MINUTES

First Meeting of Technical Committee on Lightning

January 8, 1964 Room 510A, 800 Independence Avenue, S.W.

The meeting was called to order at 9:05 a.m. by Mr. Auburn.

1. Introduction and explanation of purposes and objectives.

In his introductory statements, Mr. Auburn advised the members and advisors of the committee that he had been designated as the coordinator of Agency lightning activities. One portion of the Agency effort to provide a solution to the lightning problem led to the formation of this technical committee composed of representatives of each government agency with interest in the lightning protection problem. In addition, the committee intends to invite participation, as advisors, other persons from both Government and industry who can be of assistance in arriving at solutions to the various aspects of the problem. In this connection, Mr. Auburn requested that those agencies that had not already done so make specific designations as to the persons that they wish to name as members of the committee. He noted that it is intended that the committee stay on top of the various programs to press for early answers to the various proposals and questions. To this end, frequent committee meetings will be required for a time, perhaps, at intervals of two weeks.

To introduce the problem, Mr. Auburn summarized the situation to date. He pointed out that, in the process of certificating jet aircraft, the lightning hazard was recognized and taken into account. All jet transports have had a great deal of attention paid to protection against lightning strikes. In the case of the accident at Elkton there is a strong suspicion that lightning was the cause. On this account, it appears that we do not know as much as we should regarding the protection of aircraft against lightning strikes. The Federal Aviation Agency has launched a program to try to fill the apparent voids in our current knowledge and to develop specific methods to remove any deficiencies in current protection. The urgency of the situation has led to this program being undertaken concurrently with the accident investigation. It is planned that the information developed by the accident investigation will be integrated into the Agency's program. To accomplish this effectively, it is necessary that the committee retain flexibility in its programs, and have people qualified to accomplish the integration of new data into the program in an effective manner. It is the immediate objective of the committee to have useful results from the short range program before the period of maximum thunderstorm activity this year.

Mr. Auburn then reviewed a summary of the purpose and scope, composition, and operation of the committee that had been handed out as an attachment to Agenda for the first meeting. (Appendix A). In connection with this, he noted that

he had been designated as Executive Director, and Mr. H. H. Osborne, Jr. had been designated as recording secretary. He then reemphasized that the committee will call upon any segment or group of Government or industry that might be in a position to provide help in getting the job done. In this connection, representatives of the Boeing Company are present as interested parties who can be of material assistance in the work of the committee. In concluding these remarks, Mr. Auburn reminded the participants that the purpose of the committee is to provide steering and advice in the lightning program to ensure maximum results in a minimum time. This activity by the committee in no way denogates the responsibility of others to get their own jobs done.

2. Briefing on Elkton accident investigation by Civil Aeronautics Board representatives

Mr. A. B. Hallman of the CAB provided a briefing of the accident and progress of the investigation.

The aircraft involved was a Pan American World Airways 100 series Boeing 707. At the time of the accident, it was on the Baltimore to Philadelphia segment of a San Juan to Baltimore to Philadelphia flight (No. 214). The San Juan to Baltimore segment appears to have been uneventful. At San Juan the aircraft had been fueled with JP-4. At Baltimore it was fueled with JP-1 (kerosene). At this time no fuel was put into the No. 1 and No. 4 reserve tanks, accordingly, there was only residual fuel in these tanks (about 12 pounds each). This residual fuel would have been essentially JP-4. It is calculated that, after fueling at Baltimore, the No. 1 and No. 4 main tanks contained a mixture of fuel consisting of approximately 69 percent kerosene and 31 percent JP-4, and the No. 2 and No. 3 mains contained about 71.4 percent kerosene and 28.6 percent JP-4. The temperature of the fuel at Baltimore, based upon specific gravity calculations, was approximately 42°F. in the outboard mains and 46°F. in the inboard mains. It is estimated that at the time of the accident, the temperature was 40°F. in the outboard tanks and 44°F. in the inboard tanks. No temperature has been estimated for the reserve tanks.

