(NASA-TM-84100) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX D, PANEL 11 (NASA) 44 p

N82-72198

Unclas
00/18 11544

REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX D

PANEL 11

(NASA-TM-X-72182) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX D, PANEL 11 (NASA) 44 p ~~LIMITED ACCESS~~

X75-70676

Unclas
00/98 15888

APOLLO SPACECRAFT

The spacecraft (S/C) consists of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft/lunar module adapter (SLA). The LES assembly provides the means for rapidly separating the C/M from the S/M during pad or suborbital aborts. The C/M forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and comfort of the crew. The S/M is a cylindrical structure located between the C/M and the SLA. It contains the propulsion systems for attitude and velocity change maneuvers. Most of the consumables used in the mission are stored in the S/M. The SLA is a truncated cone which connects the S/M to the launch vehicle. It also provides the space wherein the lunar module (L/M) is carried on lunar missions.

TEST IN PROGRESS AT TIME OF ACCIDENT

Spacecraft 012 was undergoing a "Plugs Out Integrated Test" at the time of the accident on January 27, 1967. Operational Checkout Procedure, designated OCP FO-K-0021-1 applied to this test. Within this report this procedure is often referred to as OCP-0021.

TESTS AND ANALYSES

Results of tests and analyses not complete at the time of publication of this report will be contained in Appendix G, Addenda and Corrigenda.

CONVERSION OF TIME

Throughout this report, time is stated in Greenwich Mean Time (GMT). To convert GMT to Eastern Standard Time (EST), subtract 17 hours. For example, 23:31 GMT converted is 6:31 p.m. EST.

REPORT OF PANEL 11
MEDICAL ANALYSIS PANEL
APPENDIX D-11
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

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MEDICAL ANALYSIS PANEL

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Medical Analysis Panel, 11. The task assigned for accomplishment by Panel 11 was prescribed as follows:

This panel is to provide a summary of medical facts together with appropriate medical analysis which would be of interest to the investigation. Examples would be cause of death, pathological evidence of overpressure, and any other areas that might be of technical value in determining the cause of accident or in establishing corrective action.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Medical Analysis Panel:

Dr. G. F. Kelly, Chairman, Manned Spacecraft Center (MSC), NASA
Dr. Alan C. Harter, Manned Spacecraft Center (MSC), NASA
Dr. Norman W. Pincock, Manned Spacecraft Center (MSC), NASA
Mr. Robert L. Spann, Manned Spacecraft Center (MSC), NASA
Mr. Richard L. Thompson, Pan American Airways (PAA)
Mr. Thomas H. Parish, David Clark Co.

2. COGNIZANT BOARD MEMBER:

Dr. Floyd L. Thompson, Langley Research Center (LaRC), NASA, was assigned to monitor the Medical Analysis Panel.

C. PROCEEDINGS

1. NARRATIVE:

In preparation for the Space Vehicle Plugs Out Integrated Test, the crew had been examined and fitted with sensors prior to departing the Manned Spacecraft Operations Building (MSOB) at approximately 12:30 pm EST (17:30 GMT). After ingress, voice, bioinstrumentation data and certain environmental parameters were monitored at the aeromedical console in the blockhouse. In the Apollo 204 spacecraft, only one crewman could be monitored at a time. During the course of the test, a switch in the cockpit was positioned at the request of the medical monitor so that data from each crewman could be monitored in turn. The Medical Data Acquisition System recorded data only from the Senior Pilot throughout the test.

At the time of the accident, two NASA physicians in the blockhouse were monitoring data from the Senior Pilot. Upon hearing the first voice transmission indicating fire, the senior NASA physician turned from the biomedical console to look at the bank of television monitors. He could see on one what appeared to be flames coming from around the spacecraft but could not pick out a monitor which was focused on the hatch. When his attention returned to the console, the bioinstrumentation data had stopped. The biomedical engineer in the Acceptance Checkout Equipment (ACE) Control Room called the senior medical officer for instructions; was told to make the necessary alarms and informed that the senior medical officer was leaving his console at that time. The two NASA physicians were transported from the blockhouse to the base of the umbilical tower shortly before ambulances and the Pan American physician arrived. The Pan American log fixes the time of ambulance arrival at 6:43 pm EST (23:43 GMT) (Reference 11-1).

At this time considerable smoke was still rising from the White Room area. An estimate of the number of individuals who were working in the White Room was obtained, and the Pan American physician was asked to make arrangements for the care of over 15 injured personnel. One of the injured who had proceeded to ground level was interviewed briefly as to the condition in the White Room and the Spacecraft.

The two NASA physicians and the Pan American physician then proceeded to the spacecraft. The time of arrival at the White Room on the 8th level is estimated at 6:45 pm EST (23:45 GMT). When the physicians first arrived, the hatches had been removed, the spacecraft was still smoldering, pyrotechnics had not been safetied and smoke was too thick to spend any time in the vicinity without a breathing apparatus.

After a quick evaluation, it was decided that nothing could be gained by attempting immediate egress and resuscitation. By this time, some 12 to 15 minutes had elapsed since the fire began. It was evident that the crew had not survived the heat, smoke, and thermal burns. Conditions within the spacecraft (later confirmed by toxicological determinations) were such as to produce high levels of carbon monoxide (CO), carbon dioxide (CO_2), and other toxic gases and irritants. Also, oxygen was markedly depleted after the rupture of the spacecraft. These conditions would have necessitated institution of resuscitative measures within a very few minutes, since under optimal conditions, resuscitation commenced more than four minutes after cardiac arrest is usually unrewarding. The three physicians then returned to ground level until adequate ventilation could be established.

Shortly thereafter, they returned to the spacecraft with equipment for an attempted removal. After trying to remove the Senior Pilot by cutting his suit umbilicals and electrical connections, it became apparent that extensive fusion of the suits to molten nylon from the spacecraft would make removal very difficult. For this reason, it was decided to discontinue efforts at removal in the interest of accident investigation and attempt to get photographs of the spacecraft and relative positions of the crewmen before evidence was disarranged. The two NASA physicians remained in the vicinity of the spacecraft while the Pan American physician returned to ground level. NASA Security arranged for photographic coverage.

After this was accomplished, one of the NASA physicians returned to the blockhouse for approval to resume egress operations. Approval was received from Major General Samuel C. Phillips, U.S. Air Force/Apollo Program Manager, shortly after midnight, local time, and egress was begun at approximately 12:30 am EST (05:30 GMT), January 28, 1967. The Pan American Dispensary log indicates that the ambulance with the Senior Pilot arrived at the Pan American Dispensary at 1:17 am EST (06:16 GMT). The ambulance with the Command Pilot arrived at 1:35 am EST (06:35 GMT) and the ambulance with the Pilot arrived at 2:08 am EST (07:08 GMT). Therefore, removal of the crew took approximately 90 minutes and was completed about seven and a half hours after the accident. The crewmen were removed to the Bioastronautics Operational Support Unit for post-mortem examinations at 4:17 am EST (09:17 GMT).

2. INVESTIGATION:

Conclusions of the Medical Analysis Panel are based on evaluation of information obtained by the following procedures:

a. Photographic Analysis:

Numerous color and black and white photographs were obtained of:

(1) The spacecraft and its interior prior to the removal of the crewmen.
(2) The suited bodies after removal from spacecraft.
(3) The suits, constant wear garments, and other crew equipment after removal.
(4) Special post-mortem photographs.

Photographs were studied in detail by the Panel and the Armed Forces Institute of Pathology investigators to correlate suit damage, position of bodies and pathological findings with fire propagation, sequence of events and cause of death. These photographs were made available to Members of the Board and other Panels as required.
(Reference 11-2)

b. Interrogation of Witnesses and Review of Records:

One Panel member was at the blockhouse aeromedical console at the time of the accident. Two members of the Panel participated in the removal of the crew from the spacecraft. Three Panel members were present during desuiting and post-mortem examination. Other witnesses were interrogated as required. These included some of the smoke inhalation victims, several Pan American Airways medical personnel and members of the egress crew.

Also reviewed in detail were:

(1) Witness statements

(2) Pan American Airways, Cape Kennedy Medical Facility treatment records of smoke inhalation victims (Enclosure 11-1)

(3) Complete Department of Defense (DOD) and NASA medical records of deceased crewmen (Reference 11-3)

(4) Pertinent findings of other Apollo 204 Review Board Panels.

c. Biomedical and Communications Data Analysis:

In order to coordinate voice and biomedical parameters with environmental measurements and establish sequence of events, the following procedures were performed in conjunction with Panel 3:

(1) Blockhouse biomedical tapes and on-board Medical Data Acquisition System tapes from the Senior Pilot were analyzed in detail. The electrocardiogram (EKG): PHONOCARDIOGRAM (PKG) and impedance pneumogram (ZPN) records were studied at speeds of 10, 25, 50 and 100 millimeters per second for indication of movement or change in physiological status. The EKG tracings were reproduced after passage through a 25, 35, and 100 cycles per second low-pass filters. Audio transcriptions and graphic records of the terminal five minutes of the Senior Pilot's phonocardiographic data were recorded after passage through 100, 200, 300, 400, 500, 750, and 1000 cycles per second low-pass filters. These were studied for evidence of voice communications and indications of movement. It is noted that physiological data were available only from the Senior Pilot.

