side one was in place on the right wing; the left-side one was found with the main wreckage, crushed and detached from the left wing. These outlets were later subjected to a series of tests intended to ascertain any possible traces of lightning (see pars. 11.3 and 11.4).

The seven submerged pumps of the seven tanks were recovered and identified: those belonging to tanks Nos. 1, 3, 5, 6 and 7 had been torn from their respective seats at the bottom of the tank following the breaking off of the light alloy coupling plates; the protective casing of pump No. 5 showed signs of heat due to fire. Operational tests and disassembling for check-up, done in the care of all pumps, showed that they were in proper working order.

None of the other parts making up the system showed any signs of abnormal conditions.

Hydraulic system

Nothing abnormal was found in the system, with the exception of minute bronze residues in the flange and the angle joint of the return pipe of hydraulic pump No. 1. Dismantling the pump disclosed that the residues came from pistons Nos. 3 and 8; however, the pump was found to be in working condition just the same. The hydraulic fluid of system No. 1 was somewhat darker than normal, but the inspection of all parts of this system showed no signs of defective operation.

Through the examination of the individual parts and kinematic motion tests thereon it was deduced that the two sides of the landing gear and the landing wheel assembly were in the retracted position when the plane disintegrated, and the fact that the left portion of the landing gear was found in an extended position and the right portion in a partly extended position is to be ascribed to the inertia forces generated by the breaking off of the right wing and by the impact of the right wing, the fuselage, and left wing with the ground.

About 80% of the accessories of the front compartment of the hydraulic system were recovered. Since some of them, as well as some structural parts of the compartment, showed signs of fire, this compartment was reconstructed (see par. 11.2.1) with a view to ascertaining whether such signs were due only to the fire that followed the crash. From the examination of these parts it could not be established whether fire broke out

in this compartment while the plane was in flight; however, if there actually was such a fire, it could have been only a small one.

Lubricating oil system

Nothing abnormal was found.

Oxygen system

Nothing abnormal was found. Specifically, it was found that the system had not been used.

Instruments and controls

The condition in which the various flight instruments and installations were recovered was such that the Commission could not arrive at any reliable factual deductions from its examination of them. In fact, following the disintegration of the plane in flight, the impact of the wreckage with the ground, and the fire, generally speaking the instruments were broken, twisted, and damaged.

The same is true of the controls of the engines and of the various installations, as we have already mentioned at the beginning of this par. 11.2.3.5.

From a concurrence of evidence and clues, however, it was possible to deduce that the plane, at the time of the crash, was proceeding toward Biella within the prescribed limits of speed, altitude and route and that it did not make use of any emergency measures. For instance, the switch controlling the sign for fastening the safety belt was found in the "Fasten Belts" position. This was later confirmed by the fact that the passengers were found with the belts fastened, while the [switch for the] "No Smoking" sign was found "off."

Likewise, none of the four emergency levers on the "emergency shut-off quadrant" was moved to the second or third notch (which would have shut off the fuel from the engines, the cooling air from the generators, and the lubricating oil from the engines). This is deduced from the fact that the four valves for shutting off the cooling air from the four electric generators of the engines, which valves are controlled by the aforesaid levers, were found in the "open" position.

Electrical system

Nothing abnormal was found. Where the remaining entangled mass of electric wires had suffered no damage from the impact, fire, etc., those wires were stripped of their covering and examined, but nothing abnormal was found.

Other installations

The remaining installations, of lesser importance, were examined and tested in a general way, but nothing abnormal was found.

11.2.3.6. Damage from lightning

The wreckage was closely examined for evidence of damage from lightning; when necessary, the examination was done with the aid of a magnifying glass.

No traces or signs of structural damage of any significance due to lightning were found; in particular, the structures of tanks Nos. 6 and 7 showed no traces or signs of damage of this kind (see par. 11.2.3.1).

However, signs of lightning strikes were found on many parts of the plane, but they were no greater than those normally found on all planes; it was not possible to ascertain whether they had been produced during the plane's last flight or in previous flights.

Specifically, the following facts were ascertained:

[1] The lightning arrester wire of the RADAR cone on the plane's nose was burned and broken into two parts at a point 77 inches away, measured around its circumference, from the rear end of the cone's axis;

[2] Melted points, measuring 1 x 1/16 and 1 x 1/8 inches, were found, respectively, on the trailing edge of the left and right wing tips;

[3] Fifty-one cavities, or melted points, in all, warying in diameter from 1/16 to 3/16 of an inch, and one hole 3/4 of an inch in size, were found on the upper outer surface of the left aileron;

[4] Five small cavities, the largest of which was 1/4 of an inch in size, were found on the right aileron;

[5] A hole 3/4 of an inch in size and another 1 1/4 x 3/16 inches in size were found on the lower trailing edge of the right rudder;

[6] A small melted point about 1/4 of an inch in diameter was found on the lower trailing edge of the left rudder.

No signs of lightning strikes were found on the static dischargers or the areas near them. Likewise, no evidence of lightning strikes was found on the collectors of the fuel tank vent outlets.

11.2.3.7. Maintenance records of the aircraft and engines

The maintenance records were carefully examined in order to determine whether pre-existing conditions of abnormality might have had a direct or indirect relation to the causes of the crash. In particular, it was ascertained that previously the aircraft had made five landings in an overloaded condition and one landing which had been classified as a "hard" landing; however, inspections made after such landings had disclosed nothing abnormal. It was also disclosed that the automatic control of the pressurization system had, in the past, given continuous trouble and was still doing so at the time of the last flight; however, the system's manual control was in good working order. The records showed, lastly, a series of minor troubles and difficulties, which were taken into account in the examination of the wreckage. Included in these were some leaks in the fuel tanks, which had been promptly repaired as soon as discovered.

11.3 Supplementary inquiries

Parallel with the inquiries described in par. 11.2, a series of tests on various accessories, material and parts were made in the plants of the Alfa Romeo, Secondo Mona, and other industrial firms.

The following is a summary of the results of those texts.

11.3.1 Inspection of the seat of cap P.N. 700438-13 on the wing top of tank No. 6

The inspection was made in order to ascertain whether a burn mark found in the seat of the cap had been caused by lightning. It was determined that the mark had been caused by welding, done in the course of repair work.

