

Colonel BORMAN. Sir, I would be remiss if I did not admit that I am extremely anxious to meet the goals of this program. I am extremely—quite frankly, personally I am very anxious to make sure that, to see that we have an American lunar landing first. That is a personal desire.

However, never since I have been associated with NASA have I ever experienced any decision where a known detriment to crew safety was sacrificed to any operational requirement. And although I am willing to accept risk as I pointed out yesterday to the House committee, I am not willing personally to accept undue risk and I would not participate in any decision which I thought was expediting a program in an unsafe manner; and in the final analysis the crew is the real review board because if we do not like the way the spacecraft is configured, we don't have to get in.

Senator CANNON. And you would have no hesitancy if your recommendations were followed; you would have no hesitancy as a pilot yourself to proceed on that basis?

Colonel BORMAN. That is correct, sir.

Dr. THOMPSON. Could I add something on that point, Senator?

Senator CANNON. Yes, sir; you may.

COMPARES ONE-GAS AND TWO-GAS SYSTEMS

Dr. THOMPSON. I referred in my statement to the necessity for working out all the operations that would be associated with the two-gas system. Those problems have not been solved and whereas we have a very extensive record of reliable operation with oxygen, pure oxygen, in flight, we have no record that shows that we really know how to work with all these problems of diluent gas, identification of all the constituents in there, all the machinery or all the mechanisms that would be required to get out of the spacecraft and go into space; get out of the spacecraft and get on the moon, get back in.

Now, those problems are very considerable and as long as we are able to go along with this system that has proven to be so reliable until this last event; I think there is a pretty strong compulsion to stay with it.

Now, there are times I think if a craft is going to stay in space for long periods of time, it will probably be necessary to use a two-gas diluent system. But those problems, say, are not solved and I think we have to be very careful in trading off the unknowns of an unproven system for one identifiable item of risk in a well-proven system.

So that our feeling is that one of the most important things is to deal with matters as Colonel Borman has talked about, we have talked about getting rid of the sources of ignition, reducing the combustibles, making a greater use of materials that will not easily ignite, and otherwise reengineering the interior relative to this whole question of ignition and flammability rather than say we want to undertake a risk that we have not even properly assessed.

BOARD PERSONNEL DISCUSSED

Senator CANNON. Thank you, Doctor.

My time is about up. I would like to ask you just one final question relating back to my initial point.

There has been some criticism as you know that there are, or were too many NASA personnel and not enough outside experts on the Review Board.

What would have been the effect of bringing in more non-NASA experts in your judgment?

Dr. THOMPSON. In my opinion it would have been rather difficult. If Dr. Van Dolah does not mind my referring to his indoctrination into the system required to pursue a review of this magnitude without familiarity with it, I am sure he will agree that at times he became very impatient with the system because it seemed to get in the way of progress, but the system is the one thing, paperwork, the direction to people, is one of the major elements that makes a program like this possible, that makes it possible to organize efforts on a large scale with people on a 24-hour basis and a 7-day week basis and that system at times gets in the way of quick steps, but if we did not have people who were conversant with that, I am afraid we would have been very—would have felt frustrated and probably would have had a lot of trouble with them.

Senator CANNON. When you say “had a lot of trouble with them,” do you mean just delaying your decisions or—

Dr. THOMPSON. I think it would—

Senator CANNON. Or impeding progress?

Dr. THOMPSON. I think they would have felt frustrated and felt dissatisfied with the lack of progress.

Senator CANNON. We are not concerned here with what the members might have felt. We are concerned with what the Board might find and might have found and what they can report to this committee and to the public.

Dr. THOMPSON. We acquired a great many experts to work with the Board. We canvassed the whole country and we got an extremely responsive effort from experts in all areas wherever we looked for help, and some volunteered their help and were very helpful, and I don't think, in any way, we suffered from lack of expertise in the areas that we pursued because the country as a whole seemed to be very, very interested in contributing anything that they could.

The heads of—well, the president of MIT, and the other colleges, offered to help and did contribute. We got help, expertness from the FAA, the CAB. We employed the expert assistance of the Naval Research, one of the Naval Research's most active people on fire. I don't see how we could have gotten much better help than we had.

Colonel BORMAN. Sir, don't you think really it is safe to say that regardless of who composed the Board, the findings and determinations and recommendations would probably not have been materially changed. Is that what you are getting at?

Senator CANNON. That is what I am trying to get at.

If that is your conclusion, I am very happy to have it, Colonel.

Do you agree with that, Doctor?

Dr. THOMPSON. I think that we were able to do an adequate job with the people that we had and with all the help that we got and I don't see how we could have much improved our capability.

Senator CANNON. And you had all the expert help you needed according to your testimony.

Dr. THOMPSON. Expert help from any source we asked for help, we got it.

Senator CANNON. Thank you, Mr. Chairman.

The CHAIRMAN. Before Senator Curtis starts, will you please review the statements by panel No. 9—Design Review Panel—on page D-9-6 and give us some statement this afternoon because in that report the panel speaks of design deficiencies. It says: "Some areas of wiring exhibited what would be referred to as rat nests." I think those are pretty strong words and you might have something to say.

Senator Curtis?

BELIEVES FIRE DUE TO ERROR IN JUDGMENT

Senator CURTIS. Thank you, Mr. Chairman.

Did this fire occur because of a wrong decision or decisions made by our space scientists?

Dr. THOMPSON. I don't think it was a particular decision that caused it. I think it was a situation as has been pretty clearly described that resulted in it but I don't see any particular decision that caused it.

I don't see how we could identify it beyond what we have already described in that connection.

Senator CURTIS. What I want to know is this. Was the error or shortcoming, if there were such, in the field of scientific decision, of our space scientists, or was it in the area of executing what our space scientists said should be done?

Dr. THOMPSON. I think it was an error in judgment in identifying how great the risk was with what we saw there and as Colonel Borman has said, he knew about those things and the risk that apparently lay there had not revealed itself to the point that people thought it was too great to undertake the flight.

Senator CURTIS. Well, maybe I have not stated my question very well but what I am trying to get at is this. Was the plan scientifically wrong or was the shortcoming in executing the plan?

Dr. THOMPSON. There was nothing wrong with the plan that I know of.

As far as being scientifically wrong, I don't think there was anything wrong in that sense. It was simply the execution, detailed execution that resulted in this event.

Senator CURTIS. Do you concur in that, Colonel Borman?

Colonel BORMAN. Yes, sir.

Senator CURTIS. I believe you stated that you were aware of defects or problems in wiring prior to going on this board.

Colonel BORMAN. Yes, sir. I was on the backup crew for the sister ship to Spacecraft 012 and there were problems in wiring.

I must point out there are problems in the development of every vehicle.

Senator CURTIS. I understand.

Colonel BORMAN. And these were normal problems.

ASTRONAUT WOULD NOT HESITATE TO ENTER SPACECRAFT

Senator CURTIS. Now, would you have entered that spacecraft on this morning of the accident if your turn had been called?

Colonel BORMAN. Yes, sir. As a matter of fact, —

Senator CURTIS. Would you have had any hesitancy?

Colonel BORMAN. No, sir.

Senator CURTIS. And would you have been mindful of what you have just stated about criticism of some of the wiring?

Colonel BORMAN. No, sir; because in my opinion the people that were responsible for that spacecraft, including the crew, and the crew assumes a major interest in the reliability of the hardware, felt that the defects that had been noted throughout the development had been corrected and the spacecraft as it existed prior to this test was believed to be in good shape.

Senator CURTIS. Were there defects of workmanship?

Colonel BORMAN. There were, sir.

Senator CURTIS. Did they go beyond workmanship?

Colonel BORMAN. Defects in the design of the wire bundles, their routing, their construction, and in my opinion, a basic deficiency in the wiring, in the harnesses, that distribute electrical energy.

Senator CURTIS. Well, if you would have entered that spaceship that morning, would you have been motivated by a willingness for a risk taking?