(2) Pertinent sections of voice transmissions from the spacecraft were studied with Bell Telephone Laboratories personnel in both visual and auditory forms at various filter levels.

d. Pathological Studies:

At 11:00 am EST on January 28, 1967, gross examinations were commenced at the Bioastronautics Operational Support Unit located at Cape Kennedy Air Force Station. The autopsies were performed by the following personnel from the Armed Forces Institute of Pathology:

(1) Edward H. Johnston, Colonel, M.C., U.S. Army, Chief, Military Environmental Pathology Division

(2) Charles J. Stahl, Commander, M.C., U.S. Navy, Chief, Forensic Pathology Branch

(3) Latimer E. Dunn, Captain, U.S. Air Force M.C., Chief, Aerospace Pathology Branch

All Examinations included:

(1) Survey of medical history

(2) Examination of clothing

(3) External examination

(4) Appraisal of external evidence of injury

(5) Internal examination

(6) Microscopic examination

(7) Radiographic examination

(8) Toxicological examination for carbon monoxide saturation of lungs and venous blood, as well as blood from the kidney, liver, and muscle; cyanide in blood and lungs; lactic acid in brain; volatiles in liver and blood; acid, basic and neutral drugs in liver; and spectrographic analysis of lungs for seven other gases and nine metallic ions (Enclosure 11-2 and 11-3)

e. Toxicological Studies:

Toxicological studies progressed along the following lines:

(1) The quality of breathing oxygen supplied to the spacecraft before the fire was reviewed from data collected during the countdown. Additional samples collected, as a result of the crew report of odors prior to the accident, were evaluated.

(2) Attempts were made to determine cabin and suit environmental conditions from the time of onset of the fire until time of extinction.

(3) An evaluation of the products of combustion when the available consumable materials were burned in this atmosphere was considered. The variety of such materials and the decomposition variables of temperature, pressure and available oxygen condition preclude an accurate assessment of the conditions which existed at any one time during the fire.

(4) Environmental data recorded during the tests were reviewed to establish factors effecting environmental conditions. These parameters included suit flow, suit supply temperature, suit

differential pressure, compressor differential pressure, cabin pressure, surge tank pressure, compressor inlet temperature, cabin temperature, carbon dioxide (CO_2) absorber outlet temperature and CO_2 partial pressure.

(5) The Environmental Control Unit (ECU) was carefully inspected and residual samples were collected from the umbilical vent tubes and fittings. The samples were analyzed for inorganic constituents.

(6) Tests were performed to determine relative rates of carbon monoxide production from burning suit materials, polyurethane foam and activated charcoal in pure oxygen. (Reference 11-4)

(7) Information regarding possible products of combustion were transmitted to the Armed Forces Institute of Pathology for use in conjunction with the toxicological studies performed as a part of the post-mortem examination. (Enclosure 11-4)

(8) Other tests are in progress to determine the actual conditions for rapid heating of the CO_2 canisters. These tests should determine the potential of activated charcoal to provide a source of high carbon monoxide concentration into the suit loop.

f. Suit Evaluation:

A detailed visual and photographic examination of the suits was performed before desuiting in conjunction with gorss pathological studies. All items of crew equipment were removed to a secure area and a detailed analysis of damage to this equipment was performed by Flight Surgeons and suit specialists. This analysis included:

(1) Detailed mapping of items of crew equipment which became detached from the suits during the course of the accident.

(2) Photographic analysis.

(3) Detailed mapping of damage to suits.

(4) Examination of damaged metal fittings and suit material in conjunction with Panel 5.

(5) Chemical analysis of various deposits for identification of toxic products of combustion. (Enclosure 11-4)

g. Medical Analysis of Ground Emergency Procedures and Equipment:

In connection with Panel 13, Ground Emergency Procedures and Equipment were reviewed from a medical viewpoint to evaluate their adequacy in this type of emergency.

h. Medical Evaluation of In-Flight Emergency Procedures and Equipment:

In connection with Panel 20, In-Flight Procedures and Equipment were reviewed from a medical viewpoint to evaluate their adequacy in event of an in-flight fire.

i. Monitoring Capabilities

A review of capabilities for monitoring biomedical and environmental parameters in the spacecraft was performed. This review included an evaluation of spacecraft telemetry capabilities and consoles used for safety monitoring of such ground tests as well as during flight.

j. Environmental physiology:

A review of pertinent environmental physiology relative to spacecraft cabin atmosphere was performed. This review included a reexamination of physiological factors involved in the selection of a 5 pounds per square inch, 100% oxygen (O_2) environment in Apollo, and the requirement for a complete purge of cabin and suit circuit, prior to launch. This review was conducted in conjunction with the Director of Medical Research and Operations at Manned Spacecraft Center.

D. FINDINGS AND DETERMINATIONS

1. FINDING:

All three crewmen were interviewed by a Medical Officer several hours prior to ingress. Prophyllactic penicillin was administered because of exposure to Beta hermolytic streptococcus.

DETERMINATION:

There was no medical condition and no drug administration which might be expected to degrade their normal performance.

2. FINDING:

Breathing oxygen supplied to the spacecraft before the fire was of adequate quality and quantity.

DETERMINATION:
No anomalies in the suit atmosphere which could have adversely affected crew activities are evidenced from review of the data prior to the fire.
3. FINDING:
Biomedical data at the time of the accident were received from the Senior Pilot only and consisted of one lead of EKG, as well as PKG, and impedance pneumogram (respiration). These data were received by telemetry and from the on-board Medical Data Acquisition System (MDAS). (Reference 11-5)
DETERMINATION:
This configuration was normal for the test.
4. FINDING:
At 6:30:22 pm EST (23:30:22 GMT) on the biomedical tape there is some change in the respiration pattern and a moderate increase in the Senior Pilot's heart rate.
DETERMINATION:
This represents some increase in the Senior Pilot's activity, but does not indicate the degree of activity to be expected had he been aware of an emergency situation.
5. FINDING:
At 6:31:04 pm EST (23:31:04 GMT) on the biomedical tape there is a marked change in the Senior Pilot's respiratory and heart rates. There is also evidence of muscle activity in the EKG tracing and evidence of motion in the PKG. The heart rate continues to climb until loss of signal.
DETERMINATION:
This physiological response is compatible with the realization of an emergency situation. (Reference 11-5)
6. FINDING:
Voice contact from the crew was maintained until 6:31:22.7 pm EST (23:31:22.7 GMT).
DETERMINATION:
At least one member of the crew was conscious until this time.
7. FINDING:
Hatches were opened at approximately 6:36 pm EST (23:36 GMT) and no signs of life were detected. Three physicians viewed the suited bodies at approximately 6:45 pm EST(23:45 GMT) and decided that resuscitation efforts would be to no avail.
DETERMINATION:
Time of death cannot be determined from this finding.
8. FINDING:
The Command Pilot's couch was in the 170-degree position. The foot restraints and harness were released. The inlet and outlet hoses were connected. The helmet visor was closed and locked. The electrical adapter cable was disconnected from the cobra cable. The Command Pilot was found lying supine on the aft bulkhead of the spacecraft with his helmet under the Pilot's head rest and his feet resting upon his own couch. Parts of his suit and items of crew equipment were found in various locations in the spacecraft, described in the suit evaluation. A fragment of the suit material was found outside the pressure vessel five feet from the point of rupture. (Reference 11-6).
DETERMINATION:
The Command Pilot had moved from his normal position after the onset of fire. The suit failed prior to rupture of the pressure vessel (the time of spacecraft rupture has been estimated by Panel 5 to be 6:31:19 pm EST (23:31:19 GMT).
9. FINDING:
The Senior Pilot's couch was in the normal 96-degree position with the foot rest folded up against his lower couch. The head rest was up. The buckle releasing his shoulder straps and lap belts was not opened. (This strap configuration is normal for his emergency egress technique.) The straps were burned through. The suit outlet hose was connected but the inlet hose was disconnected. The helmet visor was closed and locked. All electrical connections were intact. The Senior Pilot was found lying on his left side, transversely across the spacecraft just below the level of the hatchway.
DETERMINATION:
The Senior Pilot did not leave his position until his restraining straps were burned through. He had moved from his normal position after the onset of fire.

