CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT CENTER
INDIANAPOLIS, INDIANA

TECHNICAL DEVELOPMENT REPORT NO. 327

INVESTIGATION OF FIRES ORIGINATING FROM AN AIRCRAFT OXYGEN SYSTEM

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by

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October 1957

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SUMMARY

The occurrence of a spontaneous-combustion fire in an aircraft oxygen system indicated a need for investigating this hazard. Accordingly, tests were conducted in an attempt to reproduce this accident. These were followed by tests in which combustibles were ignited. Spontaneous combustion did not occur in the first series of tests. In subsequent tests, however, and while a fire was burning at the outlet manifold, spontaneous combustion did occur in the line leading from the oxygen cylinder to the outlet manifold. This was attributed to oil contamination in the line. Ignited fires damaged neoprene valve seats and caused an explosion in the manifold. It is recommended that care be taken to avoid contamination of the system, that nonflammable materials be used, and that rate-of-flow control valves be incorporated to prevent a surge of oxygen in case of manifold failure.

INTRODUCTION

A fire occurred on TWA airplane 515, May 6, 1956, during a routine ground check of the breathing oxygen system. The fire destroyed the regulator manifold of the oxygen system and damaged the cockpit area extensively before being extinguished by ground equipment. Because the seats in the valves attached to the manifold were missing, it was thought that the fire was produced by combustion of the valve seats. It was not known whether spontaneous combustion of the seats occurred or if ignition of some foreign material in the manifold ignited the seats. If such a fire had occurred during flight, the airplane would have been destroyed and lives lost. To study the requirements for preventing and containment of fires originating from an aircraft oxygen system, a series of tests was conducted.

TEST EQUIPMENT AND PROCEDURE

The test equipment was set up to conform as nearly as possible to the actual airplane installation. A means was provided for rapidly opening and closing the cylinder valve from a remote position. The two regulator outlet connections and the three inlet fittings not connected to cylinders were blocked off. The arrangement of the test equipment is shown in Fig. 1.

Three series of tests were conducted. In the first, tests were conducted to determine if spontaneous combustion of the valve seats would occur when the oxygen cylinder valve was quickly opened and oxygen pressure allowed to build up rapidly in the manifold. Also, tests were conducted with oil and other combustible material in the manifold.

The second series of tests was conducted to determine the ability of the manifold and check valves to withstand a fire when subjected to high-pressure oxygen. In these tests, a fire was initiated in the manifold by removing one of the 1/4-inch pipe plugs which close the main passage through the manifold and inserting a wad of oil-soaked cotton. The cotton was then ignited by inserting a glowing ember, replacing the plug, and quickly admitting oxygen to the manifold.

In the third series, the manifold was completely enclosed in a protective shield made from a piece of Johns-Manville Style 89 firewall material formed into a closed cylinder approximately 3 1/2 inches in diameter shown in Fig. 2. This material will withstand a 2,000° F flame for 15 minutes without flame penetration and is considered to be fireproof. The tubing connecting the cylinder to the manifold passed through a narrow slit in the shield. The 1/4-inch pipe plugs which close the main passage through the manifold were left accessible through the ends of the shield. A wad of oil-soaked cotton was placed outside the manifold in the protective shield. One of the regulator outlet connections was allowed to leak slightly to increase the probability of fire burning through and igniting the cotton in the shield. Ignition was accomplished in the same manner as in the previous tests.

TEST RESULTS AND DISCUSSION

In the first series of tests, numerous attempts were made to cause spontaneous combustion of the valve seats by quickly opening the cylinder valve and allowing oxygen pressure to build up rapidly in the manifold. These attempts were unsuccessful. The tests then were repeated with a wad of oil-soaked cotton inserted in the main passage of the manifold. Attempts to initiate a fire or explosion in this manner also were unsuccessful, although spontaneous combustion did occur in the cylinder line at the time the cylinder valve was opened during a subsequent test and while a fire was burning in the manifold.

In the second series of tests, the oil-soaked cotton and the check-valve seat at the oxygen inlet were consumed, but the fire was not of sufficient intensity and duration to burn through the manifold block. Figure 3 shows the manifold block after it had been subjected to these tests. The damaged check-valve seats were replaced when necessary prior to each test.

In the third series of tests, one of the outlet connections was made to leak slightly to allow the fire to burn through and ignite the cotton in the shield. Difficulty was encountered, however, in getting the fire to burn through the outlet connection. In several tests the cotton inside the manifold and the check-valve seat at the oxygen inlet were consumed but the cotton outside the manifold was not ignited. In one test, ignition outside the manifold did occur and the fire which consumed the cotton was of sufficient intensity to burn a 1/2-inch diameter hole through the shield. This is shown in Fig. 4.