Flight 214 departed Baltimore at 0124 g.m.t. It was cleared to maintain 4,000 feet. Subsequently, it was cleared to the Newcastle holding pattern to hold at 5,000 feet. At 0141 g.m.t. the pilot reported that he was holding at Newcastle at 5,000 feet. As nearly as could be determined, the accident occurred at 0159 g.m.t.

Mr. Hallman then presented a summary of witness statements. He said that to date, 103 witness had been interviewed. The following are extracts from this summary:

1. Eighty witnesses stated that a ball of fire occurred within one to two seconds after the lightning was observed; 28 stated that the fire was observed a few seconds after the lightning.

2. Ten witnesses described the initial color of the fire as white, four said it was blue, 45 said it was orange, and 12 said it was red.

3. Six witnesses said they saw the lightning hit the airplane, 28 said that they recognized the fire as an airplane immediately, 48 recognized it in a few seconds, and 27 did not recognize it as an airplane at any time. (Note the nearest witness was about 1,000 yards from the accident and the most distant one was about ten miles away.)

4. Twenty-nine witnesses stated that the aircraft was in level flight when they first observed it, 10 stated that it was in a shallow dive, 16 said it was diving, and the remainder made no comment on the flight path.

Mr. Hallman then read statements from three witnesses. These reports were all in substantial agreement with the descriptions summarized in the Minutes of the Meeting on Lightning Strike Hazards (copies of which were distributed at this meeting).

Mr. Hallman then reviewed the wreckage distribution. The left wing outer panel was about two miles east and a little north. Nos. 1 and 4 engines had apparently separated relatively early and were found north of the area of the main wreckage. Nos. 2 and 3 engines were very close to the main wreckage. It appears that they separated just before impact, but this has not been determined conclusively. No. 3 was found a little to the south of the wreckage, and No. 2 was west and a little north along with the right wing, vertical fin and lefthand stabilizer.

The destruction of the aircraft was complete as would be expected under the circumstances since the aircraft went in almost vertically. There is, as yet, no good feel for the fire pattern. It is evident that there was fire in flight and there was considerable additional fire damage after impact. There was separation of the right wing near the fuselage about at the inboard side of the main fuel tank. This apparently occurred immediately before impact. The left wing, inboard of the reserve tank remained with the fuselage. The flight recorder was badly damaged; it took considerable time to get its record into condition for reading. Reading of this tape is now underway. A preliminary look at the "g" trace shows some turbulence but not enough to endanger the aircraft. Apparently there had not been enough to disturb the pilot.

The engines have been examined. Although they were badly damaged, it has been possible to determine that there had been no release of high energy parts. The rotational damage incurred by the engine is about as would be expected in a case of sudden stoppage due to engine impact with the ground.

Examination of the left wingtip area shows evidence of lightning strikes. The program to make a detailed examination of this area will be handled by Mr. Newman of Lightning Transients Research Institute, possibly Mr. Robb of LTRI, and Mr. Peterson of the high voltage laboratory of the Bureau of Standards. The lightning investigation will be done primarily at the Bureau of Standards.

A check for magnetism in steel parts has been made. A number of places have been found where there is some magnetism. These include the left wing, the vertical stabilizer fin, the horizontal stabilizer, and clamps around engine mounts. Similar aircraft have been checked at Dulles and Andrews Air Force Base and magnetism was also found in these same locations. It appears that the magnetism is a little stronger on the wreckage, but it has not yet been determined if this is significant.

There have been some surveys by airlines of resistance values between access plates and wing covers. Boeing recommends a value of not more than .008 ohms. Some cases have been found with resistances of 1 ohm or higher, other typical values have been on the order of .01, .3, and .015 ohms. There is no correlation of these values to time in service. It is intended that there will be followup checks to determine if there is a correlation between these values and time in service.

Examination of the wing structure, including the No. 1 reserve tank, shows evidence of high internal pressures. The associated surge tank is essentially intact and shows some evidence of sooting. It has not yet been opened and soot not yet analyzed. This is being delayed until LTRI and the Bureau of Standards can examine the wing.