10. FINDING:
The Pilot's couch was in the 264-degree position. All restraints were disconnected, all hoses and electrical connections were intact. The helmet visor was closed and locked. The Pilot was found supine in his couch.
DETERMINATION:
There is no evidence that the Pilot moved from his normal position after the start of the fire. This is consistent with the emergency egress procedure which calls for the Pilot to be the last to the leave the spacecraft.
11. FINDING:
The cause of death of the Apollo 204 Crew was asphyxia due to inhalation of toxic gases due to fire. Contributory cause of death was thermal burns. (Enclosures 11-3, 11-5, 11-6, and Reference 11-7)
DETERMINATION:
It may be concluded that death occurred rapidly and that unconsciousness preceded death by some increment of time. The fact that an equilibrium was not established throughout the circulatory system indicates that circulation of blood stopped rather abruptly before an equilibrium could be reached.
12. FINDING:
Panel 5 (Origin and Propagation of Fire) estimates that significant levels (over two percent) of carbon monoxide (CO) would be present in the spacecraft atmosphere by 6:31:30 pm EST (23:31:30 GMT). By this time at least one suit had failed, introducing cabin gases to all suit loops.
DETERMINATION:
The crew was exposed to a lethal atmosphere when the first suit was breeched.
13. FINDING:
The Environmental Control System contains activated charcoal which, if heated, will produce CO. (Reference 11-11)
DETERMINATION:
It is the opinion of Panel 5 that heating of the CO_2 canister occurred late in the progress of the fire after significant levels of CO were already present in the cabin atmosphere, and after at least one suit had failed.
14. FINDING:
The distribution of CO in various organs indicates that circulation stopped rather abruptly when high levels of carboxyhemoglobin reached the heart (Enclosure 11-3).
DETERMINATION:
Loss of consciousness was due to cerebral hypoxia due to cardiac arrest, due to myocardial hypoxia. Factors of temperature, pressure and environmental concentrations of carbon monoxide, carbon dioxide, oxygen and pulmonary irritants were changing at extremely rapid rates. It is impossible to integrate these variables, on the basis of available information with the dynamic physiological and metabolic conditions they produced in order to arrive at a precise statement of time when consciousness was lost and when death supervened. The combined effect of these environmental factors dramatically increased the lethal effect of any factor by itself. It is estimated that consciousness was lost between 15 and 30 seconds after the first suit failed. Chances of resuscitation decreased rapidly thereafter and were irrevocably lost within four minutes.
15. FINDING:
All three suits were breeched by fire to some degree.
DETERMINATION:
The suits were not capable of providing crew protection in a fire of this intensity. (Enclosure 11-7 and Reference 11-6)
16. FINDING:
Suit damage increased progressively from the Command Pilot's side of the spacecraft to the Pilot's side.
DETERMINATION:
The fire was most intense on the Command Pilot's side of the spacecraft.
17. FINDING:
The outer layer of all suits was considerably more damaged than the inner layer.

DETERMINATION:
This lends support to the conclusion that the fire originated in the cabin rather than in the suit circuit.
18. FINDING:
In the Pilot's and Senior Pilot's suits, there is evidence of a path of fire damage from the failed areas coursing toward the suit outlet. In these areas, the fire damage is greater in the comfort liner and less in the outer layers of the suit.
DETERMINATION:
This tends to indicate that the compressor was still active for a period of time after the suit integrity failed.
19. FINDING:
An examination of the Senior Pilot's helmet reveals scorched and charred areas of the anterior portion of both earcups, charred portions of the passive radiation dosimeter situated near the left earcup, and evidence of fire damage on the anterior side of both microphone wires.
DETERMINATION:
The Senior Pilot's faceplate may have been open during a portion of the fire.
20. FINDING:
During continuity checks of the Command Pilot's communication and biomedical harness, some damage to the communication harness was found. (Enclosure 11-8).
DETERMINATION:
This damage is not considered as significant as a possible cause of the fire.
21. FINDING:
It was not possible from biomedical and environmental data to accurately construct a time line of environmental conditions or crew activities during this emergency.
DETERMINATION:
Available environmental and biomedical instrumentaion cannot be considered optimum for a potentially hazardous test or for flight.
22. FINDING:
Medical examinations of the rescue personnel were made by the Pan American World Airways Dispensary. Breath analysis from the most severe victims of smoke inhalation were negative for gases other than low concentrations of carbon monoxide. Urinalyses for beryllium and chest x-rays were also negative in these men. (Enclosure 11-1)
DETERMINATION:
Medical records indicate that there were no permanent injuries to rescue personnel.
23. FINDING:
The purge with 100-percent O_2 at above sea-level pressure contributed to the propagation of fire in the Apollo 204 Spacecraft.
DETERMINATION:
This was the planned cabin environment for testing and launch, since prelaunch denitrogenation is necessary to forestall the possibility of bends at the mission ambient pressure of 5 pounds per square inch absolute. A comprehensive review of the operational and physiological trade-offs of the various methods of denitrogenation is in progress. (Reference 11-9)
24. FINDING:
Rescue personnel were equipped with gas masks designed for protection against hypergolic vapors. They had no heat-protective garments.
DETERMINATION:
Rescue personnel were inadequately equipped for a fire-type rescue.

E. SUPPORTING DATA

This section contains support data to which references have been made in previous sections. These data are organized in numerical sequence as they appear in the written text. A table of contents for this section is as follows:

ENCLOSURES

11-4 Thermal Degradation Products of Non-Metallic Materials
11-5 Post-Mortem Protocol
11-6 Post-Mortem Examination, Summary and Opinion
11-7 Analysis of Suit Damage
11-8 Continuity and Functional Tests of S/C-012 Crew Biomedical Equipment
11-9 List of References

INDUSTRIAL INJURY SUMMARY

During rescue attempts following the Apollo-204 accident on January 27, 1967, 27 persons were injured. Twenty-one of those injured were employed by North American Aviation Company, one by Pan American Aviation, and five were NASA employees.

A majority of the injuries were smoke inhalation, contusions, and abrasions. Two of the injured were admitted to the PAA Dispensary overnight for observation and released the following morning. Others were treated and sent home. There was no evidence of permanent injury and no sequelae are expected.

A record of these injuries are included in the Apollo-204 Review Board Medical Files at MSC.

ENCLOSURE 11-1

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INTRODUCTION

During the late evening of 27 January 1967, The Director, Armed Forces Institute of Pathology, Washington, D. C. was alerted by National Aeronautics and Space Administration personnel that an accident had occurred aboard the Apollo spacecraft at Cape Kennedy, Florida resulting in the deaths of Lt. Colonel Virgil I. Grissom, USA F, Lt. Colonel Edward H. White, USAF, and Lt. Commander Roger B. Chaffee, USN. A request was later made the same evening for autopsy support and a team of three pathologists and a medical photographer (Colonel Edward H. Johnston, MC, USA, Commander Charles J. Stahl, MC, USN, Captain Latimer E. Dunn, USAF, MC, and TSgt Larry N. Hale, USAF) was sent to Cape Kennedy via special USAF plane. Facilities for the postmortem studies were made available by Colonel Frederick Frese, USAF, MC and his Deputy, Lt. Colonel Paul Hoffman, USAF, MC of the Bioastronautic Operational Support Unit. Following a general conference among Colonel Frese, Lt. Colonel Hoffman, Fred Kelly, M.D., NASA, Doctor Alan C. Harter, NASA, Doctor Freedland, NASA, and the AFIP team of pathologists, the detailed circumstances of the accident were discussed. The postmortem examinations were then started at 1100 hours, 28 January 1967, at the Bioastronautic Operational Support Unit. Following photographs and examination of the deceased still clothed in their space suits and helmets, the clothing was carefully removed under the general supervision of Doctor Fred Kelly and Doctor Alan Harter. All articles of clothing and personal effects were studied and then placed in separate duffle bags, labeled, locked and retained for examination by clothing experts designated by the Board of Inquiry. With the assistance of TSgt Freddie B. Moorehead, USAF X-ray Technician, Patrick AFB, total body x-rays were made of each body and the films examined prior to performing the internal examinations. Photographs of the front, back and specific areas of injury were made. A complete detailed description of the external body in each case was made by the pathologists. During the course of the autopsy, assistance was provided to the autopsy team by following USAF personnel who also served as witnesses to the examinations:

Lt. Colonel Paul Hoffman, USA F, MC
Major Pearl E. Tucker, USAF, NC
Captain Dorothy Novotny, USAF, NC
M/Sgt. Kenneth N. Springer, USAF
A/1C Virginia Roberts, USAF

The autopsies were completed at 0100 hours, 29 January 1967. A short conference was called by Doctor Fred Kelly in which the pathologists were asked to assist in the preparation of the death certificate.