In another test, the cotton in the manifold started to burn slowly. After approximately 30 seconds, a sharp clank was heard. The fire continued to burn in the manifold for a short time, then went out. The manifold was not damaged but the cylinder valve could not be closed at the end of the test. Subsequent inspection indicated that the valve seat was destroyed at the time the detonation was heard. A small quantity of oil probably entered the cylinder line from previous tests, and when the cylinder valve was opened for this test, a spontaneous combustion occurred which destroyed the valve seat. No trace of the seat was found when the valve was disassembled. The seat retainer was discolored, indicating that the seat material had burned.

A final test was conducted in this series using a full cylinder of oxygen and a new manifold block. Oxygen was allowed to leak slowly from the outlet connection. The first time the cotton was ignited it burned for only a short time before going out. The cotton again was ignited and very shortly after the cylinder valve was opened, a loud explosion occurred. The manifold was blown off the support bracket and was found on the ground about 35 feet from its original position. One of the regulator outlet fittings was found a few feet from the manifold. The manifold was ruptured along most of the length of the main passage as shown in Fig. 5. The aluminum was melted around the oxygen inlet to the main passage and there was some indication that the fire may have burned through the manifold before the explosion occurred. The check-valve seats were still in good condition and were not damaged by the fire as may be seen in Fig. 6.

CONCLUSIONS

1. Although during the first series of tests attempts to cause spontaneous combustion in an aircraft oxygen system manifold were unsuccessful, spontaneous combustion did occur in the third series of tests in the cylinder line which destroyed the cylinder-valve seat. This is an indication of the unpredictability of spontaneous combustion of combustible materials when associated with oxygen systems. The fact that hydrocarbons will not, immediately and under all conditions, ignite in the presence of oxygen probably results in considerable negligence in the handling of oxygen equipment.

2. When combustible material was ignited in the manifold the fires were confined to the manifold, and the inlet check valve was the only part damaged.

3. A protective shield of the material tested will not contain a fire which has burned through the manifold. Such a fire would be difficult to contain because of the presence of a large supply of oxygen.

RECOMMENDATIONS

1. Every precaution should be taken to keep the aircraft oxygen system clean and free of contamination. If this is done the possibility of a fire occurring in the system is believed to be remote.

2. Rate-of-flow control valves should be installed in the lines between the cylinders and the manifold to prevent large quantities of oxygen from escaping in the event of manifold failure.

3. Replacement of the aluminum manifolds with manifolds of stainless steel or other material having a high melting point is recommended.

FIG. 1 OXYGEN EQUIPMENT IN POSITION FOR TESTS.