Mr. Auburn added that earlier reports had included an observation by a National Airlines DC-8 which was at 6,000 feet in the same holding pattern. The pilot of this aircraft reported that there had been a lightning strike to his own aircraft a few minutes prior to the accident. He observed no severe turbulence. Subsequently, following a heavy flash of lightning, he saw another aircraft going down in flames.

Mr. Auburn then observed that it is necessary to consider possible causes for this accident noting that it appears pretty clear that there was an explosion in the No. 1 reserve tank. In reply to questions concerning the lightning strikes, Mr. Auburn exhibited a sketch of the wing with the various components shown on it.

It was noted in detail that the skin had been blown off of the top and bottom of the reserve tank. There were no punctures observed in the tank area. The lightning strike marks were noted on the tip, including several small holes. The wingtip is constructed of .025 inch aluminum. As noted earlier, there were signs of sooting and burning within the surge tank.

These circumstances, Mr. Auburn observed, lead to two immediate questions:

1. Is it possible that an explosion in the wing tank was caused by a lightning strike on the wingtip?

2. If it was, what can be done to prevent it from happening again?

Mr. Nordstram pointed out that pieces of structure have been, and are being, carefully examined for possible internal discharges. Some areas have marks or signs that require laboratory analysis. There is a trace of something on an inboard vent check valve that is being examined further.

Mr. Auburn continued that problems associated with internal bonding, induction, and ignition through the vent are being actively considered. There are, however, other possibilities that must not be ignored. For example, the fire might have been caused by something other than lightning or the entire sequence of events might have been triggered by structural breakup. Mr. Nordstram added that the sequence of the progression of the fire may well have been different than has been supposed. In this connection, it has been observed that there was no particular burning damage to No. 1 engine while No. 2 engine was badly burned.

Mr. Kinzer asked if there had been any pitting found on other surfaces of the aircraft. Mr. Hallman answered that no other strike points had been found. It is quite possible that they were on the nose which was completely destroyed.

Cdr. Henderson asked if there is any ventilation of the fuel tanks. Mr. Nordstram replied that the arrangement of the vent system is such that the tank breathes with increases and decreases in ambient pressure, but there is no actual ventilation in the sense that air is flowing through the tank. He added that under normal operating conditions with no turbulence, the lower skin of the outboard reserve tanks in the area adjacent to the surge tank wall is not wetted.

Col. McDonnell of the Office of the Director of Aerospace Safety of the USAF summarized Air Force experience.

In Europe one or two years ago, a C-130 at 7,000 feet was struck by lightning. The strike was followed by one loud and one muffled explosion. Flames were observed trailing from the right wing area. After landing, it was found that the aft cone of the external fuel tank had been blown off. The fuel used was JP-4. Pitting was observed on both wingtips and on the outboard ailerons. Mr. Auburn asked Col. McDonnell if a copy of the report of this incident could be furnished. Mr. Rolle noted that we do have pictures and a wire on this subject. Col. McDonnell said that he would furnish a summary of the report.

Col. McDonnell said there are no other cases in his records of fire having been reported on Air Force aircraft following a lightning strike. Mr. Nordstram said that Boeing has a service report on a case wherein a lightning strike on the nose of a B-52 walked back to the tail vent outlet and lit a fire there, which attached and progressed four or five feet up the pipe before going out. The crew were unaware that there had been a fire until after the airplane was landed. Mr. Nordstram said that he would furnish a copy of this report.

Col. McDonnell continued with a summary of an incident involving another B-52. In this case, a strike by a cloud to ground stroke of lightning was observed, but no damage to the airplane was noted. After landing, fuel was found to be leaking from holes burned in one pylon fuel tank. This tank contained JP-4.

In another case, an occurrence of what was described as an electrostatic discharge on an F-102 blew off the radome and knocked out the instruments, and caused loss of control of the aircraft. The pilot ejected. It does not appear certain that the aircraft would necessarily have been lost in this case. This is the only case recorded by the Air Force in the period from 1959 to 1963 that an aircraft has been lost as the direct result of a lightning strike.