Colonel BORMAN. No, sir. As I pointed out earlier, I am afraid that sometimes the newspapers and the magazines attest a great deal more of the silk scarf attitude to the astronauts than actually exists. I am willing to accept reasonable risks in pursuit of worthwhile goals but I am not willing to accept any undue risk.

Senator CURTIS. I understand.

Colonel BORMAN. So I would not have entered that spacecraft if I would have thought there was any danger of the disaster that occurred.

Senator CURTIS. In other words, while you were critical of some of the wiring, workmanship, and design, you were never critical to the point that you would say, "Well, I would not get in one of those"?

Colonel BORMAN. That is correct, sir.

FIRE LASTED 25 SECONDS

Senator CURTIS. How long did that fire last?

Colonel BORMAN. Dr. Van Dolah—excuse me, may I ask him?

Senator CURTIS. Yes, sir.

Dr. VAN DOLAH. It probably lasted only about 25 seconds, sir.

Senator CURTIS. Did the fire extend beyond the time that the astronauts died, do you think?

Dr. VAN DOLAH. Well, I might say that the fire presumably went out at about 30 seconds after the minute, some 25 seconds after we had the first report that there was a fire in the spacecraft.

The levels of carbon monoxide were very high at that time because of the deficiency of oxygen for the combustion.

I think that the medical testimony, medical evidence, medical opinion states that unconsciousness probably came in a matter of perhaps 30 seconds after the lethal quantities of carbon monoxide developed, 15 to 30 seconds, I believe, and that death followed a few minutes later.

Senator CURTIS. The fire was out, then, when they died?

Dr. VAN DOLAH. Yes, sir.

FAST OPENING HATCH MAY HAVE SAVED CREW

Senator CURTIS. Well, would it have made any difference what kind of an escape hatch there would have been?

Dr. VAN DOLAH. Yes, sir.

As I pointed out in the pressure record that we have of the fire, there was a period of many seconds, many in terms of the total event, perhaps 8 seconds or so before the fire began to be very vigorous. If there had been means for rapid dumping of the pressure and a hatch that could open in 2 or 3 seconds, I believe the crew could have escaped with only minor injuries at most.

Senator CURTIS. Are you prepared to say what kind of a hatch it should be, taking into account that the vehicle be in orbit?

Dr. VAN DOLAH. No, sir. I believe this gets beyond my expertise.

I think that it needs to be quick opening for certain emergencies but needs to have ample protection against accidental opening at times when you don't want it to open, but I believe this is something that others would be better prepared to discuss.

Dr. THOMPSON. Could I say something at this point, Senator?

A hatch design, redesign, was underway prior to this and I think that perhaps Colonel Borman can describe the situation a little bit better than I can relative to that.

Colonel BORMAN. Sir, the hatch that we had on the Apollo 012, Command Module 012, was an inward opening hatch that used the pressure of the spacecraft atmosphere to seal it, help seal it on orbit. It was a hatch that was not desirable for extra-vehicular activities. As a consequence of this, a redesigned hatch for Block II spacecraft was on the way at the time of the fire.

This hatch is being pursued actively now and all Block II spacecraft will have this new hatch. It is an outward opening hatch that will open in a matter of seconds.

Senator CURTIS. Now, if that hatch had been on the vehicle at the time of the accident, would they have escaped?

Colonel BORMAN. In my opinion, yes, sir.

Senator CURTIS. That is all, Mr. Chairman.

The CHAIRMAN. Senator Young?

Senator YOUNG. Thank you, Mr. Chairman.

At this time I have no questions.

The CHAIRMAN. Senator Jordan?

BOARD MEMBERSHIP WELL QUALIFIED

Senator JORDAN. Thank you, Mr. Chairman.

Going back to the line of questioning pursued by Senator Cannon, I am not altogether satisfied, Dr. Thompson, with some of the answers. I want to go into this a little deeper.

You say in your statement the Apollo 204 Review Board was established by the Administrator of the National Aeronautics and Space Administration on January 27 and was confirmed by memorandums.

Now, we get appointments by the executive branch and confirmations by the Senate in some instances but I don't understand what confirmation by memorandums is.

Will you explain the memorandums and who issued the memorandums?

Dr. THOMPSON. Well, sir, I think this is a case where the paperwork had not quite caught up with the program, some of the same things we talk about in pursuit of this whole endeavor. The events move fast and I accepted the responsibility as Chairman and did not wait

for the paperwork to catch up. I talked to Dr. Seamans as we went along, we formulated the course of action. The paperwork caught up with us as indicated by those two memorandums, although we had oral understanding, verbal directions as to what course we would follow.

Senator JORDAN. You have already testified that you believe the members of the Board, members of the panel, and certainly I am not doubting their competence, but you testified that perhaps they were the best qualified to make this in-house investigation.

Is that true?

Dr. THOMPSON. Well, I would say they were qualified to make it. I don't know whether they are best qualified. I think they did a very good job as far as I am concerned. They supported me.

Senator JORDAN. Do you believe that it was necessary to have on this team, making an investigation of itself, the director for reliability and quality of the Apollo program?

Dr. THOMPSON. It was very useful to have someone who was thoroughly conversant with that area on the Board as far as I was concerned and I did not detect in any way that he was withholding because he thought that he was criticizing himself in any way.

Senator JORDAN. Do you believe it would be absolutely essential to have a director of the whole spacecraft operation at Kennedy Space Center on the Board?

Dr. THOMPSON. I thought it was very essential because he was the most knowledgeable one. He certainly has contributed information no one else could have contributed to this Board as far as I can determine.

Senator JORDAN. But your research and the investigations have pointed up very clearly that there was sloppy work in many respects, has it not?

Dr. THOMPSON. I don't understand the question. Stoppage of work?

Senator JORDAN. Sloppy work. Sloppy is the adjective that has been used in describing it.

Dr. THOMPSON. I don't think we used that. I read that perhaps in the newspaper. There was work that we did not think was as good as it should be.

Senator JORDAN. But you think that the men who have those responsibilities in the program are thoroughly competent to make a judgment as to exactly what happened here and how best to remedy it, in the future?

Dr. THOMPSON. I think that we have identified the problems. I think that the action that has to be taken here ought to fall in the area of the program office with the things identified as we have seen them. They may find out things, too. My experience in managing projects is that a manager always has problems. They normally don't have to air them so much in public as these are. However, a manager has to manage and he always has problems and I think we have helped identify some of the problems that management has.

Senator JORDAN. Well, criticism has been leveled, Dr. Thompson, and I think will continue to be leveled, at the fact that the Board was predominantly staffed by members of NASA. As a matter of fact,

staffed by the very people who had the responsibility for the execution of this part of the program. That is true, is it not?

Dr. THOMPSON. Yes. I think that that criticism will probably persist.

Senator JORDAN. And you think even so this particular Board could do a more objective job than could a board of independent status and background?

Dr. THOMPSON. My position is that we needed people who are very knowledgeable about the program to run this review.

Now, if we had had to get too many people who did not know how to do that, were not familiar with all the system, I think we would have had a very difficult job in moving as fast and effectively as we did.

CERTIFICATE OF FLIGHT WORTHINESS ISSUED

Senator JORDAN. The Board's report, states that in August 1966 a review of the spacecraft was conducted by NASA at the contractor's plant. Where was the contractor's plant?

Dr. THOMPSON. Downey, Calif.

Senator JORDAN. Afterward, NASA issued a certificate of flight worthiness and authorized the spacecraft to be shipped to Cape Kennedy.

The report further states that the certificate included a listing of open items and work to be accomplished at Kennedy, and one of the findings in the report states that there were 113 significant engineering orders not accomplished at the time the Command Module was delivered to NASA and yet it was given a certificate of flight worthiness at the point where it was manufactured in California.

Who would give it that certificate of flight worthiness at that point?

Dr. THOMPSON. The program manager for the Apollo Spacecraft program.

Senator JORDAN. Even though it had 113 significant orders not accomplished at that time?

Dr. THOMPSON. I think that this is a situation a program manager always has to face when it was not an off-the-shelf item. He made some judgments and he identified the number of open items and he made the judgment that it was time to ship in order to keep things moving properly.