11.3.2 Tests on samples of metal taken from the wing frame and inspection of the "fracture areas"

The tests were made in order to ascertain the characteristics of the metal and the type of the fractures.

It was found that the metal conformed to the specifications and that the fractures showed the characteristics of breakage by tearing.

11.3.3 Microscopic examination of the fuel tank vent outlets

The examination was made in order to ascertain whether some traces of blackening and heating, found on one of the vents, could be ascribed to electric discharges.

It was concluded that the presence of such traces was due to the heat of the fire and that the two vents bore no evidence of lightning strikes.

11.3.4 Examination of and bench tests on the submerged pumps of tanks Nos. 4, 5 and 7 and parts of same

The examination was made in order to ascertain whether the pumps were in good working order.

It was found that they were.

11.3.5 Examination of a roll of paper found along the path of fall of the wreckage in the area of Madonna dell'Albero

This roll of paper (item 74 in the chart showing the distribution of the pieces of wreckage) measuring 20 x 18 centimeters in size, was found in the area mentioned above in the vicinity of one of the inspection ports under tank No. 7 and of a diaphragm of tank No. 6.

The roll was imbedded in the ground at an angle and one of its ends was completely burned.

It was therefore suspected that the roll might have come from the plane and a chemical analysis of it was undertaken with a view to ascertaining the type of paper and whether it was capable of generating or inducing any process of spontaneous combustion.

It was condluded that the paper was a special wrapping paper with a body of the isocyanic type covered by a layer of polyuretanic sponge, having no properties capable of starting or feeding any process of spontaneous combustion.

In as much as the paper, corresponding to specification MIL-P.116.C, was freely sold in the Milan market, supplementary inquiries were made locally and in Milan in an attempt to ascertain its source. These inquiries met with no success.

11.3.6 Examination of the technical data supplied by the Lockheed Co. pertaining to the plans of the Super Constellation plane type 1649-A

The technical data supplied by the Lockheed Co. was taken under examination in order to interpret the results of the various tests made on the prototype, in the areas in which the breakage took place, for the various load conditions set forth by the C.A.R.4b, of the coefficients under which the breakages occurred, etc., so as to determine whether there existed conditions which might have caused parts of the plane to break off in flight as the result of aerodynamic stresses of any kind.

For the results of this examination, see par. 14.4.1.

11.4 Principal inquiries in the U.S.A.

11.4.0 The following studies were made in the U.S.A. at industrial plants, maintenance shops, special institutions, and laboratories, under direct supervision of the CAB.

11.4.1 Analysis of the breakage points of the individual pieces of wreckage

This study was undertaken in order to ascertain, on the basis of the construction calculations, the results of the breakage tests made on the prototype, and the breaks that occurred in the wrecked plane, whether disintegration of that plane in flight was due to aerodynamic stresses of any kind or to other causes.

It was concluded that disintegration of the plane was due to explosive forces originating in tank No. 7.

11.4.2 Study of the trajectory of fall of some significant parts of the aircraft which became separated in flight from the plane after its disintegration

This study was undertaken in order to ascertain, by comparing the actual distribution on the ground of some of the significant parts which became detached in flight with the position obtained by calculation, the height at which the plane disintegrated.

Within the framework of the assumptions on which the study was based, the results showed, with the same degree of probability, the following three combinations of altitude and speed (with wind):

560 knots I.A.S. at an altitude of 5,000 ft.
290 " " " " " " 10,000 "
125 " " " " " " 15,000 "

Hence, also because of the uncertainty existing in the evaluation of certain parameters entering into the calculations, the results of the study must be taken as indicative and not conclusive.

11.4.3 Pressure tests on fuel tank caps P.N. 0750438-13

To the north-east of Nizzolina, precisely at the beginning of the path of fall of the individual pieces of wreckage, was found the upper plate of a fuel tank cap. The plate was clean, without damage of any kind, and was identified, by process of elimination, as belonging to tank No. 7, or No. 6 (see par. 11.1, point 1).

These tests were made in order to ascertain whether pressure, and if so how much, could cause cap P.N. 750438-13 to separate into its component parts so that one of those parts, namely the upper plate, could appear in the same condition as the one that was found.

The tests, made on new caps, brought out that the caps in question:

(a) Can be ejected from the seat onto which they are screwed, following fracture of their lower portion, by pressures ranging between 110 and 136 p.s.i. or thereabouts, namely; a pressure much higher than that which will, in fact, cause the tank structure to collapse and the fuel intake pipe (P.N. 478301) to crack;

(b) Cannot be damaged, by stresses deriving from pressures of various strength, in such a way as to cause a breaking down of the various component parts resulting in the separation of the upper plate only [and no other damage].

On the basis of these tests, it was definitely agreed that the cap to which the plate belonged could not have been ejected from its seat (in the upper surface of the wing) as a result of explosive forces (see point b).

11.4.4 Tests on the vent outlets for the escape of gasoline vapors from the fuel tanks of the Super Constellation plane type 1649-A

These tests were made in order to ascertain whether the gasoline vapors, assumed to be flammable, emerging from the vents, can be ignited electrically, and if so, whether the resulting fire, through the outlets, will spread to the interior of the tanks.

Under the conditions in which the tests were made, it was established that the gasoline vapors will ignite under certain conditions, but the flames will not spread to the tanks.

11.4.5 Inspection of the inner surfaces of some pieces of pipes of the vent outlets for the escape of gasoline vapors, belonging to wrecked plane No. 7313 C.

The inspection was made in order to ascertain whether the condition of the surfaces gave physical evidence of the spreading of flames through these pipes.

The result of the inspection was negative.

11.4.6 Study of the possibility of sabotage

This study was undertaken in order to ascertain whether it is possible to introduce, through the fueling ports and into the fuel tanks, suitable compounds, properly prepared, which will later ignite the gasoline vapors existing in the tanks and cause them to explode, without leaving any physical evidence.

It was concluded that such a possibility existed and some examples are mentioned [later in the report].

11.4.7 Inspections and bench tests, made on the premises of specialized firms, on various parts, accessories and equipment belonging to the ill-fated plane.

These inspections and tests were undertaken in order to ascertain whether the parts, accessories and equipment in question were in proper working order at the time of the crash.

The result was positive in the sense that no evidence of abnormal conditions was found.