Since January 1962, the Air Force has required reporting of unusual occurrences that might result in flight hazards. Reporting of lightning strikes and electrostatic discharges is covered by this requirement, although it must be recognized that a great many lightning strikes, particularly where there is no noticeable damage, are still unreported. In the period since this reporting was started the following information has been collected:

1. There have been 66 reports of lightning strikes or electrostatic discharges.

2. Forty-one cases involved pitting of wingtips, elevators, radar, etc. (The preponderence of these occurred on large transport or bomber aircraft). In 22 cases the radome was hit resulting in damage extending from cracking to complete loss.

In four cases, the radios became inoperative (4 of these were due to loss of the antenna.

Eleven cases involved other skin damage.
Twelve cases resulted in system malfunctions.

3. Eight cases occurred below 5,000 feet.
Thirty-four occurred between 5,000 and 10,000 feet.
Eight occurred between 10,000 and 15,000 feet.
Eleven occurred between 15,000 and 20,000 feet.
Five were above 20,000 feet.

4. There were 11 reports involving B-52s, nine on C-124s, eight on C-54s, six on C-119s, two on KC-135s and four on F-100s. The remainder were distributed among other aircraft.

5. Twenty-nine incidents occurred in the period from March through May.
Thirteen occurred from June through August.
Eleven occurred from September through November.
Thirteen occurred from December through February.

Col. McDonnell said that a more complete compilation of these data have been put into a report which will be available in the near future, and which he will provide to the committee.

In answer to questions, Col. McDonnel provided the following additional information:

1. There has been no great amount of magnetism of steel parts observed after lightning strikes.

2. The accident involving a KC-135 that came apart in flight a few years ago did not involve lightning.

There followed a brief discussion of St. Elmo's fire and ball lightning. It appears that there is a considerable difference of opinion about ball lightning and much is yet to be learned about it.

Regarding the possibility of electrocuting occupants of an aircraft, Col. McDonnell said that the Air Force has no case on record wherein this is suspected. It is understood that a pilot flying an Auster over Belgium was reported to have been electrocuted by lightning. In this case, it appears to have come through a plastic canopy and passed through the pilot into his headphones. The Air Force had a case where two fighters were flying close to each other and experienced a simultaneous lightning strike during which both pilots experienced mild electric shock. These cases involve circumstances different from those present in transport aircraft; however; and it does not appear that electric shock is a problem with transports.

Mr. Auburn next asked if the Navy has made any surveys of experience similar to the one reported by the Air Force. Cdr. Henderson replied that Navy experience has been about the same as Air Force experience. He cited one case wherein a C-121 early warning aircraft was struck by lightning over the Atlantic. It experienced a heavy strike which blew the generators off the line and started electrical fires. After extinguishing the fires and regaining some electrical service, the aircraft proceeded to the Azores. When the aircraft departed the Azores to return home, it was discovered that sufficient magnetic disturbances had been developed to render the compasses inoperative and it was necessary to vector the aircraft to its destination. There is no case of a lightning strike on a Navy aircraft involving the fuel system. Cdr. Henderson said that he would assemble Navy data on this subject and give a report to the committee.

With regard for the nature of lightning strikes and the damage that might be caused by them, Mr. Kinzer explained that a full-blown lightning discharge is a very effective shock wave generator and that, where combustibles are close enough to the stroke, the shock waves are possible ignition sources. Mr. Pinkel added that this aspect is being explored, but that nothing definitive has yet been developed. He added that for a few milliseconds this shock wave is expanding and can generate a gas surge which introduces additional problems insofar as fire protection is concerned.

3. Precautionary Measures

Mr. Auburn presented a review of actions that have been taken and considered. He noted a program had been recommended to Aircraft Development Service and that this would be covered in detail by Mr. Hansberry. The following summary of actions was then presented:

1. After the CAB had made known their tentative ideas concerning the Elkton accident, there was a joint discussion between the CAB and FAA at which the evidence then available was described. The following day a NOTAM was issued to remind everyone involved of the need to make pilot reports concerning turbulence and lightning, and to emphasize that thunderstorm areas should be avoided as much as possible.