FIG. 2 OXYGEN SYSTEM MANIFOLD ENCLOSED IN SHIELD

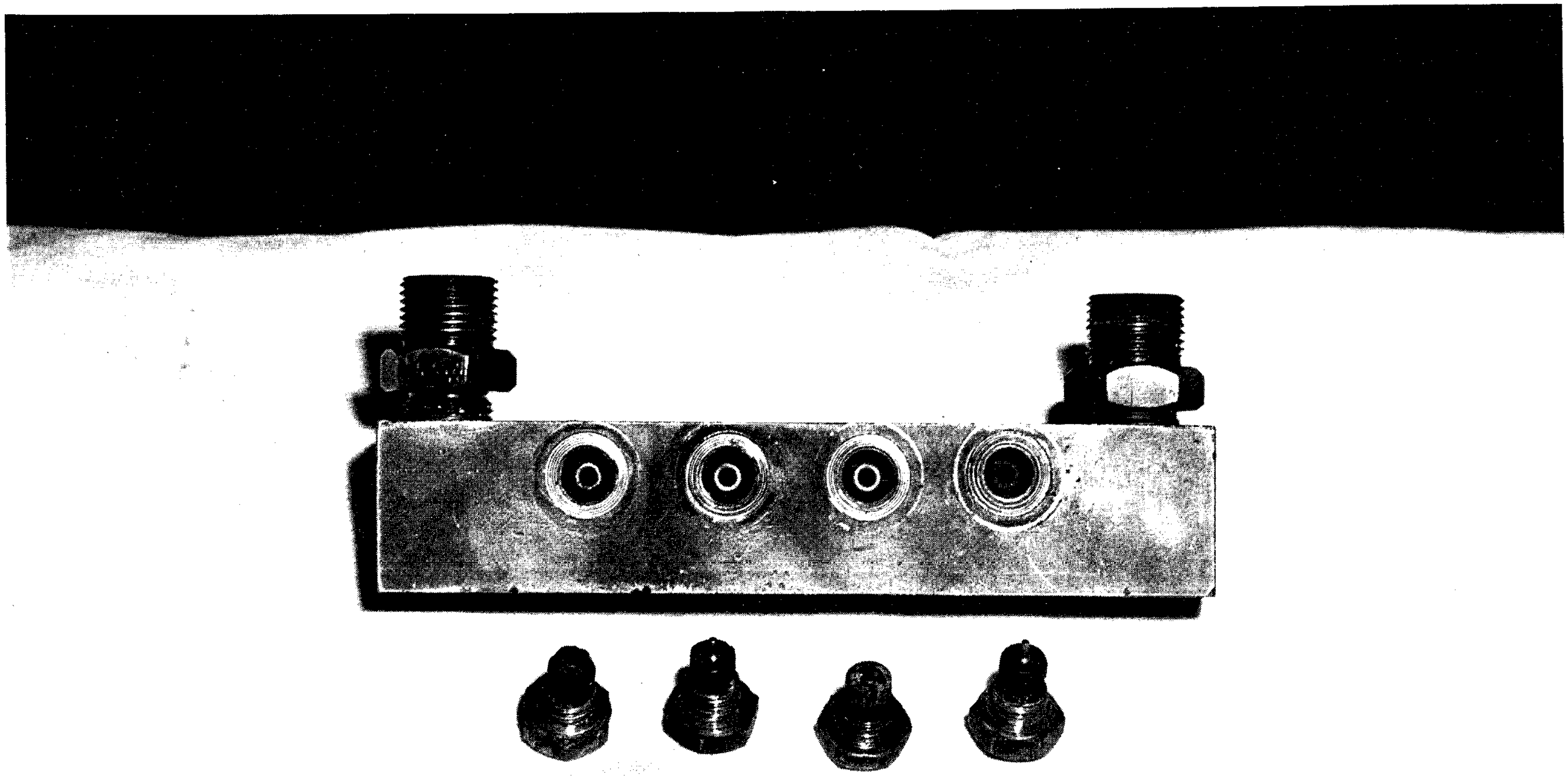

FIG. 3 VIEW OF THE MANIFOLD AFTER TESTS DURING WHICH VALVE SEATS WERE DESTROYED

