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by Ned P. Hannum and Herbert E. Scott
Lewis Research Center
Cleveland, Ohio

TECHNICAL PAPER proposed for presentation at Third Combustion Conference sponsored by the Interagency Chemical Rocket Propulsion Group
Kennedy Space Center, Florida, October 17-21, 1966

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National Aeronautics and Space Administration
Cleveland, Ohio

INTRODUCTION

The liquid rocket industry discovered years ago that acoustic mode combustion instability could often be eliminated by the installation of injector face baffles. The method by which these baffles are effective has been variously hypothesized as (1) devices which compartmentalize the combustion, (2) simple acoustic damping devices, (3) devices to reduce the cross-velocity effect of the local mixture ratio and, (4) as the name implies, interference devices to obstruct the acoustic paths in the combustor. The test program conducted at the Lewis Research Center to investigate injector face baffles was intended as a cursory investigation of the problem. For these tests, one concentric tube injector with a thrust-per-element of 50 pounds was used with a 10.77-inch diameter cylindrical combustion chamber producing a nominal thrust of 20,000 pounds which was used as the basic engine configuration.

EXPERIMENTAL PROCEDURE

Seventeen injector face baffle configurations were evaluated experimentally with approximately 94 hot firings. The heat-sink test hardware that was used limited the duration of these tests to 2 to 3 seconds each. The number of injector face baffle compartments was varied from 3 to 100 with lengths of from 1/2 inch to 2 inches. These tests were conducted over the oxidant-fuel ratio range of 4 to 6.

The stability rating of each baffle configuration was expressed in terms of the hydrogen temperature at which screech was encountered. The technique employed was to preset the hydrogen valves to obtain a selected initial hydrogen temperature; then, approximately 1 second after ignition, the gas valve was started ramping toward a closed position while the liquid valve was concurrently ramping toward an open position. Constant total hydrogen weight flow rate was, therefore, maintained while reducing the temperature of the injected hydrogen to a value below the anticipated screech limit. The screech limit was defined as the instantaneous hydrogen injection temperature corresponding to the initiation of high frequency pressure oscillations on the oscillograph trace of a flush mounted high frequency pressure transducer. This initiation was considered to take place when a periodic wave-form with an amplitude greater than the noise level was observed on the oscillograph record. Data were obtained over a range of oxidant-fuel ratios to establish a limit curve.

DISCUSSION

The predominant mode of instability of the basic combustor was first tangential with a peak-to-peak amplitude of 150 psi. At an oxidant-fuel ratio of 5.0, the minimum stable hydrogen injection temperature for the 421 element basic combustor was 130° R (Fig. 1). Sector, triangular, and diamond shaped injector face baffle compartments were evaluated (Table I, Figs. 2, 3, 4, 5 and 6). The specifications for the basic injector are shown in Table II and stability data typical of that achieved with each configuration is shown in Figure 7 for the 7 spoke baffle.

The data for all of the 1-inch length configurations are correlated in Figure 8. The correlating parameter selected to describe the individual baffled compartments was the average maximum dimension in a single cavity. It can be seen that the effectiveness is improved as the maximum cavity dimension is decreased for dimensions greater than 4 inches. The effectiveness is constant for compartments with maximum dimensions less than 4 inches.

All 17 configurations are correlated with the average maximum compartment dimension and baffle length in Figure 9. It can be seen that all of the 2-inch length configurations were stable down to 55° R which is the minimum temperature limit of the test facility. One-inch length baffles were stable to 55° R when the maximum cavity dimension was less than 4 inches. Larger cavities required longer baffles to provide stability down to 55° R.

Since the same total number of injection elements were used in all of the thin baffle tests, the result of increasing the number of compartments meant fewer injection elements per compartment. An extension of this kind of reasoning would lead to the limiting case of one injection element per baffle compartment. There is, therefore, the possibility of a similarity in the mechanism by which oxidizer tube recess and injector face baffles are effective in improving combustion stability (Fig. 10).