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Chaffee, Roger B.
AFIP Accession 1232463

REPORT OF TOXICOLOGY

CARBON MONOXIDE	Lung - 69% saturation	
	Blood - 45%.	"
	Kidney - 22%	"
	Brain - 37%	"
	Liver - 10%	"
	Muscle - 7%	"
	Spleen - 5%	"
CYANIDE	Blood - 1 microgram/3ml	
	Lung - 3 micrograms/5gm	
LACTIC ACID	Brain - 151 mg%	
VOLATILES	Liver - 0	
	Brain - 0	
	Blood - 0	
DRUGS (Acid-Basic Neutral)	Liver - 0	

*OTHER GASES — LUNG (Normal lung used as control was negative for these gases)

Acetylene	- 40 moles%
Hydrogen cyanide	- 32 "
Fluoro-methanes	- 14 "
Fluoro-ethanes	- 2 "
Hydrocarbon (unsaturated) as butane	- 7 "
Methane	- 5 "

**METALLIC IONS — LUNG (Normal lung used as control)

Lithium	- within level of concentration of control
Selenium	- "
Calcium	- "
Zinc	- "
Manganese	- "
Lead	- "
Chromium	- "
Nickel	- "
Beryllium	- "

* Examination by National Bureau of Standards (mass spectrograph)

** Examination by Biochemistry Division Walter Reed Army Institute of Research

All other examinations by Toxicology Branch Armed Forces Institute of Pathology

White, Edward H.
AFIP Accession 1232464

REPORT OF TOXICOLOGY

CARBON MONOXIDE		Lung - 58% saturation
		Blood - 38% "
		Kidney - 44% "
		Brain - 18% "
		Liver - 27% "
		Muscle - 22% "
CYANIDE		Blood - 2 micrograms/3 ml
		Lung - 3 micrograms/5 gm
LACTIC ACID		Brain - 183 mg%
VOLATILES		Liver - 0
		Brain - 0
		Blood - 0
DRUGS (Acid - Basic - Neutral)		Liver - 0
*OTHER GASES		LUNG (Normal lung used as control was negative for these gases)
	Acetylene	- 22 mole%
	Hydrogen cyanide	- 16 "
	Fluoro-methanes	- 5 "
	Fluoro-ethanes	- 1 "
	Hydrocarbon (unsaturated) as butane	- .2 "
	Methane	- 54 "
**METALLIC IONS		LUNG (Normal lung used as control)
	Lithium	- within range of normal control
	Selenium	- slightly above control, but in range of normal
	Calcium	- within range of normal control
	Zinc	- "
	Manganese	- "
	Lead	- "
	Chromium	- "
	Nickel	- "
	Beryllium	- "

*Examination by National Bureau of Standards (<u>mass spectrograph</u>)

**Examination by Biochemistry Division-Walter Reed Army Institute of Research

All other examinations by Toxicology-Branch-Armed Forces Institute of Pathology

Grissom, Virgil I.
AFIP Accession 1232462

REPORT OF TOXICOLOGY

CARBON MONOXIDE	Lung - 58% saturation	
	Blood - 48%	"
	Kidney - 37%	"
	Brain - 20%	"
	Liver - 20%	"
	Muscle - 17%	"
CYANIDE	Blood - 3 micrograms/3 ml	
	Lung - 2 micrograms/5 gm	
LACTIC ACID	Brain - 163 mg%	
VOLATILES	Liver - 0	
	Brain - 0	
	Blood - 0	
DRUGS (Acid - Basic - Neutral)	Liver - 0	

*OTHER GASES — LUNG (Normal lung used as control was negative for these gases)

Acetylene	- 39 moles%
Hydrogen cyanide	- 28 "
Fluoro-methanes	- 10 "
Fluoro-ethanes	- 2 "
Hydrocarbon (unsaturated) as butane	- 7 "
Methane	- 13 "

**METALLIC IONS — LUNG (Normal lung used as control)

Lithium	- within level of control
Selenium	- slightly elevated above control, but in range of normal
Calcium	- within level of control
Zinc	- "
Manganese	- "
Lead	- "
Chromium	- "
Nickel	- "
Beryllium	- "

*Examination by National Bureau of Standards (mass spectrograph)

**Examination by Biochemistry Division Walter Reed Army Institute of Research

All other examinations by Toxicology Branch Armed Forces Institute of Pathology

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OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : HU1/Dr. F. Kelly

DATE: FEB 23 1967

In reply refer to:
DB24/02/005

FROM : DB/Chief, Biomedical Research Office

SUBJECT: Thermal degradation products of nonmetallic materials

An analysis of nonmetallic materials in the suit loop and cabin results in a breakdown into several generic groups. Individual materials are too highly variable to obtain specific, reproducible degradation products. Ultimately, all hydrocarbons would be expected to produce CO_2 and H_2O in an excess of O_2 and high temperatures. However, the following compounds and classes can be expected to result from the uncontrolled thermal degradation of the nonmetallics:

a. Carbon monoxide.
b. Homologous aldehydes from formaldehyde and acetaldehyde upward.
c. Organic acids of all types.
d. Organotins as catalysts and preservatives in a variety of plastics.
e. Virtually every known solvent.
f. Methane.

ACRYLICS (various types)

Methyl alcohol
Acrylic acid
Methyl methacrylate
C_4-C_6 oxygenated compounds
Isobutylene
Methacrylic acid

DACRON (also Mylar)

Terephthalic acid and more complex chain fragments
Acetaldehyde
Methane
Ethane
Benzene
2-Methyl dioxolane

Enclosure 11-4

5010-108

Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan

SILICONES

Too many and too complex to analyze - primarily methane, benzene, methyl silanols, and siloxanes

POLYETHYLENE, POLYPROPYLENE

Ethylene
Propylene

POLYVINYL CHLORIDE

Hydrochloric acid

TEFLON

Tetrafluoroethylene
Assorted fluorinated hydrocarbons
Fluorophosgene
Octa fluoroisobutylene
Hydrofluoric acid

POLYVINYL ACETATE

Acetic acid

NEOPRENE

Hydrochloric acid

RUBBER

Oxides of sulphur
Isoprene
Dipentene
p-Menthene

PHENOLICS

Formaldehyde
Formic Acid
Benzene
Phenol
Propanol
Methane
Acetylene
Ammonia
Toluene
Oxides of nitrogen

POLYCARBONATE

No information

NYLON (including Nomex, Velcro)

Hydrogen cyanide
Cyclopentanone
Ammonia
Aldehydes
Adipamide
Oxides of nitrogen

POLYURETHANE

Hydrogen cyanide
Halogenated hydrocarbons, HCl and HF from foaming freons
Oxides of nitrogen
Organic tins
Toluene 2, 4-diisocynates

EPOXYS

Ammonia
Methane
Benzene
Propylene
Acetone
Acetaldehyde
Dipropyl ether

Lawrence F. Dietlein, M.D.

DB24:ESHarris:jb 2/21/67

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Standard Form 503
Revised August 1954
Bureau of the Budget
Circular A-32 (Rev.)

U.S. GOVERNMENT PRINTING OFFICE

CLINICAL RECORD	AUTOPSY PROTOCOL			
DATE AND HOUR DIED: XXXX A.M. / P.M. 27 January 1967	DATE AND HOUR AUTOPSY PERFORMED 1100 A.M. / XXX P.M. 28 January 1967	CHECK ONE: FULL AUTOPSY X	HEAD ONLY	TRUNK ONLY
PROSECTOR Charles J. Stahl Commander, MC, USN	ASSISTANT Colonel Edward H. Johnston, MC, USA			
XXXXXXXXXXXXXXXXXXXXXXX	Latimer E. Dunn, Captain, USAF, MC			

CAUSE OF DEATH: ASPHYXIA DUE TO INHALATION OF TOXIC GASES DUE TO FIRE

CONTRIBUTORY CAUSE OF DEATH: THERMAL BURNS

MANNER OF DEATH: ACCIDENTAL

PATHOLOGICAL DIAGNOSES

1. ASPHYXIA DUE TO INHALATION OF TOXIC GASES DUE TO FIRE, MANIFESTED BY:

   a. CARBON MONOXIDE POISONING.

   b. SOOT WITHIN NOSE, ORAL CAVITY, TRACHEA AND BRONCHI.

   c. HEMORRHAGIC PULMONARY EDEMA, DIFFUSE.

2. THERMAL BURNS, 1ST, 2ND AND 3RD DEGREE, ESTIMATED 60% TOTAL BODY SURFACE AREA, as follows:

   1st and 2nd Degree: Estimated 24% total body surface area.

   3rd Degree: Estimated 36% total body surface area.

   4th Degree: None.

