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National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: MAY 28 1992

In reply refer to: A-92-45 through -48

Honorable Barry L. Harris
Acting Administrator
Federal Aviation Administration
Washington, D.C. 20591

Since 1989, six accidents have occurred in which vital flight recorder information from cockpit voice recorders (CVR) and flight data recorders (FDR) was lost as a result of the thermal destruction of the magnetic tape recording media. Summaries of the accidents follow:

In March 1989, a Fokker F-28 crashed in a forest near Dryden, Ontario, Canada, shortly after takeoff. The aircraft burned for about 2 hours. The temperature of the fire, which consumed most of the aircraft, was estimated at 850° C. The magnetic tape recording media from the CVR and FDR were both destroyed by the postimpact fire.

In November 1989, a Boeing 727, operated by Avianca, was destroyed by a bomb shortly after takeoff from Bogota, Colombia. The CVR was recovered from outside the area of a localized fire and showed no evidence of heat damage. The magnetic tape recording medium from the FDR, however, was destroyed by the postimpact fire.

In May 1991, a Boeing 767, operated by Lauda Air, crashed near Suphan-Buri, Thailand. The airplane suddenly entered a rapid descent as it was climbing through 24,800 feet and impacted the ground about 30 seconds later. All 223 persons onboard were killed.

At the request of the Accident Investigation Commission of Thailand, the Safety Board attempted to read out the CVR and the FDR. Although the CVR sustained both impact and fire damage, data could be read and provided vital information regarding the uncommanded deployment of the left thrust reverser precipitating the sudden descent. The FDR, however, could not be read out because the magnetic tape recording medium was destroyed by the postimpact fire.

In December 1991, a Boeing 747, operated by China Airlines, crashed shortly after taking off from Taipei, Taiwan. The fire/crash protective enclosure of the FDR was breached by impact forces, and the magnetic tape recording medium was destroyed by the postimpact fire. The protective enclosure of the CVR was destroyed by impact and fire; however, its magnetic tape recording medium was undamaged.

On January 2, 1992, a Beech 1900, operated by CommuterAir, crashed on approach to the airport in Adirondack, New York. One passenger and one crewmember were killed as a result of the crash. The postimpact fire, which witnesses reported burned for about 2 hours, was sustained by fuel leaking from a ruptured fuel tank and forest products trapped under the wreckage. The CVR, the only onboard recorder, was destroyed by the postimpact fire. The airplane was not equipped, nor was it required to be equipped, with an FDR.

On January 20, 1992, an Air Intere Airbus A320 crashed on approach to the airport in Strasbourg, France. The postimpact fire, sustained by aircraft fuel and forest products, burned for 6 hours 20 minutes. Although the CVR was extensively damaged by the postimpact fire, its data were readable. The magnetic tape recording medium of the FDR, however, was destroyed by the fire.

The six accidents summarized above involved just 10 of the 90 flight recorders known to have sustained thermal damage by postimpact fires since 1966.[1] Although all 90 recorders were destroyed, the magnetic tape recording medium was undamaged in 48 of the recorders, damaged in 17 of the recorders, and destroyed in 25 of the recorders (see enclosure 1). The extent of damage to the 17 damaged tapes ranged from reduced fidelity to the total loss of portions of the most recently recorded data.

The seven flight recorder media destroyed by postimpact fire in the six recent accidents described above prompts concern about the adequacy of the performance standards for flight recorders. Minimum performance standards for impact and fire protection are outlined in four Technical Standard Orders (TSO): TSO C84 and TSO C123 address CVRs, and TSO C51a and TSO C124 address FDRs. TSO C51a and TSO C84 have essentially the same fire protection requirements; the fire test protocol requirements outlined in these TSOs are less stringent than the requirements outlined in the recently issued TSOs C123 and C124.[2] (The impact and fire protection requirements for the four TSOs and the dates the TSOs were issued are summarized in enclosure 2.) Further, the fire test protocol in TSOs C51a and C84 is so vague that a recorder could be subjected to temperatures much lower than 1,100° C and still pass the test. The FAA recognized this deficiency in its 1970 report, "Fire Test Criteria for Recorders." The report states:

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[1] The survival history of flight recorders was compiled from records of the following investigative authorities: the National Research Council and the Transportation Safety Board (Canada); the Bureau Enquete-Accidents (France); the Aviation Accident Investigation Board (United Kingdom); and the Civil Aeronautics Board and the National Transportation Safety Board (United States).