11.4.8 Static tests on fuel tank caps P.N. 750438-13

The purpose of these tests was the same as that mentioned in par. 11.4.3.

The tests, conducted on used caps, brought out that the breakage of the individual component parts of the caps occurs under loads corresponding to pressures ranging between 126 and 141 p.s.i., namely, pressures far greater than those required to cause the tank structure to give way and the fuel intake pipe (P.N. 478301) of tank No. 7 to crack.

11.4.9 Statistical inquiry into the trouble encountered in the practical use of submerged pumps in the fuel tanks

This inquiry was undertaken in order to examine the typical defects encountered in pumps of this type and to ascertain whether such defects, if found present in the submerged pumps of wrecked plane 7313 C, might have directly or indirectly caused the gasoline vapors in the tanks to ignite and explode.

It was established that the pumps of the wrecked aircraft had no such defects.

11.4.10 Tests on the highest temperature that the body [casing] of a submerged pump can attain when the pump is, by mistake, kept operating for a long time in a practically empty tank

These tests were made in order to ascertain whether, under the conditions in question, the result would be an explosion of the gasoline vapors contained in the tanks.

The tests showed that the highest temperature reached under the conditions cited would be about 120°.

11.4.11 Statistical inquiry into the replacing of P.N. 750438-13 caps and P.N. 481742-1 dipsticks on TWA planes at some past time

Since it was found from the wreckage of the ill-fated plane that the caps of tanks Nos. 6 and 7 and the dipsticks of tanks Nos. 1 and 6 (these caps and sticks are screwed onto the top surface of the wing) were missing, an inquiry was made in

order to ascertain, from existing records, whether any cases of loss of these accessories in flight had ever occurred in the past.

No evidence was found of cases of this kind.

11.4.12 Statistical inquiry into the damage suffered by 193 planes which were struck by lightning in 1958-1959

This inquiry was undertaken in order to obtain factual elements for an evaluation, on the basis of and in accordance with past experience, of the importance to be given to damage caused by lightning to the structure of the wrecked plane (see par. 11.2.3.6).

The inquiry disclosed that such damage was no greater than that usually suffered by other planes struck by lightning. It also showed that there were no cases on record of vent outlets being struck by lightning.

11.4.13 Inspection of all the technical records on former use of wrecked plane N. 7313-C from the date it was built to the date of the crash

This inquiry was undertaken in order to ascertain whether the trouble, the malfunctioning, the stresses from abnormal landings etc., which had occurred during the practical use of the plane might have been directly or indirectly related to the causes of the crash.

The results of the inquiry were taken into consideration during the technical examination of the wreckage (see par. 11.2.1 and par. 11.2.3.7).

11.4.14 Inquiries as to the origin of the roll of paper mentioned in par. 11.3.5

The purpose of these inquiries was that mentioned in par. 11.3.5. They were not successful, in the sense that it was not possible to ascertain the origin of the paper, and in particular whether it was aboard the ill-fated plane.

11.4.15 Chemical analyses of the roll of paper mentioned in par. 11.3.5

These tests were undertaken for the dual purpose of ascertaining whether the characteristics of the paper were such as might cause or set off fire and explosion and whether, before the crash occurred, the roll had been lying where it was found afterward.

The tests disclosed only that the roll was a special type of wrapping paper having no particular characteristics of flammability, etc., and that it contained no substance that would aid combustion.

11.4.16 Inspection of the vent outlets of the wrecked plane

The inspection was made in order to ascertain whether the vents showed traces of lightning strikes or of static electric discharges (streamer corona) such as might cause gasoline vapors to ignite.

The examination disclosed that the vents showed no evidence of electric discharges; however, it was decided that this did not exclude the possibility that static discharges had occurred in the vents that could have ignited the gasoline vapors issuing from them.

11.4.17 Microspectrographic examination of the metallic mesh filter (P.N. 480909-1) of tank No. 7

This examination was made in order to ascertain whether the filter might have been, in some way, the starting point of the explosion in that tank and whether it showed anything abnormal.

The result of the examination was negative.

11.4.18 Tests on the ignition of gasoline vapors issuing from the vent outlets of Super Constellation plane L-1649-A, by means of static electrical discharges (streamer corona)

These tests, made in a specialized laboratory, disclosed that:

[1] On an L-1649-A plane static discharges should occur at the vent outlets if the aircraft is struck anywhere by lightning, or, if it is not struck, when it flies through clouds that are charged with electricity;

[2] Static discharges, generated at the vent outlets, can and do ignite the gasoline vapors issuing from the outlets;

[3] Static discharges can, and generally should, develop without leaving on typical aircraft metals, and therefore on the vent outlets, any normally visible evidence.

CHAPTER XII

GROUND INSTALLATIONS

They are not pertinent to the purposes of this inquiry.

CHAPTER XIII

COMMUNICATIONS

The communications exchanged between the plane and the Malpensa control tower and between the plane and Milan Regional Control were duly recorded by the respective control agencies. Also recorded was the Milan Regional Control's authorization pertaining to flight TWA 891, from Malpensa to Orly, which was telephoned to the Malpensa control tower.

These communications are reported in Annexes XIII 1, 2, and 3. The communications were made in proper phraseology over the proper channels and the authorization given by Milan Control is entirely in accordance with the rules in effect as published on the AIP-Italy. The recording of the communications between the plane and Regional Control Milan shows that the message which was being communicated at 4:24 p.m. is incomplete. (This was due to an interruption of the electric current caused by the storm, as shown by telegram 31/96/T-526/12 of June 26, 1959. (See Annex XIII-4).

By connecting that communication with the authorization received and the previous conversations with the Malpensa control tower, it is assumed that the aircraft's commander was reporting that he had reached the altitude of 4,000 feet and was proceeding toward Saronno.

From the communications exchanged between the plane and the control agencies, there is no evidence which might indicate any anxiety on the pilot's part as to the manner in which the flight was proceeding.

CHAPTER XIV

DISCUSSION OF THE CLUES

14.0 Explosion in fuel tanks Nos. 7 and 6

As shown by Annexes XI-5 - XI-7, central tank No. 7 is subdivided into two symmetrical parts by a central bulkhead having an ample opening through which the two sections communicate with each other. In the tight right bulkhead of tank No. 7, which separates this tank from tank No. 6, there are three holes. The fuel intake pipe (P.N. 478301) which runs through tank No. 6, connects hermetically the said three holes with the fuel intake port recessed below the top surface of the wing at a point where that top surface constitutes the ceiling of tank No. 6. Said fuel intake port is hermetically closed by cap P.N. 750438-13.