(Continued)

APPROVED—SIGNATURE [signature] The Director AFIP 8 March 1967
JOE M. BLUMBERG, MAJOR GENERAL, MC, USA

MILITARY ORGANIZATION (When required)	AGE	SEX	RACE	IDENTIFICATION NO.	AUTOPSY NO.
Det. 1, 1137 USAF Special Activities Sq.	40	Male	Caucasian	FR 22450	AFIP 1232462
				REGISTER NO. --	WARD NO. --

PATIENT'S IDENTIFICATION (For typed or written entries give: Name—last, first, middle; grade; date; hospital or medical facility)

GRISSOM, Virgil Ivan
Lieutenant Colonel, United States Air Force

Armed Forces Institute of Pathology
Washington, D. C. 20305

AUTOPSY PROTOCOL
Standard Form 503
503-104

Standard Form 503
Revised August 1954
Bureau of the Budget
Circular A-32 (Rev.)

U.S. GOVERNMENT PRINTING OFFICE : 1961 O—

CLINICAL RECORD — AUTOPSY PROTOCOL

DATE AND HOUR DIED		DATE AND HOUR AUTOPSY PERFORMED		CHECK ONE: FULL AUTOPSY	HEAD ONLY	TRUNK ONLY
27 January 1967	~~A.M.~~ P.M.	28 January 1967	1100 A.M. ~~P.M.~~	X		

PROSECTOR	ASSISTANTS
COL Edward H. Johnston, MC, USA	Charles J. Stahl, CDR, MC, USN Latimer E. Dunn, Captain, USAF, MC

CAUSE OF DEATH: ASPHYXIA DUE TO INHALATION OF TOXIC GASES DUE TO FIRE

CONTRIBUTORY CAUSE OF DEATH: THERMAL BURNS

MANNER OF DEATH: ACCIDENTAL

PATHOLOGICAL DIAGNOSES

1. ASPHYXIA DUE TO INHALATION OF TOXIC GASES DUE TO FIRE, MANIFESTED BY:
   a. CARBON MONOXIDE POISONING.
   b. SOOT WITHIN NOSE, ORAL CAVITY, TRACHEA AND BRONCHI.
   c. HEMORRHAGIC PULMONARY EDEMA, DIFFUSE
2. THERMAL BURNS, 1ST, 2ND and 3RD DEGREE, ESTIMATED 48% TOTAL BODY SURFACE AREA, as follows:

   1ST and 2ND Degree: Estimated 8% total body surface area.

   3Rd Degree: Estimated 40% total body surface area.

   4TH Degree: None.

(Continued)

APPROVED—SIGNATURE: JOE M. BLUMBERG, MAJOR GENERAL, MC, USA — The Director AFIP — 8 March 1967

MILITARY ORGANIZATION (When required)	AGE	SEX	RACE	IDENTIFICATION NO.	AUTOPSY NO.
Det. 1, 1137 USAF Special Activities Sq.	36	Male	Caucasian	FR 23567	AFIP 1232464

REGISTER NO.	WARD NO.
--	--

PATIENT'S IDENTIFICATION (For typed or written entries give: Name—last, first, middle; grade; date; hospital or medical facility)

WHITE, Edward Higgins II
Lieutenant Colonel, United States Air Force

Armed Forces Institute of Pathology
Washington, D. C. 20305

AUTOPSY PROTOCOL
Standard Form 503
503-104

Standard Form 503
Revised August 1954
Bureau of the Budget
Circular A-32 (Rev.)

U.S. GOVERNMENT PRINTING OFFICE : 1961 0—542527

CLINICAL RECORD	AUTOPSY PROTOCOL			
DATE AND HOUR DIED: 27 JANUARY 1967 (P.M.)	DATE AND HOUR AUTOPSY PERFORMED: 27 JAN 1967 - 1100 HRS (A.M.)	CHECK ONE: FULL AUTOPSY	HEAD ONLY	TRUNK ONLY
PROSECTOR: L. E. DUNN, CAPT, USAF, MC	ASSISTANT: C. J. STAHL, CDR, MC, USN	X		
	E. H. JOHNSTON, COL, MC, USA			

A. CAUSE OF DEATH:

ASPHYXIA, DUE TO INHALATION OF TOXIC GASES, DUE TO FIRE.

CONTRIBUTORY CAUSE OF DEATH:

THERMAL BURNS DUE TO FIRE.

MANNER OF DEATH:

ACCIDENTAL

B. PATHOLOGICAL DIAGNOSES

1. ASPHYXIA, DUE TO INHALATION OF TOXIC GASES, DUE TO FIRE MANIFESTED BY:
   - (a) CARBON MONOXIDE POISONING
   - (b) SOOT WITHIN THE MOUTH, NARES, AND TRACHEOBRONCHIAL TREE
   - (c) HEMORRHAGIC PULMONARY EDEMA, DIFFUSE
2. THERMAL BURNS:
   - (a) FIRST AND SECOND DEGREE - ESTIMATED AS 6% OF BODY SURFACE
   - (b) THIRD DEGREE - ESTIMATED AS 23% OF BODY SURFACE
   - (c) FOURTH DEGREE - NONE
3. OLD INJURY OF 7TH THORACIC VERTEBRA, CONSISTENT WITH OLD COMPRESSION FRACTURE.

APPROVED—SIGNATURE
JOE M. BLUMBERG, MAJOR GENERAL, MC, USA — 8 March 1967

MILITARY ORGANIZATION (When required)	AGE	SEX	RACE	IDENTIFICATION NO.	AUTOPSY NO.
8th Naval District, New ~~Orleans, Louisiana~~	31	Male	Caucasian	564218	AFIP 1232463

PATIENT'S IDENTIFICATION (For typed or written entries give: Name—last, first, middle; grade; date; hospital or medical facility)

REGISTER NO.	WARD NO.
--	--

CHAFFEE, Roger B.
Lieutenant Commander, United States Navy

Armed Forces Institute of Pathology
Washington, D. C. 20305

AUTOPSY PROTOCOL
Standard Form 503
503-104

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Grissom, Virgil I.
AFIP Accession 1232462

SUMMARY AND OPINION

During the evening of 27 January 1967, a fire occurred within the Apollo-Sautrn 204 Test Vehicle on Pad 34 at U.S. Air Force Station, Cape Kennedy, Florida. The primary team of astronauts for the Apollo project, Lieutenant Colonel Virgil I. Grissom, USAF, Lieutenant Colonel Edward H. White USAF, and Lieutenant Commander Roger B. Chaffee, USN, died as the result of the fire.

The post-mortem examination and toxicological studies of Lieutenant Colonel Grissom indicate that carbon monoxide poisoning is the most significant finding. Active inhalation of smoke and products of combustion in the form of acetylene, hydrogen cyanide, fluoro-methanes, fluoro-ethanes and other toxic gases were detected by mass spectrographic analysis of the lungs. There was evidence of early post-mortem change in the skin and internal organs, and the presence of methane in the lung may have resulted from either post-mortem decomposition or inhalation of products of combustion, or both.

Thermal burns, estimated as 60% total body surface area (36% third degree), are considered as a contributory cause of death. Burns involging this percentage of the total body surface are usually not immediately fatal. It is not possible to state that all of the thermal burns are antemortem.

The distribution of carbon monoxide in the various tissues provides an evaluation of the saturation of blood in these organs by carbon monoxide. The sample of blood obtained for analysis is a mixture of venous and arterial blood from the inferior vena cava and both sides of the heart. The distribution studies of the tissues for carbon monoxide indicate that an equilibrium between the carbon monoxide and blood had not occurred in all areas of the body. These studies alone are consistent with a rapid death.

Rapid depletion of oxygen by fire within the closed environment, the formation and absorption of carbon monoxide gas, and the liberation and inhalation of other toxic products of combustion, associated with a rapid increase in the pressure and temperature within the capsule, resulted in a state of severe hypoxia, or even complete anoxia, which explains a rapid death. With the information obtained from the autopsy and the toxicological findings it is not possible to determine the exact time of death. Results of analysis of air samples from within the capsule at the time of the fire are not available for correlation with the post-mortem findings.

White, Edward H.
AFIP Accession 1232464

SUMMARY AND OPINION

During the evening of 27 January 1967, a fire occurred within the Apollo-Saturn 204 Test Vehicle on Pad 34 at U.S. Air Force Station, Cape Kennedy, Florida. The primary team of astronauts for the Apollo Project, Lieutenant Colonel Virgil I. Grissom, USAF, Lieutenant Colonel Edward H. White, USAF, and Lieutenant Commander Roger B. Chaffee, USN, died as the result of the fire.

The post-mortem examination and toxicological and studies of Lieutenant Colonel White indicate that carbon monoxide poisoning is the most significant finding. Active inhalation of smoke and products of combustion prior to death is confirmed by the presence of soot within the tracheobronchial tree. Products of combustion in the form of acetylene, hydrogen cyanide, fluoro-methanes, fluoro-ethanes and other toxic gases were detected by mass spectrographic analysis of the lungs. There is evidence of early post-mortem change in the skin and internal organs, and the presence of methane in the lung may have resulted from either post-mortem decomposition or inhalation of products of combustion, or both.