[2] Although the more recent TSOs C123 and C124 have been issued, TSOs C51a and C84 remain in effect because the FAA has not canceled them.

> This requirement [TSO C51a/C84] specifies the temperature but not the source or the BTU rate of the flame. The temperature at the recorder flame impingement area must be 1,100° C (2,012° F). Thus, a recorder could meet the TSO requirements by passing a test in which the recorder is exposed to low heat out-put flames producing a temperature of 1,100° C at a point a few inches in front of the recorder while the temperature at the recorder case could be much less than 1,100° C.

The temperature and duration of the fire tests required by TSOs C51a, C84, C123, and C124 are the same. However, only the more exacting test protocol prescribed by TSO C124 is likely to determine if a recorder will actually survive a high intensity, short duration fire.

The A100 CVR and F800 FDR manufactured by Loral Fairchild are the only recorders with an accident history that have been subjected to the fire test requirements of TSO C124, issued on February 21, 1992.[3] The remaining magnetic tape flight recorders with an accident history have met the less stringent fire test requirements of TSO C51a and TSO C84. A comparison of the fire survival history of the Loral Fairchild recorders with the collective history of recorders that meet only the less stringent requirements of TSO C51a or C84 provides some measure of the relative effectiveness of the different fire protection requirements.

Of the 90 worldwide flight recorders known to have sustained thermal damage by postimpact fires since 1966, 45 (50 percent) involved the A100 and F800 recorders qualified under TSO C124, and the remaining 45 involved all other recorders. When exposed to a postimpact fire, the magnetic tape recording medium from 4 (9 percent) of the 45 recorders qualified under TSO C124 were thermally destroyed, whereas the magnetic tapes from 21 (47 percent) of the 45 recorders qualified under TSO C51a or C84 were thermally destroyed. Moreover, the tape recording media in only 9 (20 percent) of the 45 recorders qualified under TSO C124 were damaged or destroyed, whereas the tape recording media in 33 (73 percent) of the 45 recorders qualified under TSO C51a or C84 were damaged or destroyed. (Enclosure 3 contains a listing of accidents in which the magnetic tape recording media were damaged or destroyed by postimpact fire.)

The fire survival history of flight recorders clearly indicates, in the Safety Board's view, the vulnerability of recorders qualified under TSO C51a and C84 to postimpact fires. The 47-percent loss of recording media in

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[3] Although the Loral Fairchild recorders were approved for service under TSOs C84 and C51a, the manufacturer voluntarily tested the A100 CVR to the fire test requirements of TSO C124. This test was conducted to demonstrate the feasibility of the then proposed fire test requirements. In conversations with Safety Board staff, the manufacturer has indicated that if the A100 CVR passed the test requirements of TSO C124, the F800 FDR would also pass the test requirements because the enclosure, transport, and media of the two recorders are the same.

recorders exposed to postimpact fires is unacceptable. The Safety Board believes, therefore, that existing recorders that were qualified under TSOs C51a and C84 should be phased out and that the production of new recorders and spare parts qualified under TSO C51a and C84 should be suspended immediately, including two new TSO C84 CVR designs that the FAA approved just prior to issuing TSO C123. Attrition will gradually result in the elimination of those models that are not upgraded to the new TSO requirements, as the inventories of spare parts are eliminated.

The FAA's approval of the two new TSO C84 CVR designs causes additional concern to the Safety Board. By granting TSO C84 approval for new CVRs, the FAA has permitted the continued introduction of new recorders that are required to withstand only a 100 "G" impact. Most CVR manufacturers, aware of the poor survival history of early FDRs built to the 100 "G" impact requirement of TSO C51, voluntarily began building their recorders to the 1,000 "G" impact requirement of TSO C51a rather than the 100 "G" impact requirement of TSO C84. The FAA recognized the inadequacy of the 100 "G" impact requirement in TSO C51, increased the requirement to 1,000 "G", and reissued the TSO as C51a in 1966 (see enclosure 2). However, even though the impact requirement in TSO C84 was known to be similarly inadequate, the impact requirement in TSO C84 was never changed. Repeal of TSO C84 would eliminate the possibility that manufacturers could produce CVRs that comply with only the 100 "G" requirement.