Into the left section of tank No. 7 are installed the following main accessories: submerged booster pumps and respective wiring, electric level-indicator (probe unit), vent valve, and 3-way selector cross-feed valve.

Into the right section of tank No. 7 are installed the following main accessories: electric level-indicator, vent valve, and 3-way selector cross-feed valve.

Therefore, unlike the other six tanks, which have only one vent valve each, tank No. 7 has two vent valves for the escape of gasoline vapors.

The two vents are symmetrical. Specifically, they begin at the right and left bulkheads of tank No. 7 and end at two vent outlets situated one on the trailing edge of the right wing and the other on the trailing edge of the left wing, behind engines No. 4 and No. 1, respectively. To these vent outlets are connected also the vent pipes of tanks Nos. 6, 3 and 4 (outlet to the right) and of tanks Nos. 5, 2 and 1 (outlet to the left). The outlets are not equipped with anti-flame wire gauze.

From what is said in par. 11.2.3.1 and taking into account the structural features, described above, of tanks Nos. 7 and 6, it is deduced that:

(a) An explosion took place in the right section of tank No. 7;

(b) The explosion caused the fuel intake pipe (P.N. 478301) of tank No. 7, which runs through tank No. 6, to split.

(c) The splitting of this fuel intake pipe (P.N. 478301) immediately caused an overpressure, or another explosion, in tank No. 6.

14.1 Nature of the explosion

The plane had taken off from the Malpensa airport with the following fuel supply:

Tanks 1, 2, 3 and 4 (capacity of each tank 1,343-1,386 gallons)	625 gallons each
Central tank No. 7 (total capacity 1,644 gallons)	22 gallons, excluding the non-usable residual quantity (11 gallons)
Tanks Nos. 5 and 6 (capacity 1,370 gallons each)	0 gallons each, excluding the non-usable residual quantity (5 gallons)

At the time of the crash the fuel-supply conditions had changed as follows:

Tanks Nos. 1, 2, 3 and 4	550 gallons each

Conditions in central tank No. 7 and tanks Nos. 5 and 6 had remained the same.

An inspection of the plane's refueling records showed that:

[1] The non-usable residual quantity of gasoline in tanks 5 and 6 had been in the tanks for about 10 hours;

[2] The residual quantity of gasoline (22 usable and 11 non-usable gallons) in tank No. 7 had been in the tank for about 30 hours;

[3] Under these conditions, tanks Nos. 5, 6 and 7, at the time of the crash, contained gasoline vapors issuing from the residual fuel;

[4] The igniting of those vapors in tank No. 7, whatever its cause, resulted in the explosion of tank No. 7, and that in turn "immediately" either produced an excess of pressure or another explosion in tank No. 6 (see par. 14.0, point c).

14.2 Characteristics of the crash

From the concurrence of all the inquiries made, it emerges that:

(1) Weather conditions in the area at the time of the crash were very unfavorable, with continuous electrical discharges and strong turbulence, as is confirmed also by the fact that the [bodies of the] passengers and the crew were found, in the wreckage of the fuselage, with their safety belts fastened;

(2) At 4:32 p.m. the plane was leaving Saronno NDB at an altitude of 10,000 ft., climbing in the direction of Biella NDB;

(3) At 4:32'40" p.m. the plane, en route toward Biella NDB at an altitude above 10,000 ft., was 12'20" flying time away from Biella NDB;

(4) At 4:33' p.m. the plane sent out its last radio signal to Milan Regional Control;

(5) At the time of the crash the plane, in all probability, was flying within the configuration and speed set forth in the operational procedure, on the prescribed route.

(6) In flight, at between 4:33' and 4:35' p.m. (see points 4 above and 8 below), an explosion occurred in tank No. 7, and this explosion spread to tank No. 6 (see par. 14.0, point c);

(7) No emergency call was sent out by the plane's crew;

(8) The main piece of the wreckage struck the ground at 4:35 p.m. at about seven kilometers from the point where the radio signal mentioned in point (4) had been sent out;

(9) The emergency conditions, which arose after the last radio contact mentioned in point (4), the disintegration of the plane in flight and its crashing to the ground took place within the space of about 2 minutes.

(10) No particular emergency measure appears to have been taken by the crew aboard the plane.

From the factual elements summed up above, it appears evident that the accident was of a sudden and violent nature and was due to unexpected conditions of abnormality which rapidly resulted in the explosion of tank No. 7, immediately followed by either an excess of pressure or another explosion in tank No. 6 (see par. 14.0, point c) and then by the plane's disintegrating in flight (see par. 14.4, points a and b).

14.3 Position and altitude at which the disintegration occurred

On the basis of various considerations, and taking into account also some of the testimony believed to be reliable, it has been estimated that the position where the disintegration of the plane took place must have been in the air space above the area bounded by the towns of Ravello, Rescaldina and Nizzolina (see Annex XI-1).

However, as to the altitude at which the disintegration of the plane took place, considering also the fact that the flight instruments, because of the condition in which they were found, did not supply any positive information (see par. 11.2.3.5), it has not been possible to arrive at any conclusive and definite results.

In particular, the study of the path of fall of some of the main wreckage parts which became separated from the plane in flight disclosed that their actual distribution on the ground was in agreement with that obtained from the calculations for three different combinations of speed and altitude (see par. 11.4.2).

Now, considering that:

[1] At 4:33 p.m., the time of the last radio signal (par. 14.2 point 4), the plane should have been, according to operational procedure, at an altitude slightly below 11,000 feet;

[2] the accident occurred suddenly and rapidly and was over in about two minutes (par. 14.2, point 9);

[3] the operational procedures, subsequent to the last radio signal (par. 14.2, point 4) give as most probable for the

plane a speed of about 170 knots I.A.S. along its flight path and a climbing speed of about 800-1,000 ft./m.

The afore-mentioned study of the path of fall shows that its results are not completely in conflict with a possible disintegration of the aircraft at a height of 11,000 - 12,000 feet and a speed of about 170 knots I.A.S.