2. A telegraphic message was sent to operators recommending that static dischargers be put on aircraft not already having them as a precautionary measure. This was a recommendation instead of a requirement because the effectiveness of dischargers in providing protection against lightning has not been established. There is a considerable body of authoritative opinion that their effect is minimal.

3. There has been considerable pressure to prohibit the use of JP-4 or avoid having empty fuel tanks. After considerable study of this matter, it was concluded that this would not be a very reasonable approach. There is no clear safety advantage of one fuel over the other. The environmental conditions in the fuel tanks determine the degree of hazard associated with the fuel being used, and these conditions vary to an extent and through a range that makes it unlikely that any fuel in use will provide well defined protection against flammable mixtures in the tanks.

4. A question concerning skin thickness on the surge tank has been raised. Information now available indicates that a skin thicker than .081 inches is unlikely to be penetrated. The thickness of the skin in this area of the aircraft involved in the Elkton accident was .064 inches, however, it should be noted that there has been no indication that this skin was struck by lightning. Some 707 aircraft have leading edge flaps and slats which introduce a possible lightning strike hazard in the surge tank area. Boeing Service Bulletin 1642 provides for an armor skin to be placed on the wing in this area. The Western Region is considering requiring mandatory installation of this armor.

5. Bonding of the fuel tank access doors is being studied by Boeing and the Western Region. It appears that there are several arrangements of these doors in service and that most are affectively insulated from the wing skin, requiring bonding straps. Mr. Tanke noted that, even

with bonding straps, some arcing may occur around plates because of induction. He added that they have looked at other aircraft and it appears that most are a little better because their access panels are structural members, permitting good metal to metal contact. Mr. Duffy observed that, where wing stiffeners are chromated prior to assembly, there may be a number of isolated current paths which would create numerous opportunities for arcing. Mr. Tanke said that the Scotchweld process also creates this situation in skin panels where it is used for bonding. Mr. Tanke directed a question to Mr. Nordstram as to Boeing's work on the bonding plates. Mr. Nordstram replied that a final answer has not yet been found. The problem concerns fretting corrosion because there is relative movement between the structure and the non-structural access plates. A lubricant with 60 percent aluminum powder is being evaluated but no conclusion yet reached. An active team is working on this.

6. The Propulsion Branch has a program to assemble all information available on lightning strike experience. This will be compiled in a report which will be provided for the use of the committee and program guidance.

7. It is desirable that it be determined that we are aware of all of the research already done in the area of lightning protection on aircraft and fuel tank ignition. Mr. Auburn, therefore, requested that the committee members prepare a list of reports known to them. This will then be compiled into a master list. In response to a question as to whether the reports should be presented at the same time, Mr. Rolle answered that, since we already have a considerable number of reports, it would be better to prepare the list first then collect only the reports we do not already have.

After asking for suggestions or comments on the portion of the program described and receiving no further discussion. Mr. Auburn summarized that the group appears to be in general agreement with these current steps being taken, and that there were no suggestions for additonal specific precautionary actions.

4. Briefing on FAA Program

Before proceeding to the specific briefing, there was a short discussion of some detailed points.

Mr. Peterson suggested that it would be helpful to establish a glossary of terms. Mr. Hemingway agreed. It was suggested that the Bureau of Standards and LTRI undertake to do this, but there appears to be a question of cost that might make it impractical.

Mr. Rolle asked if Boeing or the CAB had looked at the overhead fuel filler caps in the aircraft involved in the accident. Mr. Hallman replied that these will not be removed until the Bureau of Standards and LTRI have examined the wreckage. Mr. Nordstram pointed out that the 707 filler caps are different from those tested by LTRI.

In reply to a question by Mr. Auburn, Mr. Bache stated that the information available to the Western Region had been covered in the discussion. He did note, however, that Boeing is looking into flame arresters, but this was scheduled for later discussion.