SUMMARY

The results indicate that injector face baffles 2 inches long produced acoustic stability to the minimum hydrogen injection temperature limit of the test facility (55° R) with average maximum compartment dimensions as large as 9.1 inches. Acoustic stability down to a hydrogen injection temperature of 55° R could also be achieved with injector face baffles 1 inch in length when the average maximum compartment dimension was less than 4 inches. Some of the configurations were, however, only marginally stable at this reduced temperature (Fig. 11).

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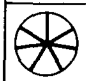
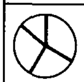
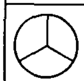
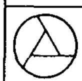
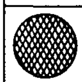
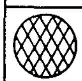
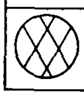
Table I.

BAFFLE CONFIGURATIONS TESTED

H–O 20K

TYPE		LENGTH, IN. 2	$1\frac{2}{3}$	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{1}{2}$
	7 SPOKE	S 54^0			T 58^0		T 82^0
	4 SPOKE	S 60^0			T 85^0		
	3 SPOKE	S 60^0					
	EXTENDED TRIANGLE	S 58^0					
	100 EGG CRATE	S 60^0			M 57^0		
	25 EGG CRATE	S 55^0	S 55^0	S 58^0	S 58^0	T 87^0	
	7 EGG CRATE	S 57^0		S 58^0	T 93^0		

S - STABLE
T - TRANSITION
U - UNSTABLE
M - MARGINAL

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Table II.

INJECTOR SPECIFICATIONS

TYPE	NO. O_2 ELEMENTS	NO. H_2 ELEMENTS	DIAM O_2, IN.	DIAM H_2, IN.	AREA O_2, IN.^{2}	AREA H_2, IN.^{2}
BASE LINE	421	421	0.052	0.172	0.894	4.616
MODIFIED 7 SPOKE	293	293	0.052	0.172	0.622	3.212
MODIFIED 4 SPOKE	339	339	0.052	0.172	0.720	3.717

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BASE LINE INJECTOR-COMBUSTOR FOR HYDROGEN-OXYGEN BAFFLE TESTS

CHAMBER PRESSURE	300 PSIA
CONTRACTION RATIO	1.9
INJECTION AREA RATIO	5.16
CHAMBER DIAMETER	10.77 IN.
421 ELEMENT CONCENTRIC TUBE	

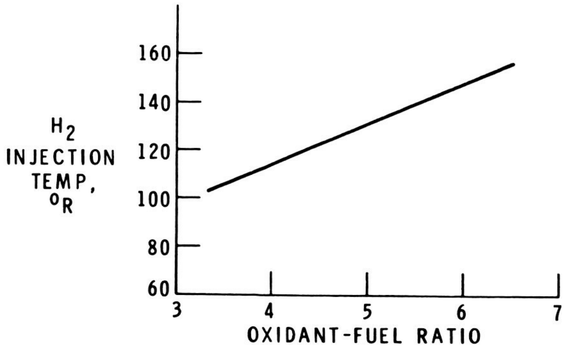

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Figure 1.