Thermal burns, estimated as 48% total body surface area, (40% third degree) are considered as a contributory cause of death. Burns involving this percentage of the total body surface are not immediately fatal. It is not possible to state that all of the thermal burns are antemortem.

The distribution of carbon monoxide in the various tissues provides an evaluation of the saturation of blood in these organs by carbon monoxide. The sample of blood obtained for analysis is a mixture of venous and arterial blood from the inferior vena cava and both sides of the heart. The distribution studies of the tissues for carbon monoxide indicate that an equilibrium between the carbon monoxide and blood had not occurred in all areas of the body. These studies alone are consistent with a rapid death.

Rapid depletion of oxygen by fire within the closed environment, the formation and absorption of carbon monoxide gas, and the liberation and inhalation of other toxic products of combustion associated with a rapid increase in the pressure and temperature within the capsule resulted in a state of severe hypoxia or even complete anoxia which explains a very rapid death. With the information obtained from the autopsy and the toxicological findings it is not possible to determine the exact time of death. Results of analysis of air samples from within the capsule at the time of the fire are not available for correlation with the post-mortem findings.

Chaffee, Roger B.
AFIP Accession 1232463

SUMMARY AND OPINION

During the evening of 27 January 1967, a fire occurred within the Apollo-Saturn 204 Test Vehicle on Pad 34 at U.S. Air Force Station, Cape Kennedy, Florida. The primary team of astronauts for the Apollo Project, Lieutenant Colonel Virgil I. Grissom, USAF, Lieutenant Colonel Edward H. White, USAF, and Lieutenant Commander Roger B. Chaffee, USN, died as the result of the fire.

The post-mortem examination and toxicological studies of Lieutenant Commander Chaffee indicate that carbon monoxide poisoning is the most significant finding. Active inhalation of smoke and products of combustion prior to death is confirmed by the presence of soot within the tracheobronchial tree. Products of combustion in the form of acetylene, hydrogen cyanide, fluoro-methanes, fluoro-ethanes and other toxic gases were detected by mass spectrographic analysis of the lungs. There was evidence of early post-mortem change in the skin and internal organs, and the presence of methane in the lung may have resulted from either post-mortem decomposition or inhalation of products of combustion or both.

Thermal burns, estimated as 29% total body surface area (23% third degree), are considered as a contributory cause of death. Burns involving this percentage of the total body surface are usually not immediately fatal. It is not possible to state that all of the thermal burns are antemortem.

The distribution of carbon monoxide in the various tissues provides an evaluation of the saturation of blood in these organs by carbon monoxide. The sample of blood obtained for analysis is a mixture of venous and arterial blood from the inferior vena cava and both sides of the heart. The distribution studies of the tissues for carbon monoxide indicate that an equilibrium between the carbon monoxide and blood had not occurred in all areas of the body. These studies alone are consistent with a rapid death.

Rapid depletion of oxygen by fire within the closed environment, the formation and absorption of carbon monoxide gas, and the liberation and inhalation of other toxic products of combustion, associated with a rapid increase in the pressure and temperature within the capsule, resulted in a state of severe hypoxia, or even complete anoxia, which explains a rapid death. With the information obtained from the autopsy and the toxicological findings it is not possible to determine the exact time of death. Results of analysis of air samples from within the capsule at the time of the fire are not available for correlation with the post-mortem findings.

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APOLLO - 204 SUITS, ANALYSIS OF DAMAGE

1. PURPOSE

The purpose of this report is to record the damage to the Space Suit Assemblies and associated personal equipment worn on board Apollo-204 at the time of the accident on January 27, 1967. A secondary purpose is to set forth observations recorded during the survey which may add useful information concerning origin and path of the fire and lead to recommendations and conclusions for future design.

2. INTRODUCTION

The survey was conducted during the period February 14 through February 28, 1967 at Kennedy Space Center, Florida, Pyrotechnics Installation Building (PIB), Room 106. The equipment had been brought to the location from the Bioastronautics Building, Cape Kennedy, after removal of the crewmen. The equipment had been impounded in Room 106 of the PIB and placed under direct control of Panel 11 Medical Analysis.

Also included, but laid out separately, was the constant wear garments with attached bioinstrumentation, short lengths of the Environmental Control System (ECS) umbilicals with nozzles for the Command Pilot and Senior Pilot, and still attached space suit cobra electrical adapters.

3. SCOPE

The survey was conducted during the period February 14, 1967 through February 28, 1967 at Kennedy Space Center, Florida, Pyrotechnics Installation Building (PIB), Room 106. The equipment had been brought to the location from the Bioastronautics Building, Cape Kennedy, after removal of the crewmen. The equipment had been impounded in Room 106 of the PIB and placed under direct control of Panel 11 Medical Analysis.

A thorough inspection was also made of the spacecraft removed components (couches, struts, back pans, electrical cables, ECS umbilicals, etc) and the spacecraft interior to identify and account for missing items. All items found on the couches and back pans were photographed in place, removed, and transferred by Test Preparation Sheet (TPS) to the space suit inspection area in Room 106, PIB. A total of eighteen (18) samples of deposits and materials of interesting condition and location were removed from the space suits (e.g. inlet and outlet connectors and nozzles, ECS umbilical interiors, helmet areas, and certain soft goods areas) and transferred to the Kennedy Space Center Materials Analysis Branch for analysis.

Electrical equipment was inspected on location by the Fire Panel and then removed to the Materials Analysis Branch for closer inspection and documentary photographs. Since there was evidence of possible pin burning at the pin interface between the cobra cable adapter and the cobra cable 37 pin connector on the Command Pilot suit (which was found disconnected at this joint), the connection between this adapter and the space suit 61 pin connector was not broken but was removed intact from the space suit (flange included) for electrical continuity and functional checks. Arrangements were made to have continuity and functional checks of all electrical components (e.g. helmet communications, biocommunication harness, bioinstrumentation belt components, and space suit cobra cable adapters). Prior to removal of samples, a complete photographic survey was made of the space suit components including close-ups of pertinent areas in stereo as well as regular color film.

4. BACKGROUND

a. Space Suit Configuration Description

The Apollo Block I Space Suit Assembly, Part Number S-987-000, NASA designation type A-1C, is basically identical to the Gemini G-4C space suit used in the Gemini-Titan 4,5,6,8,9,10,11, and 12 flights. The complete space suit assembly is described in detail in DCM-999A-019-00 CEI Detailed Specifications for the Apollo Block I Space Suit Assembly.

Specific part numbers of all components used in the assemblies aboard Apollo 204, together with inspection and utilization data packages, are set forth in the individual log books for these space suit assemblies (located in Room 3343, MSOB).

The serial number designations of the space suits (and respective log books)used were:
(1) Command Pilot: A-1C-16
(2) Senior Pilot: A-1C-17
(3) Pilot: A-1C-17

For parts descriptions and drawing numbers of the Apollo-204 suit configuration, see Reference 11-6

An additional more detailed description including sketches and photographic documentation, is available in the National Aeronautics and Space Administration, Manned Spacecraft Center Medical Files in Houston.

b. Pilot Accessories

The space suits provide accommodations for much of the pilot's personal equipment, primarily in any array of pockets attached to the outer coverlayer. The equipment carried on board Apollo 204 is listed below:

ITEM	PART NUMBER	PART NAME	LOCATION/NO. PER CREWMAN
(1)	SEB 4010000095-201	Life Vest Ass'y	One set of 2 for each crewman attached by harness at each armpit.
(2)	A-1193-000	Neck Seals (Water Egress)	One each, upper right arm pocket
(3)	A-1193-000	Neck Seal (Ventilation)	One each, any leg pocket
(4)	ACS 1505	Wrist Dams	Two each, upper left arm pocket
(5)	SEB 12100029-201 SEB 12100030-201	Chronograph Wrist Watches with Velcro band	One each, left wrist below suit pressure indicator
(6)	SEB 12100033-201	Sunglasses (In Nylon Pouch)	One each, left lower leg pocket
(7)	EC 30045	Combination Knife (with lanyard)	One each, Command Pilot and Pilot, Outboard lower right leg
(8)	EC 20541	Shroud Cutter (with lanyard)	One, Senior Pilot only
(9)	RFB-OP-4-3-003	Pocket Dosimeter	One, Senior Pilot only, Inboard Left leg
(10)	SEB 12100031-001	Marking Pens	Two each, one in left leg inboard pencil pocket, one in upper left arm pocket
(11)	SEB 12100032-202	Mechanical Pencils	Two each, upper left arm pocket