However, as it has already been pointed out, other combinations of speed and height are just as possible (see par. 11.4.2).

14.4 Hypotheses regarding the causes of the explosion

The possible causes of the igniting of the gasoline vapors in tank No. 7 and consequently of the exploding of tanks No. 7 and 6 in the manner described in par. 14.0, points a, b and c, may be classified into two main groups, namely:

(a) Structural failure due to aerodynamic stresses of any kind (turbulence, excessive maneuver loads, etc.), ensuing explosion of the fuel tanks and, finally, disintegration of the aircraft;

(b) Explosion of the fuel tanks, caused directly or indirectly by:

(1) faulty operation and fire in the engines; (a) fires of a different nature; (3) breakdowns and malfunctioning of the flight instruments and controls in general; (4) foreign bodies of any kind striking the aircraft; (5) sabotage; (6) electric discharges from the atmosphere, and consequent disintegration of the aircraft.

These hypotheses are discussed below.

14.4.1 Structural failures due to stresses, ensuing explosion in the fuel tanks and final disintegration of the aircraft

On the strength of the technical data mentioned in par. 11.3.6, a study was made of the various conditions which might substantiate the hypothesis of structural failure as the primary cause of the crash. The inquiry was limited to the wing because, as gathered from par. 11.2.3.4, the breaking away of the wing preceded all other breakages that took place as the plane crashed to the ground.

The considerations and deductions set forth hereunder are valid only if we assume that, at the beginning of its last flight, the aircraft was in a normal condition as regards care and maintenance and that, in the course of previous operations, it had not been subjected to stresses or deterioration of such a nature as to constitute a substantial impairment of its sturdiness and structural soundness. Actually, the information assembled in this connection and the examination of the wreckage attest to the fact that, at the beginning of its last

flight, the plane was in normal condition as regards care and maintenance and structural soundness.

14.4.1.1 Breakdown because of metal fatigue

The possibility of a collapse of the wing structure as the result of [metal] fatigue appears unlikely for the following reasons:

(a) No evidence of breakage from this cause was found in the wreckage;

(b) The resistance of the main structures to fatigue is positively evidenced by the results of the specific laboratory tests made in due time by the Lockheed Co., and by the results of the practical use of the L.1649-A planes. In fact, of the 29 planes of this type in service on TWA routes, 19 have had a total number of flight hours greater (by as much as 1,000 hours in some cases) than those flown by plane N. 7313-C, without showing any signs of fatigue.

(c) The wing structure meets the well-known Fail Safe (C.A.R. 4 b-270) requirements; therefore, even in the case of breakdown of a structural element, no collapse of the entire wing structure should have occurred.

14.4.1.2 Breakdown as the result of excessive maneuver stress or of gust

Under the conditions of weight and position of the plane's center [of gravity] at the time of the accident and in the presumed climbing trim, with the speed of 170 knots or less indicated on the flight path, neither intentional maneuver nor positive, or negative, gust of any intensity could have caused the breakdown of the wing because, before the forces necessary to cause the collapse of the structure had appeared, the wing would have gone into a stall.

At speeds higher than that indicated above, that is, in case the plane had gone into faster flight trims than its climbing trim, the wing could not have broken away except under one of the following conditions:

(a) Maneuver: Exceeding the positive load factor 4.5 g. This condition appears to be unlikely, because the coefficient 4.5 is very high (180% of the prescribed maneuver limit factor) and to reach it would have required a sharp maneuver at a very high speed, such as after a prolonged dive, which does not seem likely to have happened in view of the suddenness of the accident, but above all, because the breaking of the wing should have occurred in the outer part between station 525 and the wing tip and not in the inner part, as actually happened.

(b) Gust: At the typical design cruising speed V_c and design speed for maximum gust intensity V_b, that is to say at the plane's speed of 261 and 326 knots (EAS), the wing was capable of standing, without breaking, vertical gust speeds not in excess, respectively, of 100 ft. per second (30.5 m/sec.) and 75 ft. per second (22.7 m/sec.).

These figures are very high and give a convincing demonstration of the structure's margin of safety with respect to stresses due to gusts, even if the calculations concerning this inquiry were developed exclusively from the static aspect, without taking into consideration the dynamic effect of the gusts.

However, a further investigation for the evaluation of the dynamic effect of gusts on the wing of the model 1649-A plane disclosed that the increase factor of the bending moment on the wing, due to said dynamic effect, is not very great, ranging as it does between 1.06 and 1.2, and that in any case it is no greater than that calculated for the previous models 749 and 1049-C, both of which have been tested extensively. In as much as it is shown by the foregoing that the breakdown of the wing by overstress from gust requires the concomitance of high flight speeds (not admissible in a highly turbulent atmosphere) and gusts of extreme intensity, and in as much as in this case also the breaking of the wing should have occurred, in all probability, in the outer part of the wing as explained above, the hypothesis of the breaking of the wing by stress from gusts is believed to be wholly improbable.

14.4.1.3 Breakdown from excessive diving speed

This condition has been considered in the event - which cannot be excluded a priori - that the plane, having gone out of control in rough air, exceeded its design diving speed V_D = 326 knots EAS.

(a) Static overload - Under this condition, the structure that undergoes the greatest stress is not the wing but the fuselage (on the rear area) because of the depressive force exerted on the horizontal tail surface (downward flexion). Actually, the breaking up of the fuselage and separation of the complete tail assembly occurred in flight; however, as the examination of the wreckage disclosed, the separation occurred after and not before the wing broke away (see par. 11.2.3.4). Proof of this is the consideration that, had the tail assembly become separated before, the plane would have dived abruptly, with the result that the wing would have broken off by inverse flexion, which did not happen.

(b) Dynamic overload

1. Wing flutter

The data mentioned in par. 11.3.6 show that the wing is free from self-induced vibration up to the speed of 1. 2 V_D (391 knots) and under any condition of fuel load.

Since the worst condition exists when the wing has a fuel load of 7,650 gallons, it follows that with the fuel load the plane was carrying at the time of the accident (2,200 gallons) the possibility of flutter was very remote. Besides, the flutter would have caused the maximum bending stresses in the area of the nacelles of the outer engine and the maximum torsion stresses in the area between the outer and inner nacelles. Examination of the structural parts recovered revealed no breakage from stresses of this type. Lastly, it is to be considered that self-induced flutter vibrations would very likely have caused the lead masses fitted on the leading edges of both wing tips to break away during flight. Instead, they were recovered very close to their respective wing portions. All this shows that wing flutter could not have been a determining cause of the accident.