Proceeding to a briefing of FAA programs, Mr. Auburn asked Mr. Hansberry to summarize the work being done by Aircraft Development Service.

Mr. Hansberry passed out a sheet entitled "Program for Investigation of Aircraft Lightning Measures" (Appendix B). He reviewed the details of this program, noting that it represents the immediate effort of the Agency and that Phase I and Phase II, listed in this program, will be carried out concurrently, coming together in the latter phases. He added that there is a longer range program planned to accomplish the tasks that will require more time.

Mr. Pinkel suggested that the overall effectiveness of the program would be considerably enhanced if the experiments and tests were overseen by persons having a broad range of knowledge of fuel and ignition problems, and an appreciation of the subtleties involved. Mr. Hansberry asked for recommendations and Mr. Pinkel suggested that the group that had been used by Lockheed, Dynamic Sciences was very knowledgeable in this area. The Stanford Research Institute is also qualified in this area.

Mr. Auburn asked which part of the program was causing Mr. Pinkel concern; and he replied that he was primarily concerned with the long range program, but there might also be some need for guidance in the short portion. Mr. Auburn then suggested that an effort be made to obtain the services of a group such as Dynamic Sciences or SRI for the long range program, and the talent immediately within or available to the committee be used to oversee the short range program. Mr. Auburn believes that the committee will meet frequently enough to stay on top of program. There was general agreement with this approach and Mr. Pinkel indicated that he would be available for this effort. Mr. Weeks suggested that, for the long range portion, the Agency might also be able to provide the necessary management of the program. Mr. Hansberry replied that basically Aircraft Development Service is doing this. The matter of providing effective, on the spot, and qualified guidance to the specific experiments will be looked into further.

Mr. Nordstram expressed concern that a quick fix type of solution, as might grow out of the first phase of the Agency program might produce severe economic burdens. Mr. Auburn replied that we hoped to avoid this through the efforts of the committee and the work being done by Boeing and others, and that concern over this problem should not deter the effort to get answers as quickly as possible. Mr. Nordstram said that he was inclined to agree as long as the committee is steering the program.

In connection with the specific items in the proposed program, Cdr. Henderson said that BuWeps have some material on flame arresters that they will provide to the committee when assembled.

Col. McDonnell added that there has been work done by the Air Force on propagation of flames in aviation gasoline through vent lines. Mr. Hansberry added that the Air Force is interested in the Agency's long range program. He had spoken to some Air Force personnel at Miami on Tuesday, January 7.

Mr. Nordstram recommended that the effect of fuel leakage causing fuel to collect in the wing should be considered in the short range program since a fire in the trailing edge was noted in the accident., and that the effects of airflow should be taken into account. Mr. Pinkel concurred with these suggestions. Mr. Pinkel also suggested that the flame arrester tests include the effects of breathing. Mr. Hansberry noted the suggestions and indicated that LTRI will have a facility for producing airflow.

No further information regarding the availability of a wing section. Boeing has one in New York and one in Paris. It appears that the Air Force has no available spares. There are some minor differences between the 707 and KC-135 wings; the details are not immediately available, but it appears that these differences would not adversely affect the proposed tests. Mr. Hansberry reiterated the need for an actual wing section.

Later in the afternoon, Mr. Hoekstra brought in more recent information regarding wing panels. There are none at OCAMA. The Air Force has no knowledge of any salvaged wing. There are two at New York available over-the-counter for airliner use at present. There are two at Seattle from the KC-135 fatigue test article. (It was noted that these would not be satisfactory because they have no sealant or hardware.) It appears that price on the wings at New York is about $100,000 each. Aircraft Development Service would have difficulty in purchasing one of these. Mr. Nordstram said that Castle Air Force Base had a C-135 wing being used as a sealant application trainer. This at least indicates that there may be wings around that are being used for other things or surveyed and forgotten. Co. McDonnell said that he has had a records search made and has not yet found anything. The question of acquisition of a wing, which is vital to program, remains unresolved, but renewal efforts are being made to locate and obtain one.