(12)	EC 30190	Apollo Scissors (with lanyard)	One each, Senior Pilot and Pilot, inboard lower right leg
(13)	CSD 20542	Gemini Scissors (with lanyard)	One-Command Pilot Only, inboard, lower right leg
(14)	EC 30115	Penlight	One each, inboard lower right leg penlight pocket
(15)	N/A	Nylon Glove Liners	Two each, worn on hands inside pressure gloves
(16)	RFB-OP-4-3-002	Passive Radiation Dosimeters	One set of four each: (a) In helmet at left of eye (b) In Constant Wear Garment at right chest (c) In CWG at inside left thigh (d) In CWG at inside right calf
(17)	14-0105	Urine Collection Device	Worn on crewman @ pelvic area
(18)		Biocommunication Harness (with 61 Pin Connect-Bioinstrumentation Package (a) Signal VConditioners	One each worn inside suit at chest with 61 Pin connector secured to Bio Flange
		(a) Signal Conditioners	(a) Four each worn in pockets of CWG bio belt at abdomen
	103120	(b) Wire Harness	(b) Connected at lower end of Signal Conditioners
	Phonocardiogram 104119 sig. cond. 103020	(c) Sensors	(c) Four, Senior Pilot only
(19)	A 1912-003	Constant Wear Garment	One each, color coded: (a) Command Pilot-Red (b) Senior Pilot-White (c) Pilot-Blue

c. VENTILATION SYSTEM

For purposes of clarification and to aid in the visualization of the damage description of the space suit ventilation system, the following description of the ventiliation system is offered as a reference guide.

The ventilation system consists of a network of individual tubes which extend from a common manifold at the inlet ventilation connector (blue) to the arms, legs, helmet, and waist which carry a fresh supply of ventilation or pressurization oxygen from the Spacecraft ECS hoses to provide metabolic requirements for body cooling, breathing oxygen, and CO2 removal. The flow exits at the bottom of the feet, the wrists, the scalp, across the face, and at the back waist. The flow is approximately divided as follows:

(1) Helmet: 35%
(2) Each leg: 15% (30% total)
(3) Each Arm: 15% (30% total)
(4) Waist: 5%

After exhausting from the ventilation channel ends, the flow returns across the body, exiting at the exhaust ventilation connector (red), and into the outlet ECS umbilical. The routing of the ventilation tube is as follows (all starting at the inlet manifold at the left abdomen area):

(1) To helmet; three double tubes up center of chest to connections at the neck ring sides and front center.

(2) To arms; one double tube each, up and across chest to armpits, across front of arm, to lateral surfaces of arm splitting into two single tubes above and behind the elbow and then running down each side of the forearm to the wrist connector.

(3) To legs; two quadruple tubes each running across abdomen to outside of legs splitting into two double tubes above the knee which continue down the side of the legs to the boot ventilation pads.

(4) To torso; one double tube around left side of waist to center back.

d. TORSO

The majority of the suit described in this damage assessment is the basic four layer soft goods anthropomorphous body covering encompassing the arms, legs, feet, and trunk, and including all major subassemblies such as glove connectors, helmet connectors, and ventilation system and fittings. Also considered are the Constant Wear Garment, Helmet, Gloves and Electrical Systems.

The torso layer is as follows:

(1) Outer Cover Layer: White, 6 oz. Oxford Weave HT-1 (Nomex) Nylon;
(2) Restraint Layer: Link net, HT-1 Nylon Cord
(3) Gas Container: Neoprene Coated Nylon Cloth
(4) Inner Liner: Blue, 3 oz. Oxford Weave Nylon Cloth

The cotton Constant Wear Garment is worn immediately under the inner liner.

5. INITIAL CONFIGURATION (before crew removal from Spacecraft)

a. Command Pilot: Suit Assembly Designation, A-1C-16

The ventilation hose nozzles were engaged with the suit connectors and the connectors in locked position. The Pressure Garment Assembly (PGA) electrical adapter was connected to the 61 pin space suit electrical connector but was disconnected at the cobra cable end (37 pin male); The helmet was installed and properly locked with the visor down and bailer bar fully locked. The gloves were installed and locked and entry closure assembly (pressure sealing zipper) was fully closed.

The ventilation umbilicals were cut 37 1/2 inches above the nozzle and removed still engaged with the suit.

b. Senior Pilot: Assembly Designation, A-1C-17

Outlet ventilation hose nozzle connected and connector in locked position. The inlet ventilation hose nozzle was disconnected and connector in the unlocked position. The PGA electrical adapter was connected to the space suit electrical connector and to the cobra cable connector (through the two stages of electronic adapters). This adapter cable had been cut through 6 in. above suit connector to allow crewman removal. The helmet was installed and properly locked with the visor down and the bailer bar fully locked. The gloves were properly installed and locked and the entry closure assembly (pressure sealing zipper) was fully closed.

The ventilation umbilicals were cut 18 in. above the nozzle and removed with the suit (outlet nozzle still connected).

c. Pilot: Assembly Designation, A-1C-18

The configuration was identical to the Command Pilot's described above except that the PGA electrical adapter was connected to the cobra cable. This was subsequently disconnected at the cobra cable to allow crewman removal from the Spacecraft. The ventilation hose nozzles were disengaged from the suit to allow crewman removal from the Spacecraft.

6. DAMAGE DESCRIPTION/OBSERVATION

a. Torso

The most severe damage was incurred at the Command Pilot's suit (70 percent destroyed), while the Senior Pilot's suit was moderately damaged (25 percent destroyed) and the Pilot's suit was the least damaged (15 percent destroyed).

The heaviest damage to the Command Pilot's suit was over the legs, right arm, and over the anterior trunk from chest to the upper abdomen.

The heaviest damage to the Senior Pilot's suit occurred over the left arm, left leg, left side of trunk extending across mid abdomen, and right knee.

The Pilot's suit shows damage along the lateral aspects of both arms, discrete areas on the posterior aspects of both shoulders, the anterior portions of the lower right leg, and at the back of the neck. The survival of areas with heavy seams was more apparent here, indicating less direct flame impingement to this suit than the other two. The greater percentage of coverlayer remaining indicated far less exposure to intense heat than the other two crewmen.

The damage patterns to the space suit assemblies indicated an external heat source. The external layer was the most severely damaged and the inner layer was the least damaged. Thus as the suits were qualitatively examined, a greater percentage of each individual layer remained as the examination progressed inward.

An observation which recurred often during the examination was that materials which were shielded from the flame path by the suits relative position, or by external material layers, generally survived relatively intact. This is especially true in areas of heavy seam construction, some areas and accessories covered by pockets, and webbing. It was also noticed that materials adjacent to hardware and layer build-ups of relatively high mass (e.g. neck ring, wrist ring, and ventilation connector flanges; and areas at the leg cuffs, wrist cuffs, and around the entry closure) escaped with moderate damage while surrounding areas were consumed.

In nearly all cases the burn damage for any sublayer followed an almost identical pattern to the damage of the next outermost layer, except that the damage was less, and more material remained, indicating partial protection from the preceding outer layer.

The Constant Wear Garment, on a percentage basis, showed less overall damage than any other suit layer. The damage area generally matched corresponding damage areas in the immediately preceding suit layer but the damage was not as severe.

b. Ventilation System-This system is indicated in detail in Section 4 c.

In general the major portion of the ventilation tubing systems remained intact. About 75 percent of the Command Pilot's system, and 90 percent each of the Senior Pilot's and Pilot's systems were undamaged. The ventilation tubes were penetrated at various places, apparently by external heat sources or direct flame impingement from adjacent materials or Spacecraft ambient circulation. This is indicated because most tube penetrations correspond in location to external penetrations of space suit layers between the tube surface and the cabin ambient. In many cases only the side of the tube exposed to the highest indicated heat source is burned away leaving the side away from the heat source intact. There is no evidence of an internal source of combustion causing rupture from the inside.

Examination of the interior of the Pilot's and Senior Pilot's ventilation tubes found them clean with little evidence of soot. The inlet manifolds of these two suits were perfectly intact showing no damage and little exposure to elevated temperatures, demonstrating that no appreciable heat or smoke was being introduced into the suit from the ECS system. The damage source and path determination of the Command Pilot's ventilation system is more difficult because of the destruction of the suit at the torso front. The inlet manifold section was entirely consumed except for an aluminized asbestos pad which backs the manifold. There is light sooting in the lines leading to the helmet, especially at the left side. This indicates that some smoke and heat were being forced into the helmet ventilation system. The sooted ventilation tubes leading to this area were badly burned upstream, while tubes leading to unsooted areas were relatively intact. Indications are, again, that penetration was from the outside of the ventilation tubes with smoke and heat initially being forced into the helmet ventilation by the incoming flow as it passed the ruptured area until the rupture became extensive enough to cause short circuiting of the helmet ventilation system.