2. Tail flutter

As in the case of the wing, the absence of flutter up to the speed of 1, 2 V_D = 391 knots EAS was ascertained also with respect to the tail assembly. Furthermore, the traces of smoke and fire on the tail assembly show that the separation of the tail took place after the events which caused the accident (see par. 11.2.3.4)

Therefore, as in the case of the wing, tail flutter cannot be considered a primary cause of the accident.

14.4.1.4 Breakdown from excessive rolling or excessive yawing

A violent rolling maneuver, or an excessive rolling speed, would have caused signs of torsion on the wing covering in the area of the outer nacelles - which signs were not found - or aileron breakages of a type different from those observed when the wreckage was examined. With respect to yawing maneuvers, the most critical structures are the back portion of the fuselage and the vertical tail surface. Actually, there is evidence that the plane was yawing at a high angle of drift, with strong side stresses, but the traces of fire on the tail assembly and the symmetrical nature of the breakage on the tail indicate a breakdown from excess of unsymmetrical loads while yawing as the primary cause of the accident.

Conclusion:

On the basis of the premise stated above, namely, that before the crash the plane was in normal condition as regards care

and structural soundness. No condition of overstress from maneuvering, gust, excessive speed, flutter, etc., can explain the type of breakage the aircraft was found to have suffered.

14.4.2 Explosion of the tanks and subsequent disintegration of the plane

14.4.2.1 Explosion set off by malfunctioning of, or fire in, the engines

The technical inquiries made into the power plants, dealt with in par. 11.2.2.2, exclude the possibility that the engines may have broken down or been on fire prior to the explosion in tanks Nos. 7 and 6 and, therefore, may have been the determining cause of the explosion.

Specifically, this is confirmed by the fact that:

[1] Neither the flow of air cooling the generators nor the flow of gasoline and oil to the four engines was interrupted (see par. 11.2.3.5);

[2] The fire extinguishers of the four engines were not turned on (see par. 11,2.3.5);

[3] None of the propellers was feathered (see par. 11.2.2.2).

14.4.2.2 Explosion set off by other fires

The possibility cannot be excluded, with absolute certainty, that, prior to the explosion, a fire may have broken out on the plane in flight and set off the explosion; however, such a possibility appears to be remote and wholly improbable.

In fact, the damage caused to the wreckage of the plane by the fire, however it occurred as a consequence of the explosion, would hardly be such as to prevent recognition of any evidence of fire occurring during normal flight, in as much as, because of the suddenness with which the entire accident took place (see par. 14.2, point 9), a fire of that sort would have left very characteristic, and therefore easily identifiable, marks. Yet a careful examination of all the wreckage failed to disclose any concrete and significant evidence in support of such an eventuality.

14.4.2.3 Breakdown and malfunctioning of the flight instruments and controls in general

As stated in par. 11.2.3.5, a careful examination of the plane's installations, equipment and controls failed to disclose any physical evidence of breakdowns or abnormalities, as the direct or indirect cause of the explosion of the tanks, which were not attributable to the consequences of the explosion itself (disintegration of the plane, fire, impact with the ground, salvage operations).

In particular, no evidence of electrical discharges was found in the interior of tanks Nos. 7 and 6 (see par. 11.2.3.1).

As to the upper plate of cap P.N. 750438-13 (see par. 11.1, point 1), found at the beginning of the path of fall of the wreckage, in view of the tests made in the U.S.A. (mentioned in pars. 11.4.3 and 11.4.8) the following hypotheses may be considered:

(a) The cap, to which said plate belonged, was removed, at the crash site, from the wing panel to which it was attached (see par. 14.0) by some unauthorized person who, after having disassembled the cap into its component parts, kept one or more of them and threw away the others, including the plate.

This hypothesis, although wholly plausible, is subject to doubt in view of the following considerations:

[1] The plate was found at a distance from the wing panel in the middle of a field about 100 meters away from the nearest road;

[2] In spite of diligent searching, not one of the remaining parts of the cap was found in said field and immediate vicinity;

[3] The place where the plate was found is exactly at the beginning of the path of fall of the wreckage, where it probably would have fallen if, for any reason whatever, it had become detached from its cap and from the wing as a consequence of the explosion, or just before it (see hypotheses on the following points b and c).

(b) The cap became detached from the wing and then broke up into its component parts as a consequence of the explosion.

Considering the results of the tests mentioned in pars. 11.4.3 and 11.4.8, this might be explained, for instance, as the result of some hidden fault in the thread of the central stem onto which the check nut is screwed.

In fact, if the central stem should break off in that area, the cap would automatically separate into its component parts. In as much as the link chain of the cap was not found in its place on the wing panel, it must either have become detached as a consequence of the explosion or it was removed by unauthorized persons who detached it from the panel.

Against this hypothesis is the fact that the P.N. 750438-13 caps are subject to periodical inspection and tests.

(c) Hidden fault, etc., as mentioned in point (b), with the variation that the final breaking of the thread of the central stem occurred immediately before the explosion as a consequence of the pre-stress exercised by the check nut, the repeated opening and closing of the cap for refueling, etc. - that is to say, in the course of the practical use of the P.N. 750438-13 cap.

Of the three hypotheses mentioned above, the one in point c), regarding the loss in flight of one of the fuel tank caps, is manifestly by far the least probable. Specifically, there is no record that loss in flight of P.N. 750438-13 caps has ever occurred in the past (see par. 11.4.11). However, since such a hypothesis is the only one of the three which is pertinent in so far as the search for the causes of the explosion of tank No. 7 is concerned, it has nevertheless been taken into consideration, in relation to the contents of par. 14.2.5.6.

14.4.2.4 Explosition set off by bodies striking the plane's outer surface, whether such bodies were extraneous to the plane or were parts of the plane which had become detached from it.

The wreckage of the plane showed no trace of such an eventuality; in particular, all the propellers were found on the ground, together with the engines they belonged with (see par. 11.2.2.2).