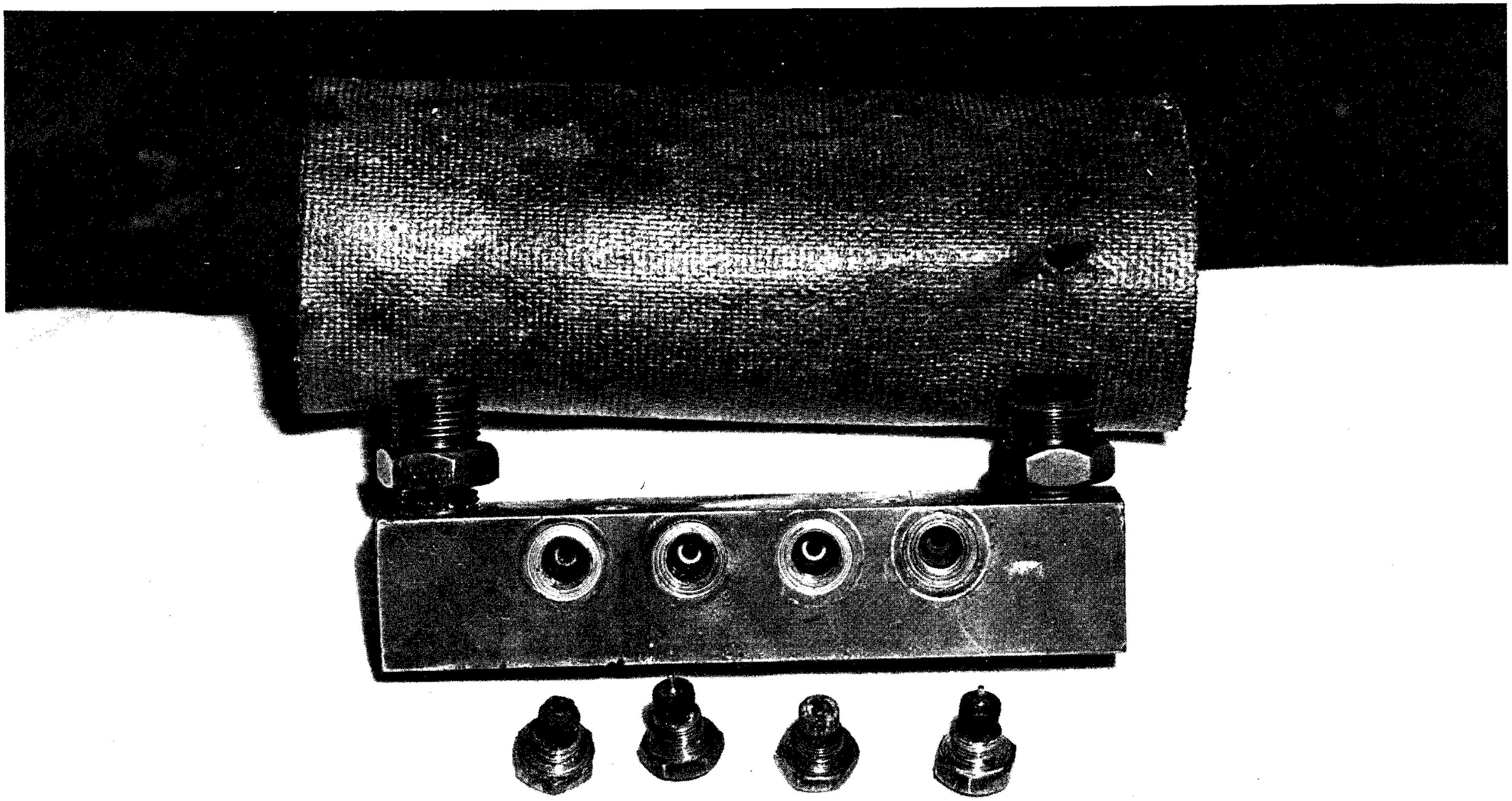

FIG. 4 DAMAGE TO MANIFOLD SHIELD

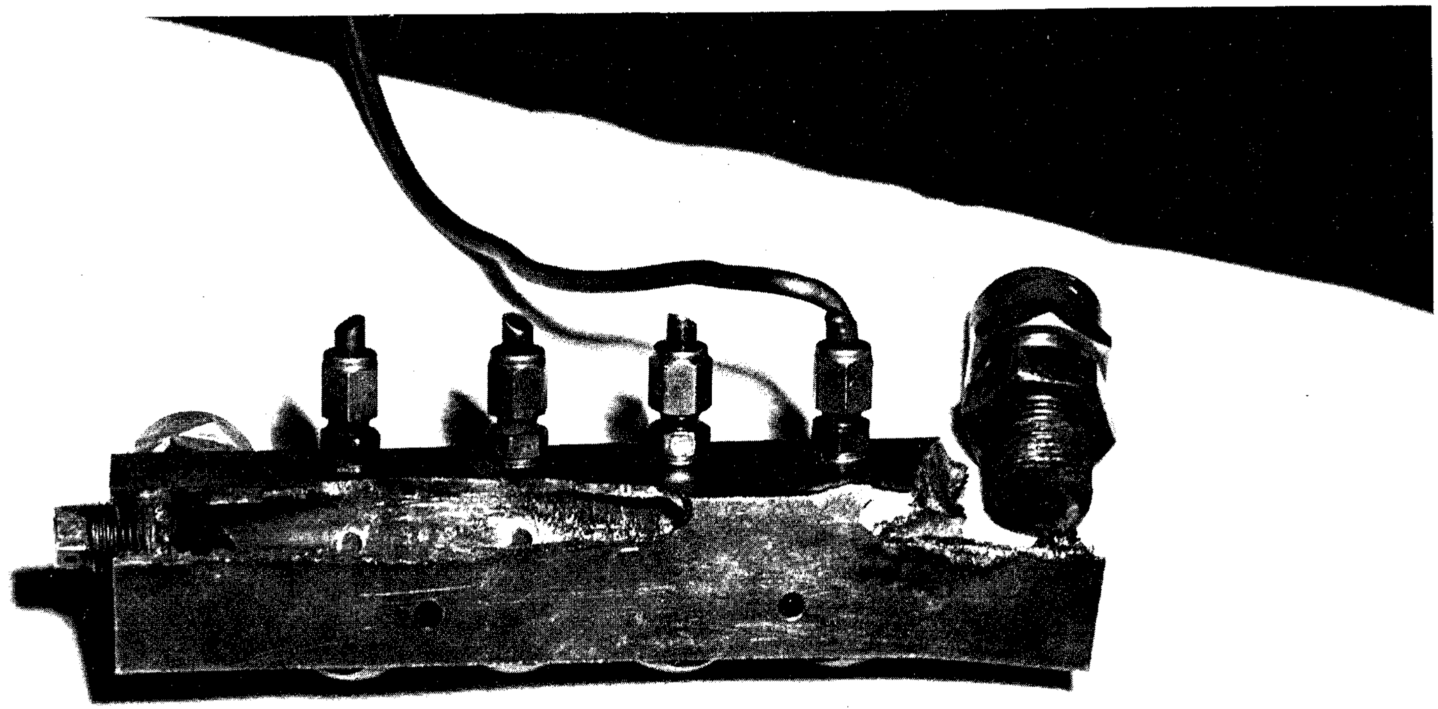

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FIG. 