Mr. Auburn noted that the program proposed for early completion is detailed and the long range program is not. This has been done deliberately so that the long range portions can be planned to accommodate the knowledge that is developed through the immediate program and the findings of the accident investigation. One of the functions of this committee will be to participate in the formulation of the details of the long range program.

5. Review, Discussion, and Recommendations.

A. Investigation of bonding and internal sparking.

Mr. Hansberry explained that because we don't know what is important in evaluating the effects of lightning insofar as bonding and sparking are concerned, it is especially important that an actual, fully equipped wing

section be used in this program. Even so, a substantial amount of uncontrolled variables are introduced by considerations of age and service. Mr. Nordstram agreed that changes do take place but recognized that we have no way of simulating them. Among other things, maintenance procedures introduce variables beyond the control of the manufacturer. It is understood that Pan American is investigating bonding and resistances of some older aircraft. They have inquired about the normal values of electrical resistance across skin joints.

Mr. Pinkel expressed concern about fuel probes in the tank. Mr. Nordstram replied that these probes are not very likely discharge points as they lay at an angle and are up against intermediate ribs.

B. Flame arrester studies

Mr. Auburn reviewed the plan for the first studies to look at the mechanism of flame propagation. Assuming that propagation through vent pipes can occur, there will than be specific investigation of particular designs of flame arresters. For example, an arrangement suggested by Mr. Pinkel will be investigated. Suggestions for other approaches were solicited.

In reply to Mr. Tanke's suggestion of a lot of small tubes, it was observed that sparks can be driven through these.

It appeared that information to be submitted by Cdr. Henderson might provide some help in this area. The Navy's approach in this area generally is to have their contractors work closely with LTRI to develop suitable arrangements.

Boeing's view on work to date on flame arresters is that none developed to date has been able to cope completely with lightning. Mr. Rolle replied that our objective now is to find one that will provide protection against lightning. Mr. Weeks commented that we appreciate that we may be going over old ground, but we now have more urgency in our search for an answer. Mr. Nordstram, agreed, saying that Boeing is now working on flame arresters on an exceptionally high priority basis, and Mr. Utterstram added that they will make the results of their work known.

Mr. Nordstram observed that strikes right in the vicinity of vent outlets pose different problems because of the plasma phenomenon. It looks as if some design ingenuity may be needed to solve this. Mr. Pinkel agreed. He said that he has in mind as a last resort type of measure some device such as oscillating check valves that introduce periodic interruptions to the venting such that there is never an open flow path all the way through the vent and the flame is held at some point long enough to cause it to go out before the succeeding vent passage is opened. A device known as a Lisk Disc was also discussed. This is a circular shaped arrangement with a spiral passage provided for gasses passing through and folded metal contained within the spiral passage to provide small area openings and act as heat sink material.

It is accepted by the Fire Underwriters, Bureau of Mines, and USPA as an effective flame arrester.

Mr. Pinkel then suggested that the same means might be used for protection against detonation waves and plasma, if a passage is suddenly enlarged. As in a plenum both of these phenomena will tend to dissipate. The critical factor seems to be the area ratio between the cross sections of the vent and the plenum. Work is needed in this area. A flame arrester would probably still be needed.

C. Fuel liquid/vapor conditions in flight

Referring to the meeting of December 17, 1963, Mr. Auburn noted that it had been recommended that we find out more than we know about fuel liquid/vapor conditions in flight, under varied operating conditions. It is recognized that there is now little knowledge about what goes on in the fuel tanks under actual flight conditions. A study of this is being considered as part of the long range program. Mr. Nordstram expressed the view that it may not be too difficult to do this. For example, clock driven sampling devices have been used successfully in other areas. There appear to be significant complications introduced in sampling fuel, however, because of the transient nature of fuel mists.

It was agreed by the committee that this is a worthwhile program to provide information that is needed for a full understanding of the possible hazardous conditions that might exist in fuel tanks.

D. Inerting

Mr. Auburn pointed out that this is also a part of the long-range program, and asked if there were any views as to what approach might be most fruitful.