ONE INCH LONG 7 SPOKE BAFFLE WITH INJECTOR

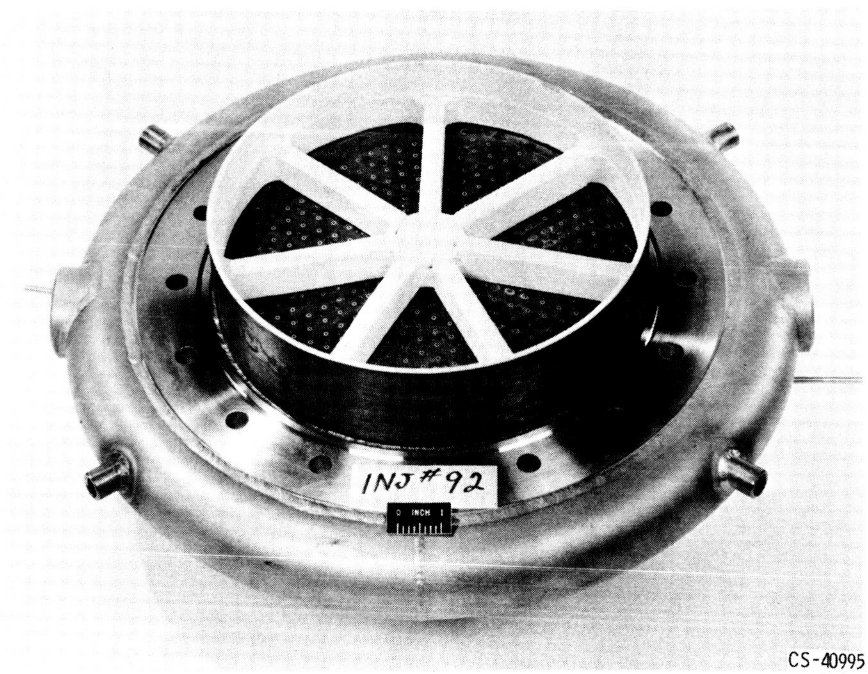

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Figure 2.

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TWO INCH LONG 25 COMPARTMENT EGG CRATE BAFFLE WITH INJECTOR

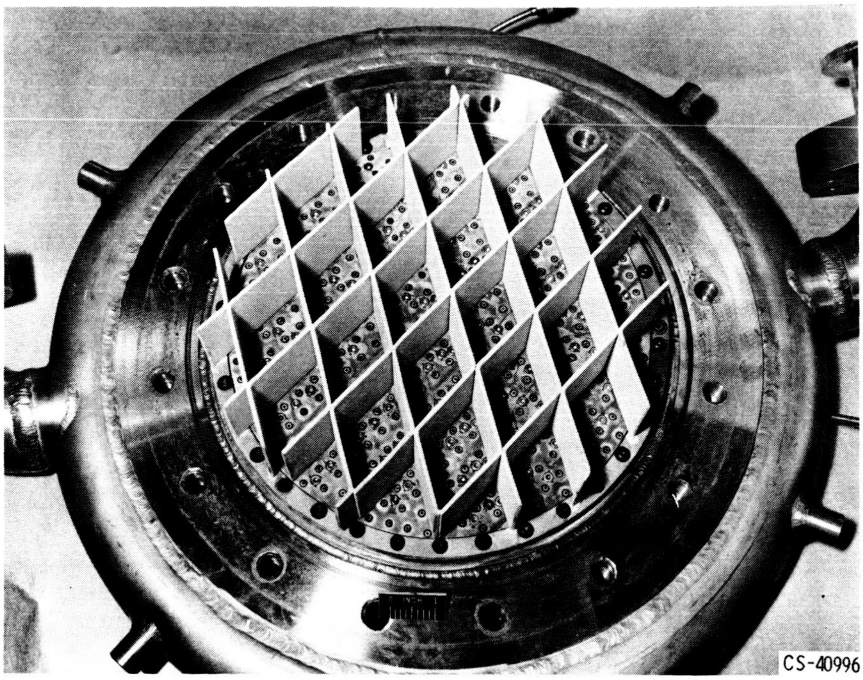

Figure 3.