Senator JORDAN. Is it usual to issue a certificate of acceptance when there are so many significant changes still to be made?

Dr. THOMPSON. There are a series of signoffs and I am not sure just—I am not at all certain that there is not always this element.

As a matter of fact, I am almost positive there is this element of lack of completion involved in this act. There has to be a judgment as to whether or not it is proper in view of that, whether the work properly should be accomplished during the next phase of the program.

Senator JORDAN. Were all these significant engineering changes eventually accomplished before initiation of manned testing of the spacecraft in the pure oxygen environment?

Dr. THOMPSON. John, do you not have the answer to that?

Mr. WILLIAMS. We had to do research. Anything that would affect the pure oxygen environment was accomplished prior to the first manned—

Senator JORDAN. A little louder, please.

Mr. WILLIAMS. Anything that would affect the spacecraft, 113 items, in a pure oxygen atmosphere had been accomplished prior to the altitude chamber run last October or November.

Dr. THOMPSON. Let me add one point.

Senator JORDAN. Yes, go ahead.

Dr. THOMPSON. The completion—the requirement for completion of all those items is judged in relation to what is being done at that particular time, too, though that does not mean that it is actually necessarily flight ready. Certain things could be left undone, at least conceivably they could be left undone and still not involve risk.

Senator JORDAN. Then it would follow that on the next page of your report you state that in December of that year the program director conducted a recertification review which closed out the majority of those open items, but would you define what is meant by “closed out”?

What do you mean when you say “closed out”?

Mr. WILLIAMS. Mr. White?

Mr. WHITE. An item is considered to be closed out when the deficiency has been corrected or it has been determined that it is not significant to the safety of the spacecraft. This involves an engineering review and signoff of a piece of paper that has this deficiency recorded on it.

While I have the microphone, here, if I may, I would like to make another statement with regard to this certificate of flight worthiness.

When the certificate is signed, it does include a list of exceptions, and it is considered normal practice that not every single one of these deficiencies must be corrected before shipment. They are listed and this list is transferred then to Cape Kennedy so that they are corrected at that point.

Senator JORDAN. Were any deficiencies listed with respect to the wiring?

Mr. WHITE. I believe there were. I can't specifically list them.

Senator JORDAN. And in your judgment they were corrected at Kennedy Space Center prior to this test?

Mr. WHITE. The deficiencies that were known to be dangerous, I would say, had been corrected.

We depend quite a bit on the tests that are conducted at the Cape which essentially operate all systems and do put power in all systems. Thereby we find whether or not there is a short or an open circuit or something of this sort.

The deficiencies of the nature of the wire routing, inadequate clearances, and lack of protection may not in all cases have been corrected.

Senator JORDAN. Had those safety precautions been taken with respect to this particular spacecraft prior to the test?

Mr. WHITE. What steps did you mean, Senator?

Senator JORDAN. The safety precautions of checking out the wiring and checking out the whole program for —

Mr. WHITE. Yes.

Senator JORDAN. For safety?

Mr. WHITE. Yes, sir.

There had been other tests run. There had been tests run in the space chamber at Cape Kennedy, two manned tests and two unmanned tests, which did operate all systems satisfactorily.

We did not encounter any problems of the sort that occurred on the pad.

QUESTIONS CONDITION OF GAS MASKS

Senator JORDAN. Going to another matter, I had very little time to get through this voluminous report but I did note that certain individuals testified that the gas masks were either faulty or did not fit well enough to prevent leaks.

Is such equipment kept in a constant state of readiness and repair and have the personnel been trained in their use?

Dr. THOMPSON. Dr. Van Dolah?

Dr. VAN DOLAH. The majority of the gas masks that were available on the pad were masks that were designed to handle toxic fumes from the hypergolic propellants in that area.

They were not designed, with only four exceptions, to handle smoke and there is some question about whether the ones designed for smoke could actually handle the rather bad smoke conditions that existed at the time of the fire at the spacecraft level.

Senator JORDAN. The point is no one expected this kind of problem.

Dr. VAN DOLAH. That is correct.

Senator JORDAN (continuing). With this spacecraft at that time, is this right?

Dr. VAN DOLAH. That is correct, and I might go on to say that all of the personnel on the pad as far as I know were trained in the use of these masks. It was primarily the design of the mask itself.

Senator JORDAN. Thank you.

The CHAIRMAN. Does any other Senator have questions?

Senator Percy?

We will meet back here this afternoon at 2:30 instead of 2 o'clock, in this room rather than the room previously announced.

Senator Mondale?

WRENCH SOCKET FOUND IN SPACECRAFT

Senator MONDALE. Mr. Thompson, pictures of the probable source of the fire show a wrench socket.

Dr. THOMPSON. Yes, sir.

Colonel BORMAN. That is not the problem.

Senator MONDALE. The stories say it has nothing to do with the cause of the fire.

Was that wrench socket supposed to be there?

Dr. THOMPSON. No. I don't think it was.

Senator MONDALE. Isn't that rather illuminating evidence of lack of adequate attention to detail?

Dr. THOMPSON. It got left there. I am not too familiar with all the procedures that are followed to see that workmen don't lose tools and not recover them. I have heard of processes of shaking the spacecraft, and so forth, but having seen that there, it seems to be quite noteworthy that it had not been recovered.

QUESTIONS FLEXIBILITY OF MANAGEMENT WITHOUT LICENSE

Senator MONDALE. You indicated that you thought one of the management objectives of the program ought to be flexibility without

license. To me that carried with it an implication that you had observed some evidence of license in the operation of the program.

Could you give us examples of what you had in mind when you made that statement?

Dr. THOMPSON. We did not observe the license.

We observed what we call the cumbersomeness of process.

Senator MONDALE. Could you give us an example?

Dr. THOMPSON. The problem in dealing with the changes in test programs at the Cape, I think that perhaps Mr. John Williams can describe some of the incidents to illustrate the point.

Mr. WILLIAMS. I think that the test program was outlined from the MSC to the Cape in the form of a GORP, a ground operations document. This is then answered by test outline and the change in GORP. A change in the GORP document requires a contract change. This goes back to the contractor and they put out the test specifications back down to the Cape, the OCP is implemented, and it is quite a long road, a long way to go to make changes in a particularly flexible program.

Senator MONDALE. Did you have any specifics in mind when you said the objective of the program from a management standpoint ought to be flexibility without license or were you speaking without a specific example?

Dr. THOMPSON. I addressed myself to the problem that is pretty well identified here I think in appendix D, page 7 of the report, which went into this in considerable detail and this is a difficult problem that I think has not quite been solved.

I think this is a problem that the management has got to try to figure out a procedure for introducing as well as they can. They cannot give up the controls but at the same time they have got a dynamic program going on and somehow or other it seems as though it would be possible to introduce a quicker response system to those dynamic requirements.

We are addressing ourselves to that problem. We have not arrived at specific recommendations to management, just how to do that.

I think that would require considerable study.

WIRING DEFICIENCIES

Senator MONDALE. Colonel Borman indicated the existence of what I think he described as a basic deficiency in wiring or basic deficiencies in wiring.

Did you identify whose responsibility or whose fault that was?

Colonel BORMAN. Yes, sir.

I believe that the responsibility for the—at least the initial design, was with the contractor.

Of course, the ultimate responsibility is NASA's because NASA has the requirement to approve the design, monitor the design and check on the workmanship involved.

So I think it is a shared responsibility.

COMBUSTIBLE MATERIALS

Senator MONDALE. What about the apparently excessive quantity of combustible materials present at the time of this fire? I think some-

one indicated nearly 70 pounds of combustible material of one kind or another was in that spacecraft.

As I understand it, there is a procedure by which before any materials can be introduced in the spacecraft, they have to be approved, for several reasons, and I assume one of the tests would be combustibility.

Were some of these materials of a combustible nature introduced into the spacecraft without complying with that procedure?

Colonel BORMAN. Yes, sir; some of them were. For instance, the pads that the hatch was to be rested on, you saw those black pads, they were not flight items. The configuration of the spacecraft is an evolving thing. When we finally get to the flight day, launch day, we have a spacecraft that would not have many of the combustibles in it that were in this particular spacecraft.