A crash protective enclosure built to the 100 "G" requirement of TSO C84 could be breached during a severe impact. Further, a breached protective enclosure would probably not provide even the limited fire protection required by TSO C84 or C51a.

In addition, one of the two CVRs recently approved under TSO C84 uses a solid state recording medium rather than tape. The inflexibility of solid-state chips, as compared to tape (or even the earlier metal foil recording medium), makes them more susceptible to impact forces. If the more flexible media that were used in recorders approved under the 100 "G" impact requirement could be destroyed by impact forces, solid-state memory chips used in CVRs that only meet the 100 "G" impact requirement would most likely be destroyed by similar impact forces. All domestic flight recorder manufacturers have introduced, or will soon introduce, solid-state flight recorders. The Safety Board believes that this is another reason that TSO C51a and TSO C84 should be canceled immediately.

Despite the superiority of TSO C124 (and TSO C123) to TSO C51a (and TSO C84), the recent loss of data from thermal damage of the two recorders that met the fire protection requirement of TSO C124 raises questions about the adequacy of the fire test requirement in TSO C124. In nearly all the accidents in which the recording media were destroyed or damaged by fire, the fires have been of relatively low temperature (from 250^{0} C to 850^{0} C) for an extended duration (2 to 46 hours). The test requirements in TSO C124 address only the short-term, high intensity fire.

In a report published in 1972, "Evaluation of Insulation for Crash Fire Protection of New Flight Recorders," the FAA recognized the need for test

conditions that would require an extended period of thermal exposure at reduced temperatures to replicate postimpact fires. Despite this recognition, no action was initiated by the FAA to improve the fire test requirements in the two decades since the FAA last addressed the issue. Even when the TSO C123 and TSO C124 test requirements were adopted from the European Organization for Civil Aviation Equipment documents ED-56 and ED-55,[4] respectively, the FAA did not address the concern it expressed two decades earlier about long-term, low intensity fires.

The introduction of solid-state flight recorders, coupled with the recent loss of two recorders that met the fire protection test requirements of TSO C124, clearly indicates the need for a reevaluation of flight recorder fire test requirements. The Safety Board believes that the FAA should conduct a study, based on accident case histories, to determine a realistic thermal profile and test protocol for flight recorder fire test requirements that reflect the actual environment of postimpact fires.

The Safety Board is aware of at least four manufacturers that are prepared to seek TSO approval for new solid-state flight recorders. The industry cannot wait for such approval until the FAA conducts a study to determine new fire test criteria, and then issues revised versions of TSOs C123 and C124. Although the Safety Board urges the FAA to expedite action on this issue, experience suggests that it could be years before new standards are issued. Therefore, it is likely that some existing and new designs approved under TSO C123 or C124 would not pass the revised standards that consider prolonged exposure to low intensity fires.

Unless the original version of TSOs C123 and C124 are canceled when revised versions are issued, TSO C123 and C124 recorders could continue to be manufactured and installed. The Safety Board believes, therefore, that within 1 year after issuing the revised TSOs, the FAA should cancel the original TSOs C123 and C124.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

Cancel TSOs C84 and C51a within 1 year. (Class I, Urgent Action) (A-92-45)

Conduct a study, based on accident case histories, to determine a realistic thermal profile and test protocol for improved flight recorder fire test requirements that reflect the actual environment of postimpact fires. (Class II, Priority Action) (A-92-46)

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[4] The European Organization for Civil Aviation equipment issued ED-56 "Minimum Operational Performance Requirements for CVR Systems," in February 1988, and ED-55 "Minimum Operational Performance Specifications for Flight Data Recorder Systems," in May 1990. Safety Board and FAA staff participated in the development of the flight data recorder specifications.

Issue revised versions of TSOs C123 and C124 to reflect the improved fire test requirements outlined in Safety Recommendation A-92-46. (Class II, Priority Action) (A-92-47)

Cancel original TSO C123 and C124 within 1 year after issuing the revised versions outlined in Safety Recommendation A-92-47. (Class II, Priority Action) (A-92-48)

Acting Chairman COUGHLIN, and Members LAUBER, HART, HAMMERSCHMIDT, and KOLSTAD concurred in these recommendations.