TWO INCH LONG EXTENDED TRIANGLE BAFFLE WITH INJECTOR

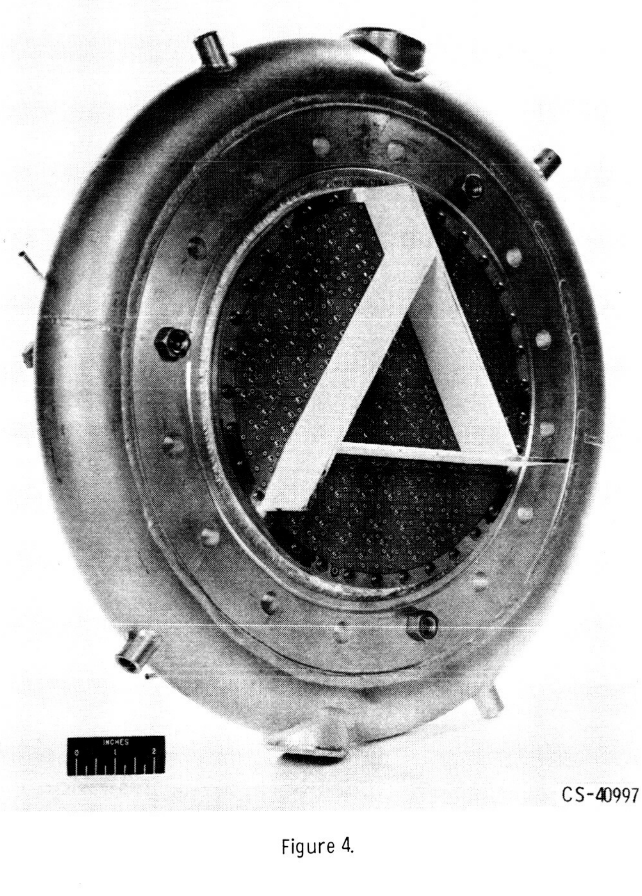

Figure 4.

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ONE INCH 7 COMPARTMENT EGG CRATE BAFFLE WITH INJECTOR

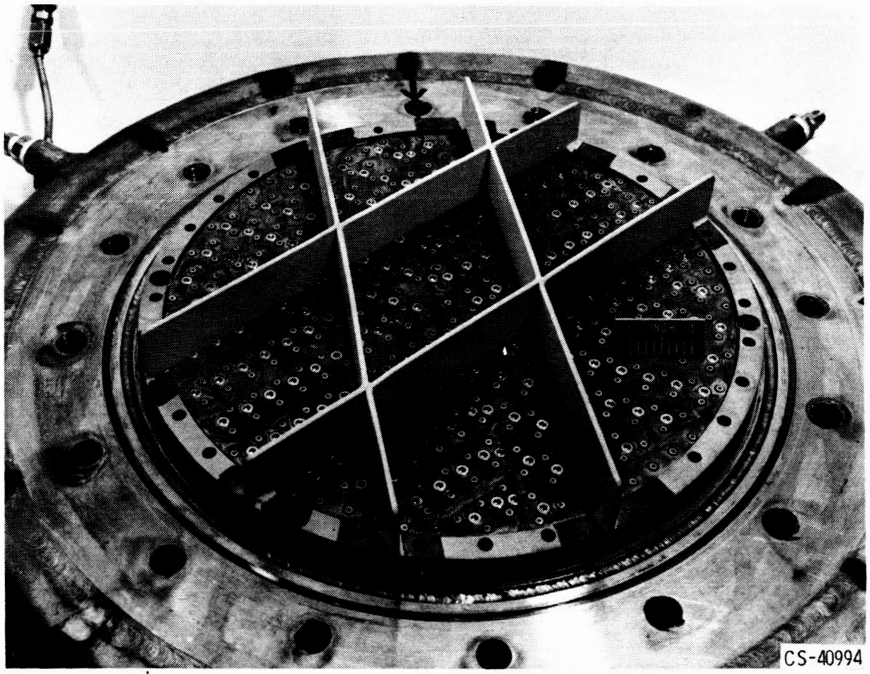

Figure 5.