However, some of the specifications that NASA used for putting combustibles within the spacecraft were sufficiently or too permissive. Some of the equipment that we did not, or that we thought was relatively harmless if kept away from wires turned out to burn very readily.

Senator MONDALE. Did the Commission seek to establish responsibility for that failure to comply with regulations?

Colonel BORMAN. Well, sir, by the failure, you mean the putting in the—

Senator MONDALE. In other words, the fact that substantial quantities of combustible materials were in fact in the spacecraft contrary to procedures that were to be followed in such tests.

Did anybody seek to establish who was responsible for this oversight?

Colonel BORMAN. Yes, sir.

I believe that the responsibility—there were two different problems. One was the fact that for flight we had too many combustibles in the spacecraft.

Now, in some cases these combustibles were installed in violation of NASA specifications.

Senator MONDALE. By whom?

Colonel BORMAN. By the contractor, they are installed by the contractor but the—

Senator MONDALE. With the approval of the Program Office?

Colonel BORMAN. Yes, sir. In other cases the specifications were not rigid enough we know now, and it involved—involves the items that were in for this test only, the mats and the protective liners over the umbilical cords, they were all in and their presence was noted but the fact that they were in was not believed to present a hazard and so although they were properly noted and their presence was documented, they still were there.

VIBRATION TEST

Senator MONDALE. Mr. Thompson, according to reports, spacecraft 012 was delivered to the Cape without being vibration tested, is that correct?

Dr. THOMPSON. Yes, sir.

Senator MONDALE. How did that happen?

Why didn't that test take place?

Dr. THOMPSON. Well, as I understand it, a management decision was made to depend on the very rigid component testing—components had been subjected to a very rigid vibration test.

The thing that we commented on was that the entire spacecraft had not been subjected to an overall vibration test.

The management decision apparently was, as shown by the record, that they would go along with the flight test, unmanned flight test, and which would in their opinion constitute a measure of the capability for this spacecraft to withstand this vibration, and that was done.

Senator MONDALE. Weren't you critical of the fact that this had not been vibration tested?

Dr. THOMPSON. We were critical because the view that we have is that the best way to really find out whether a spacecraft of this type, now, not the one that will be man flown but a spacecraft of this type with all installations abroad, will stand the vibration that is experienced, particularly through the boost period, is to vibrate it and vibrate it at a certain level that gives a vibration level that is equal to the level that will be experienced during the launch period if it could be identified, and certainly it is shaped identified now, plus a factor of about 50 percent in time. That is a procedure that is used in most spacecraft.

Senator MONDALE. Did you seek to identify responsibility for this failure? In your—

Dr. THOMPSON. Failure to —

Senator MONDALE. Failure to perform the vibration test of the spacecraft? Was any attempt made to assess—

Dr. THOMPSON. The program office. I don't know exactly who in the program manager's office but the decision was made to proceed that way.

Senator MONDALE. Would you say that—would it be fair to characterize your report as concluding that this spacecraft was not ready for flight? That it should have been vibration tested?

Dr. THOMPSON. Well, I would hesitate to say that it was not really ready for flight. It certainly is shown now by hindsight to have had risk in it that indicates it was not ready for flight.

The judgment there includes—all these things that have been done and relative to the particular vibration test, I think reliance was put on the flights that had been made. If I had been responsible at that point, whether I would have declared my own, as directing the program, that it was ready or not I don't know. I am not sure whether I would or would not.

I did think that this vibration test was a better assurance of the reliability of the spacecraft.

Colonel BORMAN. Sir, may I add something?

Dr. THOMPSON. Colonel Borman wants to add something.

Colonel BORMAN. I think if you would phrase the question, did the people that were concerned at the time feel that the spacecraft was ready for that test, to the best of their knowledge, the answer would be an unqualified "Yes".

I talked to Ed White shortly before. The crew thought they were over a lot of the problems and they were on the way. The night of the accident I talked to Wally Schirra who had just returned from running the test on a spacecraft and he was really dumfounded that the tragedy could have occurred because he had felt the spacecraft had evolved into a workable machine.

So I think if you put it in the time frame when the accident occurred, you have to say the people were satisfied.

CITES POLICY QUESTION

Senator MONDALE. Thank you, Colonel.

Mr. Chairman, if I may, I would like to make one observation here that I think is brought out by these questions.

It seems to me that this report is very sound in the technical and engineering field.

We get precise clearances as far as could humanly be determined after this tragedy and the destruction that followed the fire.

But it seems to me that our committee's responsibility is in the policy question, the management field. We should not try to compete with you in building a better spacecraft or being better pilots. Our basic question is whether it is being managed well, whether the policy approaches underlying the program are sound, and it seems to me in this particular field as distinguished from the engineering side that we are not getting the kind of hard answers that we need to do our job.

The CHAIRMAN. Well, I would think that Mr. Webb might be here on Thursday and we might ask him some questions at that time.

Senator PERCY?

Senator PERCY. Colonel Borman, you mentioned before that you would not have hesitated on this fateful day to enter the spacecraft yourself knowing what you did at that time.

I now ask the obvious question.

Knowing what you know now, would you have refused to enter the spacecraft on that day?

Colonel BORMAN. Yes, sir.

CITES AREAS OF DEFICIENCY

Senator PERCY. Could you describe in lay terms the outstanding characteristics of the spacecraft that you feel now in retrospect were deficient?

Colonel BORMAN. Yes, sir. I think that the deficiencies that we have noted here, if I were to single them out, I think the first basic deficiency was in the fact that the test was not identified and classified as a hazardous test.

Now, this was a failure in the procedures and in management, if you will.

The second deficiency was we had combustibles, too many combustibles within the spacecraft contiguous to ignition sources and in a 16.7 pure oxygen atmosphere.

This was a deficiency.

The third basic deficiency was the fact that we had vulnerable wiring that provided the ignition source.

Senator PERCY. Do you feel that responsible management could have detected these with adequate testing, ahead of time?

Colonel BORMAN. Sir, the answer is "No," but if I may expound, this spacecraft had undergone 6½ hours of testing under the exact same conditions at the Cape without any problems involving arcs, sparks, or any sort of short circuits.

It had undergone 62.2 hours of testing in an oxygen environment without any of these difficulties. I think that in pointing out the deficiencies as we have done in a very frank manner we often overlook

the fact that there is a great deal of effort to overcome and to pinpoint these.

Now, unfortunately we were not successful in this case.

Senator PERCY. Mr. Chairman, there is some doubt as to whether I can get back this afternoon.

Could I ask a question or two of Mr. Webb?

The CHAIRMAN. Excuse me.

Senator PERCY. Will Mr. Webb be speaking or testifying this afternoon?

The CHAIRMAN. He will not be testifying this afternoon.

I would prefer to wait for questions for Mr. Webb until he appears.

Senator PERCY. Would you prefer to hold those over until then?

The CHAIRMAN. If it is agreeable to you.

Senator PERCY. I will try to return if I can.

There is some doubt whether I can get back.

The CHAIRMAN. Thursday afternoon will be the time Mr. Webb testifies.

Senator PERCY. All right. Fine. I will hold off until then, Mr. Webb.

Thank you, sir. I have no further questions.

The CHAIRMAN. Any more questions?

Dr. THOMPSON. Mr. Chairman—

Senator PERCY. I will wait until Thursday.

The CHAIRMAN. Yes. Doctor?

COMPARING OF RATIO OF COMBUSTIBLES IN APOLLO AND GEMINI

Dr. THOMPSON. One point that has constantly come up here in a large amount of combustibles within the spacecraft, but in comparison with the previous spacecraft I think the ratio per man is about the same. That is, in other words, somewhere around 20 pounds, a little over 20 pounds per man, and I believe that in the Gemini—someone made the calculation for me the other day and showed that the Gemini—I think the spacecraft had about 20 pounds per man, too. This one has 70 which is a little over 20 pounds per man.

I thought it was a matter of interest to clarify the impression that it was a very large amount of combustible material, perhaps out of line with previous experience.

