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M/D. Brainerd Holmes

Combustion Oscillations in the F-1 Engine, Monthly Report

The attached report describes activities relating to the combustion instability problem in the F-1 engine for the period June 20 to July 19, 1963.

Engine testing activity was reduced during this period due to modifications being made on the test stands at Edwards. No tests were conducted on stand 1B because of the installation of a new flame deflector capable of withstanding both fixed and gimballed engine operation. Minor plumbing changes to stand 1A were also necessary.

Ten engine tests were made on engines 10 and 12 without a single case of self-triggered instability, although many runs were shut down prematurely because of mechanical problems in new components being tested, such as the skirt extension. No engine bombing tests were made.

Again, since the combustion instability problem in the F-1 engines appears not to be jeopardizing the engine development schedule and since the F-1 program is reviewed monthly in the OMSF and Associate Administrator's Program Status Review, we suggest that this separate report on the F-1 combustion instability be terminated.

Of interest is a meeting called by OART to convene a research advisory group on combustion instability problems. This group, comprising NASA, representatives of MSFC, LeRC, JPL, OART and OMSF met July 16, 1963. It is intended that this group organize a continuing research effort to examine and ultimately solve the combustion dynamics problems which underlie the combustion instability phenomenon.

Original signed by
D. B. Holmes

D. Brainerd Holmes
Director of Manned Space Flight

Attachment

cc: MD(P)/G. Low
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MEMORANDUM for the Record JUL 26 1963

Subject: F-1 Combustion Instability Report for Associate Administrator; Period June-July 1963

Summary:

Engine test activity was reduced this month as a result of the temporary de-activation of test stand 1B, to install a new flame deflector, and plumbing modifications to test stand 1A. In 10 engine tests, no case of self-triggered engine instability occurred.

A backup "uncooled" nozzle skirt design, consisting of an ablative liner, failed during a run of engine no. 10 when the ablative material came loose. The thrust chamber was damaged and will need to be replaced.

In thrust chamber tests, several growing concepts concerning those factors that increase the tendency towards instability were reinforced. Lowered fuel injection velocity has dampened a number of runs which were bombed, even in those cases where the negative influence of a solid wall thrust chamber was present. The damaging effect of random fuel injection, such as leaks, was proved in the 2-dimensional motor.

Discussion and Results:

During the period of June 20 to July 19, 1963, engine testing resulted in no case of self-triggered instability. As a result of stand modifications, only 10 tests were conducted. Stand 1A underwent facility plumbing and instrumentation changes to accommodate a new series of tests. Stand 1B was completely inactive during this period to permit the installation of a new flame deflector. This work was completed on July 17 with testing to be resumed within a week.

Engine no. 12 with the 5U flat face injector was run three times in preparation for the resumption of full range gimbal tests in stand 1B. None of the tests indicated any instability, although all three were shut down short of the intended duration because of mechanical problems. Engine 12 has now been removed from stand 1A and is being installed in reactivated 1B.

Engine no. 10, which is equipped with a 5U baffle injector, partial feed system isolation and a lowered fuel velocity, was used to test a 16:1 ablative nozzle skirt. The fourth test, which approached rated engine duration, failed due to the separation of the ablative material from its backing. The resulting buckling of the nozzle damaged the thrust chamber and engine no. 10 has been retired for thrust chamber replacement. It will be replaced with engine no. 6-2, which is equipped with ports for photographic observations. The window construction will permit about 15 seconds of engine operation.

During this period, thrust chamber tests and 21 injector tests were run on thrust chamber stand 2A. Results support previously identified trends on the parameters that affect F-1 stability characteristics. The effect of reducing fuel velocity is illustrated by injector 076. In 2 runs this injector dampened in approximately half the time when its fuel velocity was reduced from 75 ft./sec. to 35 ft./sec. The lowered velocity also appeared to outweigh the unstabilizing effect of the solid wall thrust chamber used in these tests. The fact that a solid wall chamber is more conducive to instability than a tube wall structure (which is used in the F-1 engine) is borne out by injector X007. In a solid wall chamber the injector caused 3 cases of uncontrolled instability. This same injector in a tube wall chamber dampened 4 times and was shut down 3 times by the rough combustion device.

Injector X005, one of unusual design consisting of 81 baffle compartments, self-triggered during its first run and damaged itself beyond repair.

Present evidence indicated that instability must be dampened within 40-60 milliseconds, if damage to the injector and the thrust chamber is to be avoided.

Supporting Technology Tests:

The belief that uncontrolled fuel injection can trigger instability was checked in the 2-dimensional motor by drilling holes through the baffles. With fuel entering the chamber in a random manner, the motor failed to dampen when it was bombed.

Original Signed By
A. O. Tischler

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