5 DAMAGE TO MANIFOLD AFTER EXPLOSION

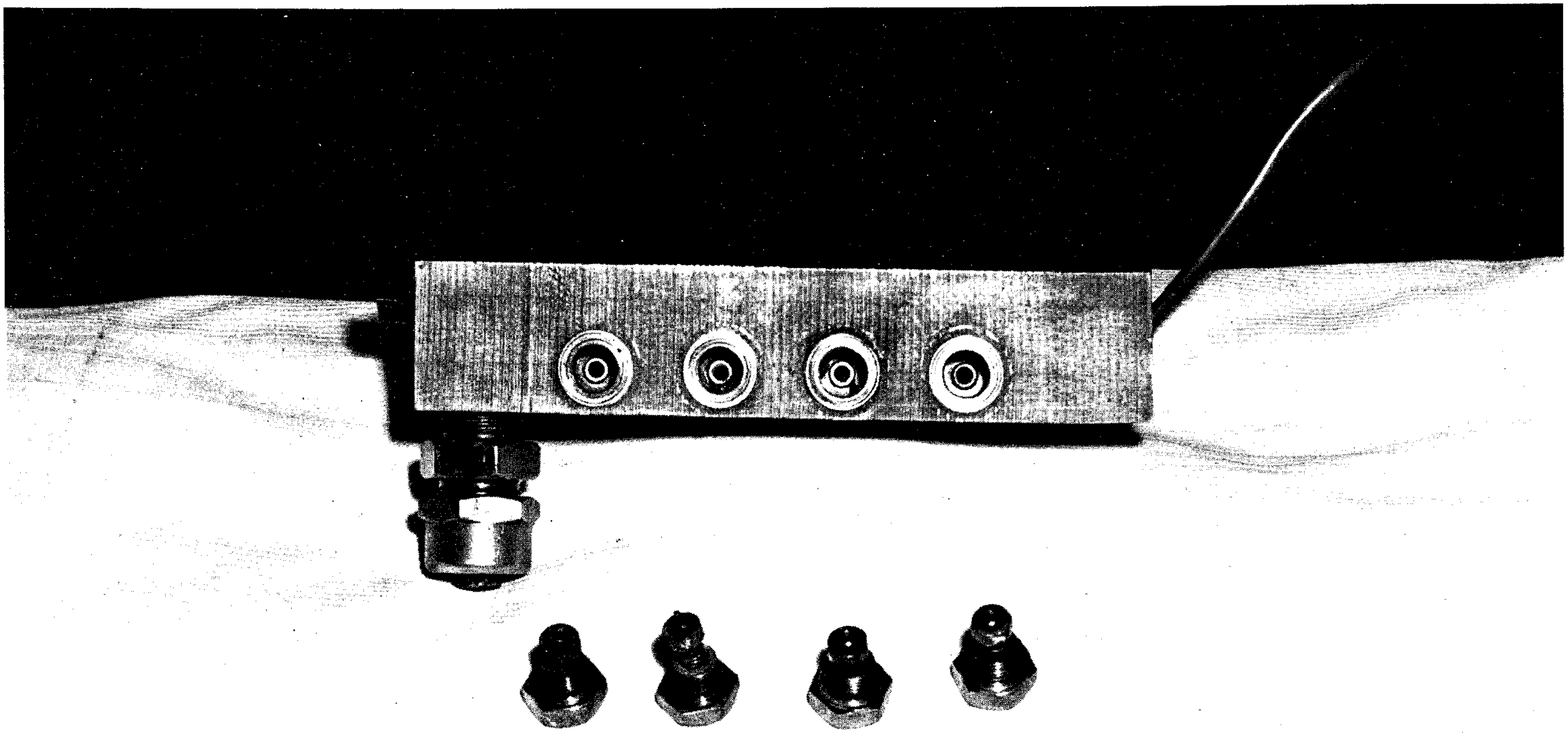

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FIG. 6 CONDITION OF CHECK VALVE SEATS