The CHAIRMAN. We will meet, then, at 2:30 again this afternoon in this room.

(Whereupon, at 1 p.m., the committee was recessed, to reconvene at 2:30 p.m., of the same day.)

AFTERNOON SESSION

(The hearing resumed in the afternoon at 2:30 o'clock with the same witnesses.)

The CHAIRMAN. Dr. Thompson, this morning in answer to one of my questions, to what would you attribute design and other deficiencies set forth in your report, you said somehow it—meaning quality—was not attained.

QUALITY RESPONSIBILITIES DISCUSSED

It seems to me that that is a function of management. If you set out to do something and you get a bad job, you do not blame the work-

men. Do you blame these difficulties on management or the workers, these conditions?

Dr. THOMPSON. Well, it seems to me management to the extent that they did not manage to get the workmanship into it. Just where that falls is a little bit difficult to say. The process somehow or other did not arrive at good workmanship, and the element—that goes back to management—they failed to get it and in that sense I guess is where it lies.

The CHAIRMAN. In conducting your review did you have any difficulty in determining who was responsible for a particular activity?

Dr. THOMPSON. I do not think we did. We have a very good delineation of the organization and responsibilities. I think all those can be pretty well traced down through the information we have.

The CHAIRMAN. This responsibility—

Dr. THOMPSON. Appendix E deals in the matter of organization, line responsibility.

The CHAIRMAN. Well, was this matter of responsibility clearly defined, do you think?

Dr. THOMPSON. I think it is; yes, sir.

The CHAIRMAN. Were there any voids or duplications?

Dr. THOMPSON. We thought that the delineation of responsibilities was very well defined there. I would not say there were any voids that were apparent to us or unnecessary duplications.

The CHAIRMAN. Do you feel that there has been a division of responsibility which contributed to the fact that the desired quality levels were not achieved, for example, divisions of responsibility between the Manned Spacecraft Center and North American Aviation? Were they properly defined?

Dr. THOMPSON. I think that the relationship between MSC, yes, Manned Spacecraft Center, and North American were very well defined, yes, sir.

The CHAIRMAN. Do you feel that about—the same definition exists on Apollo as on Mercury?

Dr. THOMPSON. I am not too familiar with the exact definition that was used of responsibilities in Mercury. As far as I know—well, I really do not have anything to base an opinion on, I guess.

The CHAIRMAN. That is the best answer you can give me, Doctor, if that is the situation.

Dr. THOMPSON. Yes, sir.

The CHAIRMAN. In its finding No. 5, the Board referred to “Those organizations responsible for the planning, conduct and safety of this test failed to identify it as being hazardous.” Was there one specific organization responsible for establishing the practices for this test?

Dr. THOMPSON. Well, as to that it is a fairly complex matter that involves not only the line organization but the criteria that are used for defining hazardous operations, and they are different levels involved in those decisions.

Without a proper definition of criteria to clearly define what is hazardous and what is not, you cannot exactly blame a line organization for not imposing—for not having a good program when all they are doing is dealing with criteria that are not quite adequate to the situation so it is sort of a mixture of levels.

I think the reason we couch it in those terms is that there is a mixture of responsibilities required to really assess the criteria and then impose and direct the line organization and set up the proper organization to see that those criteria are properly applied.

It is a little bit more than just one aspect to it. So there is some combination of organizational elements involved, it is NASA and the contractor. The contractor is the main arm that implements the program. NASA has the responsibility to see that they do it, and hold them to it. It is not too easy to just say that this one element is responsible for any particular deficiency when there is a mixture of that kind. I think it needs a pretty general review to correct the situations that have been identified.

PRAISES SELECTION OF PANEL

The CHAIRMAN. This morning, Doctor, I had the impression that there were some questions which would indicate that the panel was not very well selected because of the employees and associates. I want to say I know how hard it is to do, having had a few years experience with atomic energy when they had an examination. I think it is a very good panel that got real good results, and I do not know where you could have gone to find that type of individual outside the organization.

I may be the only one, but I, for one, feel that the panel is well picked.

Dr. THOMPSON. Thank you, sir.

The CHAIRMAN. Thank you.

Was there any one specific organization responsible for establishing procedures for this test?

Dr. THOMPSON. The contractor is responsible for that. Whatever the contractor does had to be approved by NASA so that what the contractor does is subject to that approval, but then again going back to the criteria again, they also have probably somewhat a mixture of responsibility, although NASA always is in a position of ultimate responsibility for it.

What really need review are the criteria and a complete study of those things that are pertinent to an adequate safety program.

QUESTION OF OXYGEN

The CHAIRMAN. I was wondering, if a decision is to be reached about oxygen as the sole atmospheric gas, where would a nonscientific member of the committee such as I am, find out what the judgments might be? I would like to help get a clear decision on that question of oxygen.

It seems to me in looking at it that it is pretty complicated for a lay person to decide that.

Dr. THOMPSON. Well, I do not believe there is any subject that has been studied more than that particular thing.

The one we talked about is the one common in this room, that is nitrogen that is a common diluent for the oxygen, and there are advantages from a favorability standpoint of having air as is in this room.

However, another one that is discussed and considered, has been studied at great length, is helium, and helium has the possibilities of being a suitable diluent. Neither one of them escaped the danger of bends. If a person has this gas in his system and is subject to sudden depressurization, he gets the bends, and that is one of the hazards that goes along with a two-gas system.

Now, beyond that, as soon as you have a two-gas system, you have a mixture of gases in your spacecraft and then you must have, first of all, a means for identifying what you have there, the problem of identifying the mixture so that you know in fact that what the astronaut is getting is oxygen and in proper proportion, and not all nitrogen or all helium or all carbon monoxide or a disproportionate amount of those gases, is one of the problems.

A great deal of work has been done in developing the mechanisms, devices by which you can make the proper measurement. What you can do is—there are versions now that according to our recent studies are—I am talking about the Office of Advanced Research and Technology which has research programs in this area—show that there is great promise for means of, we think, for a flight-qualified instrument that will identify the amount of oxygen, the CO₂, and the water vapor. The amount of nitrogen can be identified as to just what is left, and a device of this kind, however, has to be worked out so it really is flight-qualified before you would want to trust or rely on it for a voyage to the moon or any other voyage far away from the earth.

The CHAIRMAN. Do you not have to do this same determination for the MOL?

Dr. THOMPSON. It certainly will have to be developed for the MOL if we are going to use it. I think they are using a two-gas system.

The CHAIRMAN. Some of the people who have to speculate have speculated that you had already decided—I am sorry—that the NASA organization has already decided on a one-gas system, and it makes it kind of hard.

I remember I asked a scientist how I could learn something about this. He said, "Well, you have to respect oxygen, you have to respect pure oxygen."

He said, Some people ignite a match by scratching it on a fingernail. You try that in pure oxygen and it will burn your arm off. I have not tried it.

Dr. THOMPSON. Oxygen has to combine with something else in order to make a complete combustion process. Oxygen by itself is a very useful gas. We all use it and we depend on it, but when it gets in close proximity with certain fuels or what we call fuels or combustible materials, they will then get in trouble, and it is the removal of those things that combine so readily with oxygen that is one of the basic elements of the improvement program that we are talking about.

This whole matter, however, as I say, has been—as a matter of fact, it is a subject of continuous study not only just because of the advantages of having a diluent gas from a flame standpoint but I think there is a pretty substantial body of thought that a man should remain for an indefinite period in an oxygen, pure oxygen, atmosphere. So that in longer duration flights, we would presumably have to have another two-gas system. However, the experience up until now, I believe,

leads to a considerable confidence in up to perhaps 30 days of pure oxygen environment is suitable for the man, is not harmful to him. And the simplicity of it and the reliability of it from an operational standpoint is a very important factor in the continued use of it.

The thing to guard against is letting that pure oxygen get too close to things that will burn and then igniting them.

ELECTRICAL SYSTEM DEFICIENCIES

The CHAIRMAN. I asked this morning, and this afternoon you might want to finish your answer of the Board's finding No. 10, that deficiencies existed in the command module design, workmanship and quality control.