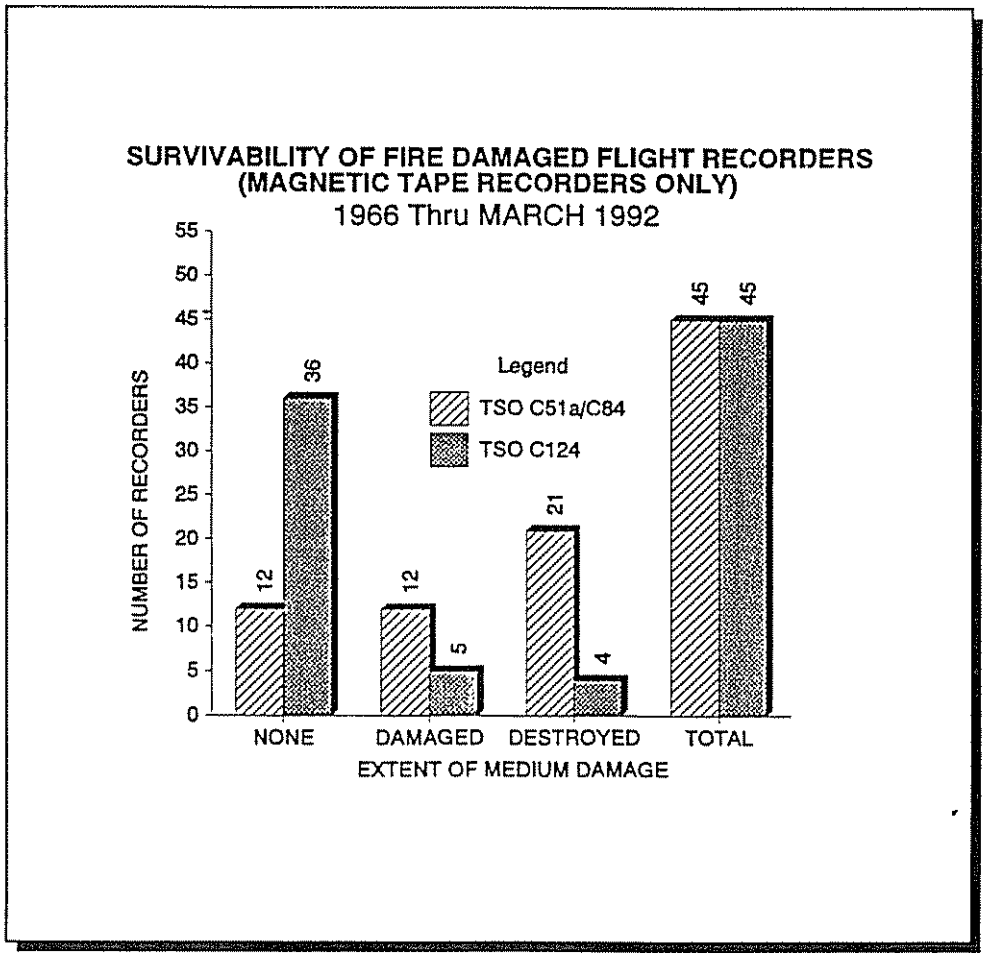
By: Susan M. Coughlin
Acting Chairman

Enclosure (3)
1. Data on thermal damage
2. TSO requirements
3. Accident lists

ENCLOSURE 1

FLIGHT RECORDER MAKE AND MODEL	EXTENT OF THERMAL DAMAGE TO TAPE			
	NONE	DAMAGED	DESTROYED	Total
SDC Model V557, CVR	6	5	10	21
SDC Model AV557, CVR	2			2
SDC Model 573, DFDR		6	1	7
SDC Model UFDR, DFDR			3	3
COLLINS & MICRODOT, CVR	4	1	5*	10*
LAS Model 209, DFDR			1	1
Leigh VDR-2, DFDR			1	1
Fairchild A100 & F800	36	5	4	45
Total	48	17	25	90

Note: Includes only those cases in which the recorder received fire damage, through March 1992.
* Includes 1 Microdot recorder.