All suit exhaust areas indicated that hot gasses were being drawn into a penetrated suit and out the exhaust port. This is evidenced by the blackened condition of the interior of the outlet nozzle, the localized damaged to the outlet port spacer spring material (adjacent areas were relatively undamaged except where flame paths led to the outlet), and melting of the trilock spacer pad (attached to the inner liner) and covering the exhaust port area on the surface between the bladder and comfort liner rather than the surface facing the man.

c. Hardware

(1) Helmet and Glove Connectors. The glove disconnects and helmet disconnects of all suits, except the Senior Pilot's, were in normal operating order and entirely functional with no signs of interior damage. The Senior Pilot's helmet disconnect could not be opened because of debris.

(2) Ventilation Connectors. All inlet (blue) and exhaust (red) ventilation fittings, except the Command Pilot's exhaust fitting, were functional, though somewhat stiff, with no evidence of damage to the locking mechanism or bore "O" ring. The areas of these fittings exposed to the interior of the suit are heavily blackened and show exposure to high heat.

The Command Pilot's outlet connector (red) showed exposure to extremely high internal heat as evidenced by the partially melted aluminum poppet valve and missing steel poppet return springs. This assembly, which had burned free of the suit, was disassembled and transferred to the KSC Materials Analysis Branch for metallographic analysis. (Report to be inclu
erials Analysis Branch for metallographic analysi. (Report to be included in Appendix G)

(3) Electrical Components. The electrical components, installed in the suits (including communications headset and harness, bioinstrumentation harness and signal conditioners) appeared to be relatively free of heat damage. These components were transferred to the appropriate technical personnel at KSC for continuity checks and functional testing. (Report to be included in Appendix G)

d. Helmet: The helmets were structurally undamaged and appeared to be in a pressurizable condition.

The bailer bar, pivot mechanism, and bi-lock assembly were functional. The visors were not penetrated but had been blackened on the exterior surface and had reached forming temperatures. This was evidenced because all visors were dished inward (concave outward) slightly with small bubbles appearing at the outer surface. The visor protector had melted into a shapeless mass. No external helmet material was observed to have burned.

The helmet interior showed little evidence of heat being conducted through the shell as evidence by undamaged leather covered polyurethane foam head liners and Velcro attachment pads. There is some evidence of polyurethane liner melting at forward exposed edges and of charring and blackening of the edges of the chamois covered earcups but this heat source is thought to have been secondary after penetrations of the upper portion of the suit.

e. Suit Mounted Accessories:

The accessories carried aboard on the day of the accident are listed above in Section 4b. All accessories have been accounted for and examined, although some of these accessories exhibit various states of melting, charring, and other damage. There is no evidence that any of these components could have been the source of the fire. In most cases, these components were relatively well protected by the space suit pockets or their individual packing covers. More complete individual descriptions of these items are contained in Reference 11-6.

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UNITED STATES GOVERNMENT

Memorandum

TO : Chairman, Panel 11, Medical Analysis

DATE: March 16,1967

FROM : J.A. Thomas, NASA/KSC

SUBJECT: Continuity and Functional Tests of S/C-012 Crew Biomedical Equipment

Report of results of TPS S/C-012 - CM-CA-034 to perform continuity and functional tests on S/C-012 suit biomedical and communications equipment and wiring.

NOTE: Procedures used and results of this TPS are referenced to the following attachments.

(1) Normal layout diagram of suit-torso (biomed-comm) wiring.
(2) PGA wiring print V16-960241
(3) Torso harness print 103120-D
(4) Configuration of PLT suit wiring at start of TPS
(5) " " SRP " " " " " "
(6) " " CMD " " " " " "

1. The PLT suit wiring was received in the Biomed Lab, Room 2440, in the configuration shown in Attachment 4.

2. A continuity check of the PLT suit wiring was performed by ringing from P2 of the PGA to connector MDI-21PL1 (comm) and MDI-9PL2 (biomed) of the torso harness.

3. Pin 21 of P2 to Pin 3 of MDI-21PL1 of the torso harness (audio warning signal shield, Reference Attachments 2 and 3) was found to be open. All other wiring was per prints.

4. The PLT PGA was disconnected from the torso harness and the PGA was continuity checked per print V16-960241 (Reference Attachment 2).

5. Pin 21 of P2 to Pin 57 of P1 of the PLT PGA was found to be open. This determined the open wire (audio warning signal shield) of step (4) above to be in the PLT PGA.

6. The PLT axillary electrode harness was checked for continuity per print with no wiring discrepancies.

7. The PLT biomedical signal conditioners (ECG1, ECG2, ZPN, and DC-DC converter) and torso harness were functionally tested using a test subject and were all operational.

8. A PIA (preinstallation acceptance test) was performed on the PLT DC-DC converter per OCP-K-5110 and there were no discrepancies. This test was made to verify complete operation of this signal conditioner which converts S/C power (16.8VDC) to biomed power (+10VDC and -10VDC).

9. Communications - No testing of the PLT helmet communications hardware was performed due to lack of current wiring prints and specifications. Work to obtain needed data and technical support is in progress. Testing will be done on a subsequent TPS.

SRP

1. The SRP suit wiring was received in the configuration shown in Attachment 5.

2. The cut in the SRP PGA necessitated that the PGA be disconnected from the torso harness for continuity checks.

3. The SRP torso harness was continuity checked from the suit connector MD53-00E15-61PN to the biomed connector MDI-9PL2 per print 103120-D (Attachment 3) with no shorts or open wires.

4. The cut in the communications wiring of the SRP torso harness necessitated that the ribbon cable be stripped approximately ½" on each side of the cut to allow continuity checks.

5. Continuity checks from the suit-torso connector MD53-00E15-61PN to the communications connector MDI-21PL1 resulted in no shorts or open wiring.

6. The SRP biomedical signal conditioners (ECG1, ECG2, ZPN, and DC-DC converter) and torso harness were functionally tested using a test subject and were all operational.

7. The wires at the cut in the SRP PGA were separated to prevent any shorting and all pins of P2 of the SRP PGA were continuity checked for shorts to all other pins of P2.

8. There were no shorts in the SRP PGA as checked.

9. A PIA was performed on the SRP DC-DC converter per OCP-K-5110 and there were no discrepancies.

10. Communications - No testing of the SRP comm. hardware was done due to lack of data.

CMD

1. The CMD suit wiring was received in the configuration shown in Attachment 6.

2. A continuity check of the CMD suit wiring was performed by ringing from P2 of the PGA to connector MDI-9PL2 (biomed) of the torso harness.

3. Pin 29 of P2 of the PGA to Pin 1 of the MDI-9PL2 (torso harness) was found to be intermittent (16.8VDC biomed power).

4. The CMD PGA was disconnected from the suit-torso harness and the PGA was continuity checked per print V16-960241. All wiring was per print.

5. Results of the previous step determined the intermittent wire of step (3) above to be in the CMD torso harness between the suit connector and the MDI-9PL2 biomed connector. Wiring in this area of the torso harness was badly scorched.

6. The cut in the communications wiring of the CMD torso harness necessitated that the wiring be stripped approximately ½" on each side of the cut to allow continuity checks.

7. Upon stripping the wires at the cut, damaged wiring inside the ribbon cable was discovered. The wires were discolored and the insulation appeared to be brittle. The wiring in the rest of the ribbon cable was normal. The wires were identified as microphone signal, microphone signal return, earphone signal, and earphone signal return.

8. Continuity checks from the CMD suit-torso connector MD53-00E15-61PN to the communications connector MDI-21PL1 resulted in the following:

(a) Pins 45,46, and 47 of MD53-00E15-61PN were shorted (mike signal, mike signal return, mike signal shield).

(b) Pins 10,11, and 12 of MDI-21PL1 were shorted (mike signal, mike signal return, mike signal shield).

(c) Pins 3,4, and 10 of MD53-00E15-61PN were shorted (earphone signal, earphone signal return, earphone signal shield).

(d) Pins 13,14, and 15 of MDI-21PL1 were shorted (earphone signal, earphone signal return, earphone signal shield).

These were the damaged wires referenced in step (7). All other wiring was per print.

9. Samples of the damaged wires were obtained per TPS S/C-012 - CM-CA-093 and delivered to the Malfunction Analysis Branch (MAB). The MAB is to perform metalagraphic analysis of these wires to determine temperature to which they were subjected.

10. The CMD biomedical wiring from the MDI-9SL2 connector to the biomedical signal conditioners and the DC-DC converter was continuity checked per print and pins 1,2, and 9 of MDI-9SL2 (biomed 16.8V power) were shorted. The ribbon cable in this area was completely burned away.

11. The CMD biomedical signal conditioners (ECG1, ECG2, ZPN and DC-DC converter) were functionally tested using a test subject and were all operational.

12. A PIA was performed on the CMD DC-DC converter per OCP-K-5110 and there were no discrepancies.

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