To what basic factor do you attribute these deficiencies in almost every aspect of the electrical system?

Dr. THOMPSON. I think we are going back pretty much to the things we have commented on earlier, that we just have not, some how or other, have not borne down enough on all the quality control machinery and have not borne down on the engineering that is necessary to the point that we have gotten what we want or should have out of this.

I can give you an example in the wiring; for example, the wiring that we see in this, particularly in this block I design, is not a very good exhibit of what we consider good wiring practice. What we think it shows is that there has not been a really adequate use of engineering before the wires were installed.

The wires—in order to avoid these problems of having wires go over sharp edges or get in front of doors that have to be opened and then have to go around elements of the vehicle in such a way as to avoid any abrasion or sharp bends—have to be engineered in a very careful way and should use three-dimensional forming to do that.

It is a pretty good engineering exercise to just lay out those wires as an engineering exercise. And this is the thing, I think, that is basically back of the faults that we see in this wiring.

The more wires were added, the conflicts were added, and then the wires were wedged up without just an engineering analysis of just where they should go and how they should be channeled around to avoid trouble of abrasion, how they should be channeled to avoid the danger of people stepping on them or misusing them after installing.

Fundamentally, I think this is what is back of what we have seen there, too much building without the real intensive use of engineering to formulate the design before allowing people to put wiring in.

30 MILES OF WIRE IN SPACECRAFT

I could add just a point perhaps about the wiring: There are according to the figures—I have, 30 miles of wire in a spacecraft, and there are 13,000 segments of wire. That 30 miles is cut up into 13,000 segments, and it does offer a fairly demanding exercise to engineer these wire bundles, 30 miles of wire in pieces so it does not get into some of these problems we see.

NO ESTIMATE ON DELAY OF GOAL

The CHAIRMAN. This question is purely related to your experience on the Board in this matter. You do not have to guess if you do not want to guess at it. What do you believe will be the impact of the accident on the national commitment to land men on the lunar surface and return them safely to earth by 1970? The goal President Kennedy set up where he said we will land a man on the moon and bring him back safely in this decade. Would you care to speculate what the results of that accident might be?

Dr. THOMPSON. Well, I have not tried to do the management exercise and to figure out how they are going to—what work is really necessary to deal with many of these questions we have brought up. We think it is necessary to deal with them, and I think they can all be solved. I do not think we have identified things that are of such fundamental nature that shows anything really wrong in the concept of this vehicle.

I think there are just a number of details that really require correction. Just how long it is going to take to do that is beyond the area of our effort. I think it will undoubtedly take a little longer than was originally anticipated but just how much that is I do not know.

The CHAIRMAN. We all seem to be guessing it might be 6 months or 12 months or 14 months and so forth. I think those have to be guesses, and I just wanted to know if you would guess.

Dr. THOMPSON. I would like to refrain from guessing. I would rather be able to estimate it, and I have not done that because that is a little beyond the area of our effort here, and I think it is more in the field of the program office. I think they are the ones who should make those estimates.

The CHAIRMAN. I have advanced it as a guess.
Senator Smith?

COMPARISON OF SPACECRAFT AND AIRPLANE DEVELOPMENT

Senator SMITH. Yes, Mr. Chairman.

Dr. Thompson, do any of the Board members have specific familiarity and experience with the development and manufacture of commercial and military aircraft?

Dr. THOMPSON. George, do you qualify for that?

Mr. WHITE. I have some experience, yes.

Dr. THOMPSON. Would you like Mr. George White to speak on this? He is familiar with this area.

Senator SMITH. I will address myself to Colonel Strang if you would rather I would.

Dr. THOMPSON. Colonel Strang is in the Office of Safety of the Air Force.

Senator SMITH. Why do I not address my questions to both of them.

Dr. THOMPSON. And see where you get the best response, maybe that is the best technique.

Senator SMITH. Although I recognize that the development and production of aircraft is not as complex as that for the Apollo spacecraft—it was my understanding that we were conducting the Apollo

program in such a way as to assure the integrity of production. Could you tell us whether the types and number of deficiencies reported in the Board's report in the area of design, workmanship, and quality control is the type of engineering practice found in the production of commercial or military aircraft?

Mr. WHITE. It has been my experience, Senator Smith, that the type of deficiencies we have found are typical of the deficiencies that are normally found in an airplane development program.

I think one of the significant differences here is that in the case of an airplane development program there is usually one aircraft set aside as an experimental aircraft, at least one, many times three or even more, and these deficiencies are found and corrected in this first experimental aircraft. When the aircraft gets into production, things are usually on a routine basis so that the deficiencies are considerably less.

In our case it was almost tantamount to having the experimental aircraft, in this case the spacecraft, being our first manned spacecraft, so not all of the bugs had been worked out of the system.

Senator SMITH. Well, should they not have been worked out in the unmanned spacecraft?

Mr. WHITE. They were to quite a degree, but not completely.

Senator SMITH. Well, whose responsibility was that?

Mr. WHITE. Well, as I said, this morning—I do not know whether you were here at the time—the original responsibility for manufacturing and for these deficiencies lies with the contractor. However, NASA does have inspectors on the spot in the contractor's facility, and NASA does control the basic policies, so that the ultimate responsibility does lie with NASA.

Senator SMITH. Well, in the aircraft industry would a plane be flown with—and I read from your finding 10—"Deficiencies in design, manufacturing, installation, rework, and quality control existed in the electrical wiring." Would you have gone ahead with aircraft as you did with the space vehicle?

Mr. WHITE. I think for comparable types of deficiencies, yes, this has been done. There have been wiring problems in aircraft that are comparable to what we have had here.

Senator SMITH. Colonel Strang, would you have anything to add?

Colonel STRANG. The only thing I could add, Senator Smith, is that in the Air Force in the missile program we accepted exceptions to the missile system in the line of what Mr. White has just spoken of. They are well-documented so that both the Air Force and the contractor are well aware of what we accept with exceptions.

Senator SMITH. Would an airplane with 113 engineering changes to be made be certified for use for example?

Colonel STRANG. Senator Smith, my remarks were primarily for missiles. In the aircraft side of the house it would be a little different as far as I am concerned in that my experience has been around aircraft maintenance engineering. As you probably know, the Air Force has a team in the contractor's facility that accepts the airplane. The airplane is then delivered to the operational units. That is the area that I would come into; and usually the items of exception—from the experience I have had in the past—would be of a minor nature. Nothing ever to affect the safety of flight.

Senator SMITH. I am using the airplane industry because it is the closest type of program to spacecraft that I can think of.

Colonel STRANG. Yes, ma'am.

Senator SMITH. You may have—Dr. Thompson.

Dr. THOMPSON. Senator Smith, we do have on the Board an ex-test pilot. Maybe you would like to hear from him. Colonel Borman is an ex-test pilot, and maybe he has experience applicable to that situation.

Senator SMITH. Thank you for that Colonel Borman?

Colonel BORMAN. Yes, ma'am, I think just as a general comment it would be safe to say that the level of workmanship or the quality control and care of detail that we find in the spacecraft business is a whole order of magnitude higher than what we ordinarily experience in the aviation business, and this is with due reason, of course, because airplanes have an extended flight test program. You do not have the final dependence upon the system that you do in a spacecraft.

So I think based on my experience in both aviation and the space business that we find a much higher level of redundancy, of detailed engineering and of documentation of effort in the space business than we do in the airplane business.

Senator SMITH. As a layman, would there not be less chance of deficiencies in the case of the spacecraft?

Colonel BORMAN. Yes, ma'am. I think that, by and large, our experience with spacecraft has been phenomenal and the success we have had and in the fine engineering that we have experienced, including the disaster, I would say, by and large, we have gotten probably the best engineering effort and the best workmanship on any machine that has ever been built by man in our space program.

Senator SMITH. I agree with you, and in this tragedy I hope we do not lose sight of that very great accomplishment.

Colonel BORMAN. I hope we get better as a result of it. As a matter of fact, it would be a shame if we did not improve based upon what we have learned from this tragedy.

