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Cleveland, Ohio
December 19, 1957

MEMORANDUM For Head, Executive Safety Committee

Subject: Investigation of Cell 22, Rocket Laboratory, explosion on December 14, 1957

1. A hydrogen-fueled explosion occurred at Cell 22, Rocket Laboratory, on December 14, 1957, following a successful test run of a fluorine-hydrogen rocket motor. Details of the explosion itself are covered by a separate memorandum. The following presents the findings of an investigating committee composed of the Rocket Laboratory Subcommittee of the Special Fuels and Lubricants Safety Committee (Messrs. J. Humphrey, H. Douglass, H. Heintz, E. Jonash, E. Baehr, and J. Gibb). This investigation took place on December 17, 1957. The test cell area, and the scrubber were closely inspected for possible ignition sources. Descriptions of the explosion were obtained from three eye witnesses.

2. <u>Eye-witness reports</u>. Mr. Walter Maxim observed the explosion from the 10 x 10 ~~[illegible]~~ Shop Building. He noted the completion of the test run, vapors from the top of the scrubber ceased, and the hydrogen venting took place. He was looking directly into the sun and could not define the initiation of the explosion. Things just seemed to come toward him. Two observers in the Rocket Operations Building saw the completion of the run, the siren ceased, and vapor continued to rise out of the scrubber. Suddenly an orange-red jet of flame poured from the top of the scrubber and enveloped the area. It was described as similar to the exhaust of a rocket. This would at first thought indicate that the explosion was initiated within the scrubber. However, it should be remembered that a hydrogen-air flame is normally quite colorless. The coloration observed must have resulted from 1) the flame picking up particles of rust, paint, etc., or 2) reflection of the sun on carbon dioxide which was present in the scrubber. The latter is probably not the case since the vapors prior to the explosion were not colored. The colorless explosion could have been initiated in the free atmosphere and fired back into the scrubber, producing then colored flame that was seen to shoot out of the scrubber. It must also be remembered, of course, that eye-witness accounts are not always accurate. The sudden shock of the explosion, discussions following the explosion can distort the true facts.

3. <u>Sources of fuel</u>. The experimental rocket motor was operated for about 15 seconds under fuel-rich conditions; hence considerable hydrogen was injected into the scrubber during this time. In addition, additional hydrogen was injected for a short period of time after the run. This hydrogen will rise out of the scrubber for some time after the test run.

Another major source of hydrogen in the area results from venting the high-pressure hydrogen propellant tank following the test run. Liquid hydrogen is pressurized to 900 psi in this tank with gaseous hydrogen. The vent is some 40 feet from the scrubber, 20 feet above ground and perhaps 20 feet below the top of the scrubber. The wind was of such a direction and velocity to carry hydrogen from the outlet of the scrubber over the area of the vent line.

4. Sources of ignition. The following potential sources of ignition were noted:

a) Four non-explosion-proof solenoid valves at the top of the scrubber used for a gas sampling system. These valves were actuated in the post-run period. The valves were inspected and tested. There was no indication that they were at fault; nevertheless they are to be replaced prior to the next test run.

b) A belt-driven vacuum pump and non-explosion proof (but inductance-type) electric motor. These were located in a wooden box, the top of which was blown off during the explosion. The box was not charred and oil in the bottom of the box did not burn. The electric motor could be a possible source of a spark, and the belt drive could create a static spark. However, the general appearance of the box did not indicate an explosion. The lid could have been pulled off by a rarefaction wave. This, does, nonetheless, still represent a possible source of ignition. It will be de-energized during future test runs.

c) A number of floodlites in the area. Those at the top of the scrubber were off during the test run.

d) A number of pieces of wood were found inside the scrubber and were, according to the operating engineers, there prior to the run. They showed some signs of minor charring. A piece of wood in the scrubber, if ignited by flame from the rocket during the run could be an ignition source in the post-run period. However, from the amount of charring this doesn't appear likely. The charring may have occurred as a result of the explosion, or may even have occurred during previous runs. This does, nevertheless, present a potential hazard and should be watched in future operations.

e) Hydrogen vented at high velocity has been known to ignite from a static discharge. The wind carried hydrogen from the scrubber outlet over the hydrogen vent. After the test run the fluorine tank was vented and then closed. The hydrogen tank at 900 psi way then depressurized to 100 psi and the valve closed. The operator checked the pressure and then re-opened the vent valve. The explosion occurred immediately. While this could very likely have been coincidental the facts strongly suggest the venting operation as the ignition source for the explosion. Fires from hydrogen vents have definitely been known to occur and the hydrogen from the scrubber was definitely above it. The problem of safely venting the hydrogen tank will have to be solved.

5. While the hydrogen vent and the vacuum pump represent the two most likely sources of ignition, all of the above sources will be removed before another test is made in Cell 22. As an additional safety measure a more extensive CO_2 system will be installed to further reduce the oxygen content in the scrubber.

6. Future tests in Cell 22 will involve lower concentrations of hydrogen, leading to more severe cooling problems. An engine burn-out is therefore more likely. Such a burn-out may throw a substantial quantity of liquid hydrogen into the test cell. The cell is ventilated to avoid accumulation of gaseous hydrogen from possible leaks. A method of completely eliminating this hazardous condition is not evident; nevertheless, an attempt should be made to inert the cell with CO_2 as well as possible.

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