14.4.2.5 Explosion set off by explosive devices as the result of sabotage

A meticulous examination of the various pieces of wreckage and the results of additional inquiries failed to disclose any evidence of such a possibility.

The presence of the roll of paper mentioned in par. 11.3.5 in a field together with other pieces of wreckage, in view of

[1] The results of the investigations mentioned in pars. 11.3.5 and 11.4.14;

[2] The fact that, after the loss of the right wing and the tail assembly, the fuselage was still a closed body;

[3] The fact that the plane's cargo was found among the main piece of the wreckage (fuselage-left wing),

has been considered fortuitous; at any rate, even if the roll of paper had been on board the plane, the chemical analyses mentioned in pars. 11.3.5 and 11.4.15 exclude the possibility of its having characteristics such as would set off explosions or start fires.

14.4.2.6 Explosions set off by atmospheric electric discharges

In as much as

[1] The examination of the structural parts of tanks Nos. 7 and 6 disclosed no evidence of internal electrical discharges within said tanks (see par. 11.2.3.1);

[2] Tank No. 7 has two vent outlets (see par. 14.0);

[3] The two vents were not equipped with anti-flame screens (see par. 14.0 and Annex XIV-1);

[4] No physical evidence of lightning strikes was found on the two vent outlets (see pars. 11.3.3 and 11.4.16),

a study was made of the possibility that the explosion might have been set off by ignition of the gasoline vapors issuing from the vent outlets, caused by discharges of static electricity (streamer corona). In fact, discharges of this type would leave no visible traces on the outlets (see par. 11.4.18).

This possibility assumes the coexistence of the following three conditions:

(a) That the gasoline vapors contained in tank No. 7 formed with the air a mixture that came within the ignition limits;

(b) That the flammable vapors issuing from the vent outlets could be ignited by an electric discharge;

(c) That after the vapors had been ignited at the vent outlets, the flames could spread to tank No. 7 through the vent pipes.

For each of the three conditions mentioned above, the following observations are made.

(a') Taking into account what emerges indirectly from the six hypotheses set forth above, the fact that there was an explosion of the vapors contained in tank No. 7 would in itself indicate that the vapors were capable of being ignited. This may be ascribed to

[1] An aging process of the gasoline residue contained in tank No. 7 (see par. 14.1 and Annex XIV-1), or

[2] A penetration of air in tank No. 7 through one of the two vent outlets, the conditions for such a circumstance having, in some way, been produced by the existence of the two outlets (see par. 14.0), or

[3] By the possible loss, in flight, of the P.N. 750438-13 cap, taken possibly as a circumstance in conjunction with the two preceding ones (see par. 14.4.2.3, hypothesis c).

(b') As mentioned in pars. 11.4.4 and 11.4.18, the possibility that electrical discharges might ignite flammable gasoline vapors issuing from the vent outlets has already been studied in the United States, with positive results.

The tests mentioned in par. 11.4.4, were made in the tunnel, as follows:

On only one of the original outlets, placed on the trailing edge of an airfoil, from whose four outlet pipes (see par. 14.0) issued vapors containing a mixture that was within the limits of flammability in the case of tanks Nos. 7 and 6, and not within those limits in the case of tanks 3-4;

at a pressure corresponding to an altitude of 1,700 ft.;

at an air flow speed of 170 knots I.A.S.;

for an outgoing speed of the vapors, for each individual outlet pipes, corresponding to climbing speeds of 900, 600 and zero feet per minute.

They disclosed that in the presence of electrical discharges, said vapors become ignited only if the plane is climbing, and that the flames will not spread to the interior of the tanks.

The tests mentioned in par. 11.4.18, conducted on the premises of a specialized institution, showed, specifically, that the weather conditions existing at the time of the crash were most appropriate for creating, on the vent outlets, electrical discharges fully capable of igniting flammable gasoline vapors.

(c') With regard to the possibility that, once the gasoline vapors had ignited at the vent outlets, the fire may have spread to tank No. 7 through the pipes, it is observed that the tunnel tests (see preceding point b'), during which such spreading did not take place:

[1] Did not reproduce the real vent outlet system of tank No. 7 (existence of two outlet pipes and, therefore, two vent outlets;

[2] Did not bring about the true conditions in which the plane must have found itself at the time of the accident

In particular, the tests did not take into account the effects generated by the turbulence, by sudden variations in flight trim, etc.; such conditions, in

concurrence with the existence of two vent outlets in tank No. 7, may have made it possible for the flames to spread to the interior of tank No. 7, causing it to explode.

Similarly, in said tests no consideration was given to the possibility, however improbable it might be, of the loss in flight of cap P.N. 750438-13 (see par. 14.4.2.3, hypothesis c), supposedly belonging to tank No. 7 (see par. 11, point 1), cap located on the upper surface of the wing. This circumstance, whether or not in concurrence with other factors (see preceding par.), may in fact, have caused the fire to spread to tank No. 7.

Lastly, the fact that the inspection of the inner surfaces of some sections of the outlet pipes taken from the wrecked plane showed no traces of the passage of flames (see par. 11.4.5), does not appear to be sufficient proof that such a circumstance did not actually take place. In fact, if flames had actually passed through the outlet pipes, their speed would have been too great to leave any traces on the inner walls of the pipes.

The likelihood of the hypothesis contemplated in this par. 11.4.2.6 requires the assumption that in the past, in spite of the continuous operation of the Super Constellation 1649-A planes, none of the aircraft of this type was ever involved in that set of circumstances and conditions which, having occurred in the case of plane N. 7313-C, caused its destruction.

Such an assumption, although only a possibility, must be regarded as a matter for consideration. In fact, no Super Constellation planes of the 1649-A model were, at least up to some time after the crash of the plane N.7313-C (see annex XIV-1), equipped with an anti-flame screen at the vent outlets and, at least on short or medium-length flights, they flew with tanks 5-6-7 empty.

Therefore, also because of the considerations mentioned above, the hypothesis in question, although based on some factual elements, can be proved only by a suitable series of tests on the ground and in flight.

This much having been said, it can be pointed out that the said hypothesis appears to be, indirectly, in agreement with almost all the statements made by the witnesses, regardless of the relative value at which such statements are taken; in fact, in these statements the crash of the plane is closely associated with a lightning strike, with the following succession of events:

(1) lightning strike (and, therefore, subsequent formation of static electricity discharges, see par. 11.4.18);

(2) sound of the explosion, or explosions;

(3) fall of the plane's burning wreckage.