DISCUSSION OF DEFICIENCIES

Senator SMITH. The main body of the report represents a summary of the Board's findings and conclusions relating to the various areas of the investigation. I believe it would be helpful to the committee if the Board discussed examples of its findings which formed the basis for its conclusions in the following areas: One, the report states that the deficiencies existed in command module design, workmanship and quality control.

Would you please discuss some of the more serious deficiencies found in each of these areas and how they relate to the Board's statement that, and I quote, "These deficiencies created an unnecessarily hazardous condition and their continuation would imperil any future Apollo operation"?

Two, the Board reports that differences existed between ground test procedures and the in-flight checklist. Would you also describe some of the more important differences and explain their significance?

That may be all too much in one question.

Dr. THOMPSON. In appendix D, 9-6, we discuss wiring. We also discuss the so-called ECS, environmental control system plumbing joints.

The wiring specifics, one, wiring of lower equipment bay was routed through narrow channels having 90-degree bends. This could cause mechanical stress on a Teflon installation. Somewhere in these areas was found damage to the sleeve which covered shielded wire. This is in line with what I was saying earlier, and it is particularly important to the use of Teflon insulated wire. Teflon insulation has a very good merit in that it is resistant to flame which is very important for wiring. It is a relatively soft material and has to be handled carefully as regards such things as an abrasion, bearing on sharp edges and so forth.

It goes on, there are several items there, there are items 1 to 6 there, that I think are rather specific and provide a specific basis for our findings.

Senator SMITH. Mr. Chairman, I would ask that the section of the report from which Dr. Thompson is reading be included as a part of his answer if that is agreeable to him.

Dr. THOMPSON. Yes.

The CHAIRMAN. Without objection, that will be done.

(The material referred to follows:)

During the wire inspection, the following design deficiencies were noted:

(1) The wiring in the Lower Equipment Bay (LEB) was routed through narrow channels having many 90 degree bends. This could cause mechanical stress on the Teflon insulation. Some wiring in these areas was found with damage to the sleeve which covers the shielded wire (Enclosure 9-4).

(2) Wire color coding practices were not always adhered to as evidenced by Enclosure 9-5.

(3) Some areas of wiring exhibited what would be referred to as "rats nests" because of the dense, disordered array of wiring. In some instances excessive lengths of wires were looped back and forth to take up the slack. Also, there were instances where wires appeared to have been threaded through bundles which added to the disorder (Enclosures 9-6, 9-7, 9-8, 9-9 and 9-10).

(4) A circuit breaker panel was pressed so close to a wire harness, that wiring indentions were left in the circuit-breaker potting (Enclosure 9-11).

(5) There were wires routed across and along oxygen and water/glycol lines.

(6) The floor wiring and some connectors in the LEB were not completely protected from damage by test personnel and the astronauts. This is evidenced by mashed 22-gauge wires found in some of the wire harnesses.

Dr. THOMPSON. The ECS, the environmental control system plumbing joints—now I make a distinction between ECU, the environmental control unit, and ECS, the environmental control system. The unit has to be connected in as a unit and then by plumbing, as I call it, tubes distribute the coolant and perform its functions of controlling the oxygen through connections to many lines within the spacecraft, so that the whole system is called ECS, and it is the plumbing, the joints, of that ECS that we have particular reference to, and their items 1 to 4, I believe the first one, the ECS design criteria, emphasizing minimum weight, resulted in the selection of aluminum piping with solder joints.

Design approach utilized the kind for the normal operating stresses but failed to account for the loads and stress had by handling it in installation.

Most of our criticism, I think, is summed up in an interpretation of that comment. Very well fabricated solder joints, not subject to

anything but the loads which they were really designed to withstand, or the pressures in the line in the protected area, could very well stand up.

The facts of life are that in putting these things in and having them exposed to the problems or installation, other activities around the area, the movement of people, and subject to the vibration of the spacecraft, that the loads on those joints, the stresses on those joints, even though they might be very well made, would fail, because they just do not have the tolerance for abuse that is almost—some of them almost certainly get.

Now, the other thing that we worry about is that the integrity of the joints, its ability to withstand the environment, also depends on its being a very good one, and in our opinion it is hard to determine the quality of a solder joint on aluminum. I have seen some very good ones, and I have seen some that are not so good.

Opinion is that the joints should be improved in such a way as to provide, I would say, a great overstrength, assurance that even though abused, it is subject to the various things that are not really planned for, it will still retain its integrity, and that in essence is the feeling about the use of solder joints.

Senator SMITH. Would this be a design deficiency?

Dr. THOMPSON. I think this is a design deficiency. The collars that are used there provide such a short connection that it has certainly impressed us as being unable to withstand the abuse they would almost certainly get.

Senator SMITH. Now, shall I repeat the second part of the question?

Dr. THOMPSON. Yes, please.

DIFFERENCES IN GROUND TEST AND IN-FLIGHT PROCEDURES

Senator SMITH. Describe and explain the significance of some of the more important differences the Board found between ground test procedures and the in-flight checklist.

Dr. THOMPSON. Will you handle that?

Colonel BORMAN. Yes, ma'am; if I may. This was my area, I believe.

The differences that existed between the in-flight checklist and the operational procedure for this test were minimal. However, we put this in because we felt that any difference was significant. In fact the in-flight checklist is designed for a flight, for launch, and the test that was being run of course was not a launch or not a proposed flight, so there were some differences existing in switch positions between the checklist for flight which was used and the operational check procedure for this test.

We feel it is important that both the crew and the test personnel on the ground operate from the same piece of paper, and that is why the recommendation is in here.

INQUIRY ON BARON REPORT

Senator SMITH. I have just one more question in a couple of parts, Mr. Chairman.

There have been several newspaper reports that a Mr. Thomas Baron, a former employee of the Apollo spacecraft contractor, had

rendered a report to both the spacecraft contractor and NASA pointing out several serious allegations concerned with poor quality assurance procedures and practices at Cape Kennedy. Did the Board read and evaluate Mr. Baron's report, Dr. Thompson?

Dr. THOMPSON. They did, at least some members of the Board, and the counsel read the report of Mr. Baron. There are two reports that he has written.

Senator SMITH. Then would you give us, give the committee, the Board's opinion of the validity of his allegations and whether or not there were any similarities between his allegations and the Board's findings?

Dr. THOMPSON. There was certain validity to some of the things that he stated. They were similar to some of the things which we have said. He was in the quality control office and saw some of the things going on in his view that he had—I think put him in a position to see some of the problems that are involved in the program.

He viewed the type of things that a quality control inspector would see in the position he had. I am not sure that he always knew what the final outcome was, how the matters that passed under his purview were actually handled.

In our opinion, after reading the report, we did not see that he was adding greatly to the knowledge we were getting from other sources, and it was generally somewhat vague as to just whether there was fault or whether he just saw things that were in process of being corrected.

Senator SMITH. Did any of the panels make a summary of Baron's report? I have not read the report thoroughly, but I am told that the Board does not include—

Dr. THOMPSON. I think—you read it, George. Did you read the full report?

Mr. WHITE. I did read it, but I have not prepared a summary of it.

Senator SMITH. There is no summary of it.

Mr. WHITE. No.

REQUESTS SUMMARY OF BARON REPORT

Senator SMITH. Dr. Thompson, would you be able to get a summary of Baron's report and give it to the committee?

Dr. THOMPSON. I will do that, yes, ma'am.

Senator SMITH. If you will, please.

Dr. THOMPSON. Yes.

(The summary submitted is as follows:)

During the course of the Apollo 204 Review Board investigation, a 58 page document called "An Apollo Report" was furnished to the Board by a Mr. Thomas R. Baron, a former North American Aviation, Inc. Quality Control Inspector and Receiving Inspection Clerk. This document was severely critical of North American Aviation's conduct of the Apollo project. Mr. Baron was requested to testify to the Board about his allegations which he did on February 7, 1967. In addition, he furnished a 275 page document entitled "The Baron Report." The testimony before the Board and the 275 page document reiterated and set out in more detail the allegations originally made against North American Aviation, Inc., in the 58 page document.