ENCLOSURE 1 (cont')

MAGNETIC TAPE FLIGHT RECORDERS DESTROYED BY FIRE
(1966 TO APRIL 1992)

DATE	LOCATION	AIRCRAFT	RECORDER	TSO
1-10-66	Wemme, OR.	DC-9	V557 CVR	C84
3-13-66	Calcutta, India	B-707	A100 CVR	C124
10-25-68	Hanover, NH.	FH227	Micro CVR	C84
11-19-69	Glenn Falls, NY.	FH227	Coll CVR	C84
11-27-70	Anchorage, AK.	DC-8	V557 CVR	C84
12-31-70	Shamsherngar, EPakistan	F-27	V557 CVR	C84
6-06-71	Durate, CA.	DC-9	V557 CVR	C84
12-30-73	New Delhi, India	B-707	V557 CVR	C84
6-11-75	Bombay, India	B-747	V557 CVR	C84
11-12-75	Jamaica, NY.	DC-10	V557 CVR	C84
3-12-76	Udrivik, AK.	L-188	V557 CVR	C84
4-05-76	Ketchikan, AK.	B-727	Coll CVR	C84
2-11-78	Cranbrook, BC., Canada	B-737	VDR-2 DFDR Coll CVR	C51a C84
9-15-82	Malaga, Spain	DC-10	V557 CVR	C84
9-18-84	Quito, Ecuador	DC-8	V557 CVR	C84
12-31-85	Nigeria	HS-125	A100 CVR	C124
1-10-87	Ilorin, Nigeria	DC-10	573 DFDR	C51a
10-04-89	Dryden, Ont., Canada	F-28	UFDR DFDR V557 CVR	C51a C84
11-27-89	Bogota, Columbia	B-727	UFDR DFDR	C51a
5-26-91	Suphan-Buri, Thailand	B-767	UFDR DFDR	C51a
12-29-91	Taipei, Taiwan	B-747	L209 DFDR	C51a
1-02-92	Saranac, Lake, NY.	B1900	A100 CVR	C124
1-20-92	Monte Sainte Odile, France	A-320	F800 DFDR	C124

Micro = Microdot, CVR
A100 = Loral Fairchild, CVR
F800 = Loral Fairchild, DFDR
VDR-2 = Leigh Instruments, DFDR
L209 = Lockheed Aircraft

UFDR = Sundstrand DFDR
V557 = Sundstrand CVR
573 = Sundstrand DFDR
Coll = Collins CVR

Note: Recorders listed as TSO C124 meet fire test requirements only.

ENCLOSURE 2

TECHNICAL STANDARD ORDER IMPACT AND FIRE TEST REQUIREMENTS

TSO	DATE	IMPACT REQUIREMENTS	FIRE TEST REQUIREMENTS
C51	AUGUST 1958	100G for 11 milliseconds	The recording medium shall remain intact so that intelligence can be analyzed after the recorder has been exposed to flames of 1,100°C, enveloping at least 50% of the outside area of the case for 30 minutes.
C84	NOVEMBER 1963	100G for 11 milliseconds	(Same as TSO C51) Plus: Any cracks or holes resulting from the impact shock test be included in the 50% flame envelopment, and that the recorder be allowed to cool naturally.
C51a	JANUARY 1966	1,000G for 5 milliseconds	(Same as TSO C51) Plus: Impact Shear ~ 500 lbs. from 10', ¼'' pin Static Crush ~ 5,000lbs. 3 sides, 5 min.
C123	May 1991	1,700G for 6.5 milliseconds	1,100°C, Flame enveloping 100% of the outside area of the case for 30 minutes, 50,000 BTU/Hr. thermal flux. Note: does not require TSO C124 fire test protocol. (Reference EUROCAE Document, ED-56)
C124	FEBRUARY 1992	3,400G for 6.5 milliseconds	Same as TSO C123 except thermal flux must be measured by a water calorimeter of the size and shape of the recorder. (Reference EUROCAE Document, ED-55)

ENCLOSURE 3

FLIGHT RECORDER MEDIA DAMAGED OR DESTROYED BY FIRE/HEAT
(MAGNETIC TAPE RECORDERS ONLY)
ALL KNOWN CASES WORLDWIDE
1966 TO APRIL 1,1992