C O N C L U S I O N

Of the seven hypotheses mentioned in par. 14.4 and discussed in pars.

14.4.1
14.4.2.1
14.4.2.2
14.4.2.3
14.4.2.4
14.4.2.5
14.4.2.6

the Commission, in the absence of further significant and concrete evidence, points to the hypothesis dealt with in par. 14.4.2.6, namely:

> Explosion set off by static electricity discharges (streamer corona) as the probable cause of the accident.

CHAPTER XV

RECONSTRUCTION OF THE FLIGHT UP TO THE MOMENT OF THE CRASH

TWA Flight No. 891/26 began at Athens (Greece) at 10:15 a.m. on June 26, 1959 by Lockheed 1649-A plane No. 8083-H, stopping at Rome at 12:15 p.m.

At Rome there was a change of plane and the flight was resumed on the Lockheed 1649-A plane No. 7313-C.

Capt. Jack Davis, who boarded the plane at Roma, was not on duty during the flight but was returning to Chicago for his rest turn.

The plane left Rome at 2:00 p.m. and reached Milan at 3:36 p.m. after a normal flight.

At the Malpensa Airport Capt. Grade went, accompanied by the TWA representative, Mr. G. Moreo, to the Weather Station and the Operations Office for the clearing operations pertaining to the Malpensa-Paris flight. At the Weather Station the information on weather conditions was given to Capt. Grade by the technician on duty, Lt. Vincenzo Vacirca.

On the chart (see Annex XV-2), the history of the flight from the Malpensa Airport up to the time of the crash was reconstructed on the basis

of the flight plan (see Annex XV-1), the exchange of messages between the plane and the Malpensa tower and between the plane and Milan Control (see Chapter XIII and annexes relating thereto), and on the basis of the distribution of the wreckage on the ground (see Annexes XI-1 and XI-1 bis) and the testimony (see Chapter IX and annexes relating thereto).

The plane's positions, with the time of each, were as follows:

Positions	Time	(See Annex XV-2)
(1)	4:05	The plane asks the Malpensa Tower for authorization to start the engines. Authorization is given.
	4:09	The plane asks for authorization to taxi. Authorization is given: runway 35L - QNH = 10 14.3 Mb.
(2)	4:16	The plane communicates that it is ready for the take-off. It is authorized to get in line.
	4:17	Malpensa Tower gives the plane the clearance from Milan Control: "Malpensa-Paris, via NDB Saronno and Biella. Above Saronno at 4,000 ft. Climb to 10,000 ft. or more above Saronno following the waiting circuit. Approach Biella at 18,500 ft. and mountain that altitude."
	4:19	The plane repeats - Malpensa Tower specifies: "approach Saronno at 4,000 ft. and no higher." The plane confirms. Malpensa Tower authorizes the take-off - turn to right - wing calm.
	4:20	The plane takes off.
(3)	4:21	Malpensa Tower communicates: "Take-off at 20' - report on reaching 4,000 ft. and Saronno." The plane confirms.
(4)	4:23	Malpensa Tower asks the plane to report its altitude. The plane communicates that is is 2,300 ft. Malpensa Tower: "Contact Milan Control on 125.3 Mc/s." The plane confirms.
	4:24	Contact is established between the plane and Milan Control (Linate), but the communication is uncertain because the electricity is off at the Milan Control station.
(5)	4:26	The plane communicate that it is on the Saronno circuit at 6,000 ft.

Milan Control: "Roger, report on leaving Saronno."

The plane confirms.

(6) 4:32 The plane reports to Milan Control that at 32' is leaving Saronno at 10,000 ft. and is proceeding toward Biella.

Milan Control: "Roger, report on reaching 18,500 ft. and estimated time for Biella."

4:32 1/2 The plane replies: "Wait one moment - I estimate Biella at 45' - 45'."

4:33 The plane: "Roger...Roger."

4:35 On the basis of the statements made by the witnesses and the time shown by the watches of the victims, the plane crashed to the ground at about 4:35 p.m.

Point (7) indicates the position of the plane at the time when the right wing presumably broke off, at an altitude below 11,000 ft.

Point (8) indicates the position on the ground of the main piece of wreckage: fuselage with the left wing and engine No. 2.

4:45 Milan Control attempts to communicate with the plane, repeating its call letters without success. The First Officer of a SABENA Airline DC-6B plane, which at that time had taken off and was over Mt. Ceneri at 16,000 ft., joined in the call, twice.

CHAPTER XVI

C A U S E S

The breaking up in flight of Super Constellation plane type 1649-A, No. 7313-C, at the points described in Chapter XI, was due to the explosion of the fuel vapors contained in tank No. 7, followed immediately by either an excess of pressure or a further explosion in tank No. 6.

In the absence of other significant and concrete evidence, taking into account the stormy weather conditions, with frequent electric discharges, existing in the area at the time of the crash, it may be assumed that the explosion of the fuel vapors contained in tank No. 7 was set off, through the outlet pipes, by the igniting of the gasoline vapors issuing from these pipes as a consequence of static electricity discharges (streamer corona) which developed on the vent outlets.

The Board feels that the hypothesis mentioned above presents the highest degree of plausibility as compared with all the others taken under examination.

CHAPTER XVII

R E C O M M E N D A T I O N S

1. In view of the hypothesis advanced, it is recommended that the manufacturers and organizations concerned undertake a program of research and tests intended to give deeper insight into the phenomena relating to the possibility of fuel-tank explosions caused by electrical discharges.

2. It is suggested that pilots be instructed to avoid, whenever possible, crossing meteorological areas where [flying] conditions are particularly dangerous.

THE BOARD

Maj. Dino GONZADI [signature missing]
Domenico CASTAGNA, Engineer [signature]
Adelio ZANASI, Engineer [signature]
Lt. Col. Mauro BOCCASSINI, C.S.A. [signature]
Lt. Col. Enrico MIGLIO, G.A.r.i [signature]
Lt. Col. Stefano CASTELLANI, Air Force [signature]
Lt. Col. Pietro ANDREOTTI, Air Force [signature]
Col. Paris PERNAZZA, Air Force [signature]

[signature]

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