The criticisms levied by Mr. Baron at his former employer, North American Aviation, Inc., can be grouped into five (5) categories: (1) quality control.

(2) safety, (3) records and documentation, (4) personnel, and (5) operations. These allegations are summarized in the following:

1. *Quality control:*

Throughout the report, allegations are made of generally poor workmanship observed by Baron. Because of faulty quality control procedures, unacceptable workmanship was often missed by inspectors. When he himself observed defects which he was unwilling to pass, Baron would report these to his supervisors. The report details various instances where nothing was done to correct the deficiencies he noted. Specific samples of poor quality workmanship discussed in the report are faulty installation of spacecraft 012 heat shield; faulty installation of spacecraft 009 rendezvous window; poor workmanship in splicing on the quads; and unsatisfactory water glycol operations in ground support.

The report is also critical of test and inspection procedures, alleging that tests were frequently conducted by unqualified personnel using equipment not suited for the particular test being conducted. The failure of NASA personnel to participate in many of these tests and to maintain a general cognizance of the daily workings on the project has, in Baron's opinion, made such lax procedures possible.

2. *Safety:*

Baron alleges that the general level of safety on the project site was low. Lack of sufficient standards was a factor, which together with supervisory and employee carelessness contributed to the hazards he observed in the operations. Among the particular hazards he details are permitting smoking during and immediately after hazardous operations; conducting fuel operations to diesel power unit when oxidizer transfer unit operation was being conducted; leaving open drains at various levels of pad 34; absence of nets and chain rails to safeguard men working at different levels of the gantry; nonoperating elevators for emergency egress; falling objects endangering personnel on the ground; and operating of high pressure valves without proper protection.

3. *Records and documentation:*

In several areas, there are no procedures established for uniform record keeping. Where records are maintained, they vary from technicians notes to standard printed forms. Because of this lack of uniformity, it is possible to initiate relatively major alterations on the systems without these alterations ever being documented for future reference. An example of this situation is seen in the removal and replacement of parts in the coolant system without proper documentation. Where record keeping procedures are fairly well established, the procedures are often grossly inefficient. Parts distribution is an example of this inefficiency. Forms used for this are printed in two copies. One copy is torn off and thrown away without ever being used.

4. *Personnel:*

Personnel working on the project are shifted from one job to another before acquiring extensive familiarization with the particular project on which they are working. This prevents technicians from becoming "professional" and hinders their opportunities for advancement in the company.

Personnel control is generally poor; technicians at times standing around with nothing to do, while at other times, there was a lack of technicians for a given task. Work that should have been done by experienced mechanics was done by NASA Quality Control personnel and engineers would from time to time perform functions that the technicians should have been performing. Some phases of the work were improperly supervised, there being no qualified engineer on the project site.

These and several other personnel problems contributed to the lowering of morale among North American Aviation employees and a resultant reduction of efficiency.

5. *Operations:*

The Baron Report alleges a "lack of coordination between people in responsible positions" and a "lack of communication between almost everyone." More specifically he alleges a failure to provide official tie in periods for work; scheduling of work in areas so nearby as to cause almost certain contamination; and difficulty in determining whether meter calibrations are up-to-date.

CONSIDERED APOLLO SHIP SAFE AT TIME OF TEST

Senator SMITH. Mr. Chairman, I think Colonel Borman answered a question this morning, and I would like to ask it over and get it again on the record.

Colonel Borman, did you consider the Apollo spacecraft safe, safe enough for yourself to have gotten into it and why?

Colonel BORMAN. And what was the last part?

Senator SMITH. And why?

Colonel BORMAN. Yes, ma'am, I considered the command module 12 to be a safe vehicle at the time of the test. I was assigned as a backup crew commander for a sister ship to spacecraft 12, and although we had development problems and wiring problems and so on, you expect these things in the normal R. & D. program, and I can state that the crew from spacecraft 12 felt that the spacecraft was rounding into shape and both the prime crew and the backup crew were of the opinion that spacecraft 12 was a safe ship at the time they entered it for this test.

Senator SMITH. Thank you very much, Colonel. I thought I understood you correctly this morning, but I wanted to get it on the record again.

Colonel BORMAN. Yes, ma'am.

Senator SMITH. Thank you very much.

Thank you, Mr. Chairman.

The CHAIRMAN. Senator Young.

QUESTIONS ON HATCH DESIGNS

Senator YOUNG. Just a few questions, I believe.

According to the finding of the Board, the inner hatch could not be opened properly, and that the crew was never able to effect emergency egress because of pressurization and so forth, and then the Board made a recommendation that the time required for egress of the crew be reduced, and the operations necessary for egress be simplified.

Now, had thought been given to that before this tragedy occurred?

Dr. THOMPSON. I think Colonel Borman could better summarize that complete situation for you, sir.

Senator YOUNG. Yes.

Colonel BORMAN. Yes, sir; if I may.

At the time of the accident there was on the drawing boards a new hatch designed to open outward and to be hinged to the spacecraft. But the prime reason for the new design was to facilitate extravehicular activities on orbit. It was considered that for every conceivable hazard on the ground the present hatch or the hatch that was on board the spacecraft would suffice.

Now we know that it did not. But as we—as I have attempted to point out, the problem here was that we overlooked the possibility of an internal spacecraft fire.

Senator YOUNG. Yes, but, Colonel, before this tragedy occurred, it was not possible to open that from the outside, was it?

Colonel BORMAN. No, sir. You could open it from the outside. The problem is that the hatch is forced on to its latch by pressure within the spacecraft, and the pressure inside the spacecraft was 2 pounds per square inch higher than the atmospheric pressure. That does not

seem like much, but over the area of the spacecraft that puts a force of about 2,400 pounds holding that hatch shut. So until you can get rid of the pressure within the spacecraft, you cannot open the hatch. And that was the problem.

Senator YOUNG. But the Board did make a finding that before the tragedy occurred there was failure to consider that the egress hatch was a hazardous situation.

Colonel BORMAN. That is correct, sir.

Senator YOUNG. Was that not negligence that the people failed to consider that hazardous before?

Colonel BORMAN. Sir, you could describe it as negligence. I would prefer to describe it, perhaps, as an oversight, since I feel that I share my full share of the blame for overlooking this problem.

I probably have had more experience or as much experience in similar test conditions as any man alive, and I certainly was not concerned about the particular situation that we had. So I agree with you, we were negligent, if you wish, but at least we had an oversight.

Senator YOUNG. Well, there was no intent, as a matter of fact, to use this new hatch design in the Apollo program, was there?

Colonel BORMAN. There was, yes, sir. It was being designed at the time for incorporation on the Apollo.

Senator YOUNG. For the Apollo application program.

Colonel BORMAN. No, sir; for the Apollo lunar program. But, you see, we had no plan for doing extravehicular activity on the Block I spacecraft. So we felt there was no requirement to incorporate this new hatch design on command module 12 because it would not be actuated on orbit.

QUESTIONS ON FUTURE EVALUATION OF FINDINGS

Senator YOUNG. Well, I think my next question should be directed to Dr. Thompson.

The Board having made findings, determinations, and recommendations, will the Board at some future time look at this matter again? Will the whole matter be evaluated to see whether all necessary actions have been taken on the Board's recommendations?

Dr. THOMPSON. Well, sir, I was hoping the Board would be able to go out of business here pretty soon. But we were charged with the responsibility by the Administrator for making this study and reporting to him, and we are currently in recess, holding ourselves together to finish up some of the reporting of tests in progress, and I have noted it will not influence our findings but they do need to be incorporated in the record, and I was hoping that having identified to the Administrator the things we found, that the discussion of whatever is done from here on would be—would fall to the lot of the program office, and I thought maybe the Board could then be dismissed and go back to our normal duties.

Senator YOUNG. Well now, important recommendations have been made to try to insure more safety for the crew. Will there not be some check made within a reasonable time as to whether all of those recommendations have been complied with? If so, when?

Dr. THOMPSON. I think it could be assured that the program office, the Administrator and the program office will report, will take this