DATE	LOCATION	OPERATOR	AIRCRAFT	RECORDER	REMARKS
1-10-66	Wemme, OR.	West Coast Airlines	DC-9	V557	CVR tape destroyed.
12-24-66	Da Nang, Viet Nam	Flying Tiger	CL-44	V557	CVR tape damaged. Fire and impact damage to CVR.
6-13-68	Calcutta India	PAA	B-707	A100	CVR tape destroyed. Fire burned for approx. 7 hrs.
10-25-68	Hanover NH.	Northeast Airlines	FH227	Microdot	CVR tape destroyed. No impact damaged. Recovered after more than 24 hrs. Still hot when removed from wreckage.
10-16-69	Stockton, CA.	Seaboard	DC-8	V557	CVR tape damaged. Portion of tape fused to recording heads due to heat damage.
11-19-69	Glenn Falls NY.	Mohawk	FH227	Collins	CVR tape destroyed. Little impact damage.
11-27-70	Anchorage AK.	Capital Intl	DC-8	V557	CVR tape destroyed.
11-30-70	Tel Aviv, Israel	TWA	B-707	A100	CVR tape damaged. Minor heat deformation on portion of tape closest to center of reel.
12-31-70	Shamshernagar East Pakistan	PIAC	F-27	V557	CVR tape destroyed.
6- 6-71	Durate, CA.	Airwest	DC-9	V557	CVR tape destroyed. Dust cover consumed by fire, all ablative material gone, no deformation of CVR.
7-25-71	Manila, Phil.	PAA	B-707	A100	CVR tape damaged. Heat deformation on portion of tape closest to the center of the reel. 4 to 5 min. affected. Complete transcription.
12-08-72	Chicago, IL.	United	B-737	V557	CVR tape damaged. Tape fused to recording heads. Complete transcription.

ENCLOSURE 3 (cont')

DATE	LOCATION	OPERATOR	AIRCRAFT	RECORDER	REMARKS
12-30-73	New Delhi, Ind.	Lufthansa	B-707	V557	CVR tape destroyed. Aluminum melted, no impact damage, fuse plugs blown, photos available.
6-11-75	Bombay India.	Air France	B-747	V557 573	CVR tape destroyed. DFDR tape damaged. The portion of the DFDR tape closest to the record heads was destroyed. Estimated thermal exposure 660°C.
11-12-75	Jamaica, NY.	ONA	DC-10	V557 573	CVR tape destroyed. DFDR tape damaged. Fire burned for about 36 hours. Aircraft fuel entered storm drain under aircraft and fed fire. The DFDR tape was readable with some data loss.
3-12-76	Udrivik, AK.	Great Nrthrn Airline	L-188	V557	CVR tape destroyed.
4-05-76	Ketchikan, AK.	Alaska Airlines	B-727	Collins	CVR tape destroyed.
2-11-78	Cranbrook, BC, Canada.	PWA	B-737	VDR-2 Collins	CVR and DFDR tapes destroyed by fire. The DFDR was produced by Leigh as a TSO C51a recorder.
11-21-80	Yap West Carolne Isl.	CAL	B-727	A100	Heat deformation on portion of tape closest to the center of the reel, fire lasted better than 48 hrs limited fire fighting equipment used in area of CVR. Complete transcription.
9-15-82	Malaga, Spain	Spantex	DC-10	V557 573	The CVR tape was destroyed by fire. The DFDR tape was damaged by heat and baked on contaminants, as a result critical data were not recovered.
12-NA-83	Kuala Lumpur, Malaysia	Malaysian Air	A300	573	DFDR tape damaged. DFDR not working at the time of accident. Source AAIB.
12-23-83	Anchorage, AK.	Korean Air	DC-10	573	DFDR extensively fire damaged, exposed portion of tape damaged by heat and baked-on contaminants. DFDR failed prior to accident. CVR not recovered.
9-18-84	Quito, Ecuador	AECA Air	DC-8	V557	CVR tape destroyed.
12-31-85	Nigeria	Unknown	HS-125	A100	CVR tape destroyed. Burned for more than 46 hrs. AAIB investigation.