Mr. Nordstram replied that Boeing is taking a hard look at inerting. The most feasible system seen so far involves the injection of freon into the fuel tank vapor space. Further studies of this are being considered. This system would not be continuous. A continuous system would have to contend with outgassing of oxygen. Scrubbing the oxygen from the fuel would be excessively expensive and outgassing of oxygen would negate the effectiveness of the inerting agent. Mr. Pinkel added emphasis that it is primarily oxygen that is released by the fuel. The dissolved gas in the fuel is about 70 percent oxygen. The major cost of fuel scrubbing would be in the equipment required so that processing fuel only on critical flight would not reduce the expense significantly.

E. Explosion suppression

Mr. Auburn noted that evaluation of explosion suppression systems is in the short-range program.

Mr. Nordstram said that he envisages a unit that is self contained using nickle-cadmium batteries and independent of the aircraft electrical system. It would be designed for easy installation so that it can be replaced at 30-day intervals. It is felt that this is a most promising area for investigation. Such a device could be used in many critical areas.

Mr. Auburn osbserved that this discussion should be helpful in framing up the work in this area.

F. Static dischargers

It was agreed that the committee would confirm the earlier view that static dischargers are not useful in providing protection against lightning. Mr. Tanke added that discussions with manufacturers of wicks, and Stanford Research Institute have also confirmed this view.

G. Diverters

Diverters are to be considered in the short range program. The question to be resolved is whether or not a diverter can provide effective protection to a vent that might otherwise be hit by lightning. Although some authoritative information indicates that diverters are effective within limits it is understood that Stanford Research Institute has expressed some reservations as to their effectiveness. It was agreed that diverters should be included in the program.

Mr. Auburn then asked for additional items for the FAA program.

Mr. Hansberry suggested that flammability curves should be investigated using high energy ignition sources. Mr. Auburn said that this would be added to the study of fuel liquid/vapor conditions in flight.

Mr. Pinkel distributed to those present copies of a proposed program that he had worked up. (Appendix C) He noted that it was essentially the same as the program discussed, but there were some detailed ideas that might be useful after the committee had an opportunity to review it. Mr. Pinkel also suggested that the investigation of bonding and internal sparking should consider the effects of damage (e.g. skin damage effectively compromising the Faraday cage). In addition, he felt that the problems of the charge on fuel, including that induced by turbulence, should be examined.

Mr. Auburn noted that Mr. Pinkel's suggestions would be considered.

6. Other Programs

Mr. Auburn stated that this had been touched on earlier and that the objective is to introduce any related work into the programs to avoid duplicating things that have already been done and to take the greatest possible advantage of existing knowledge. He expressed concern that there may often be military work that we are unaware of. Mr. Wight said in reply to this point, that in this area most of the work has been unclassified. He will look into the "Rough Rider" program to see if there is any useful material there.

Mr. Nordstram said that he believes that there might be something going on now with regard to inerting in some models of the C-130. It was suggested that this should be looked into.

Mr. Auburn in his concluding remarks said that we will want continuing contacts with all members and advisors and the benefit of the results of their efforts, findings, and views in the conduct of this program, as well as their support in obtaining the necessary material including a wing. We would desire to have Boeing observe the work done by LTRI. In this connection, it may be advantageous to have available knowledgeable individuals meet at Miami when the program is ready to go. The committee expects to be able to call upon any members on very short notice, to provide support as needed.

Col. McDonnell suggested that, while Norton AFB is willing to provide support, their situation tends to make membership on the committee impractical.

Mr. Auburn advised that we had considered meetings at approximately two-week intervals, and that the committee should tentatively plan to meet in about two weeks.

Two comments were made concerning the minutes of the meeting of December 17.

1. Mr. Berman raised an issue with the substance of the discussion on page 8 of the relative hazard of JP-4 and kerosene.

2. Mr. Peterson asked that the reference on page 3 be revised to indicate that there was no bulging of the skin of the right surge tank.

H. H. Osborne, Jr.
Recording Secretary