TWO INCH LONG 100 COMPARTMENT EGG CRATE BAFFLE WITH INJECTOR

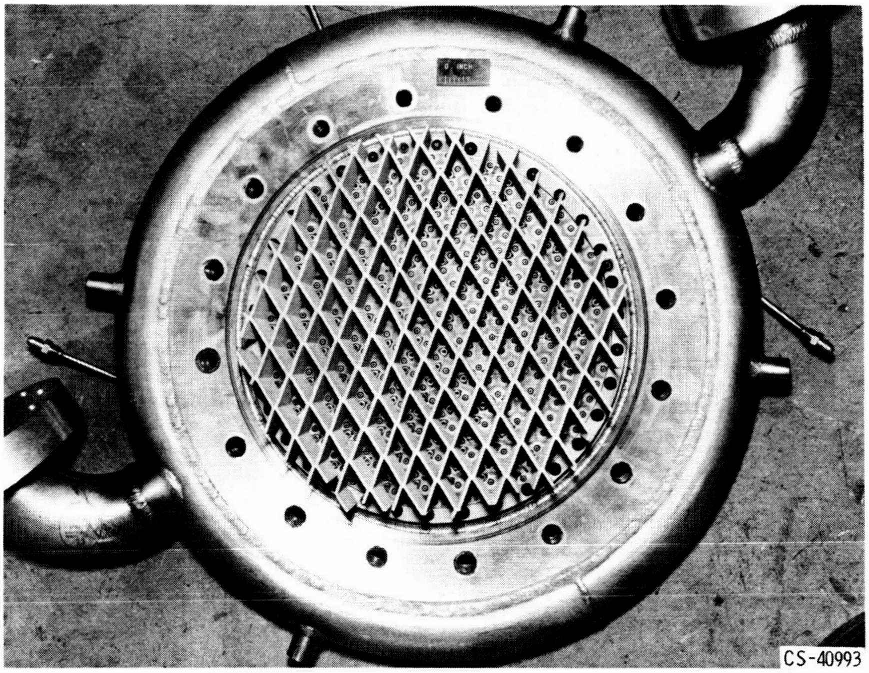

Figure 6.

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COMBUSTION STABILITY LIMITS FOR 7 SPOKE BAFFLE CONFIGURATION

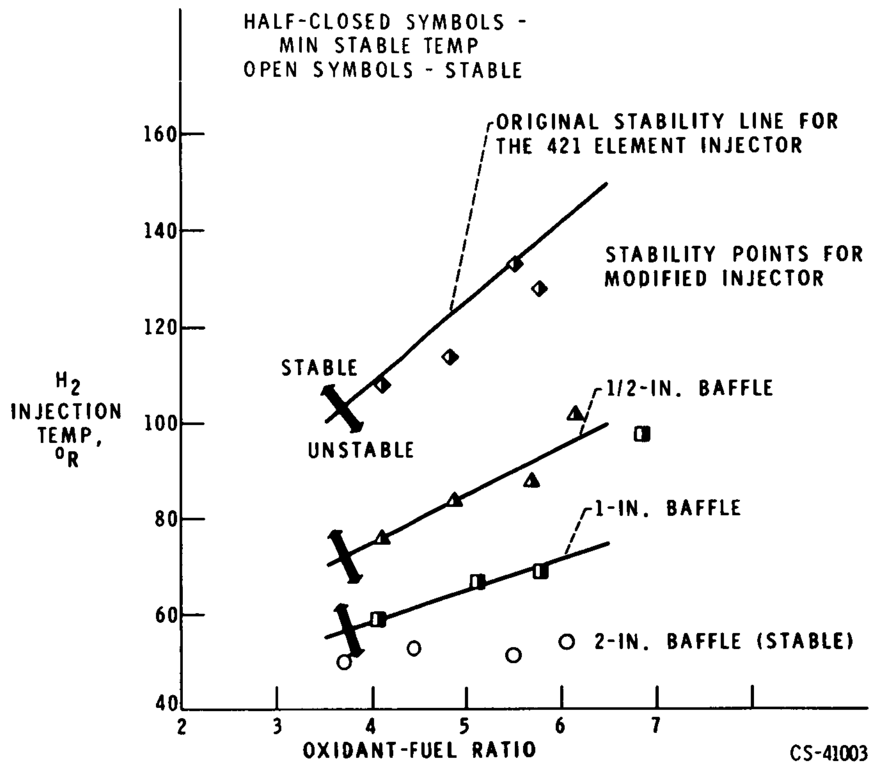

Figure 7.

THE EFFECT OF MAXIUM BAFFLED COMPARTMENT DIMENSION ON COMBUSTION STABILITY LIMITS WITH SEVERAL ONE INCH LENGTH BAFFLES

OXIDANT-FUEL RATIO, 5.0

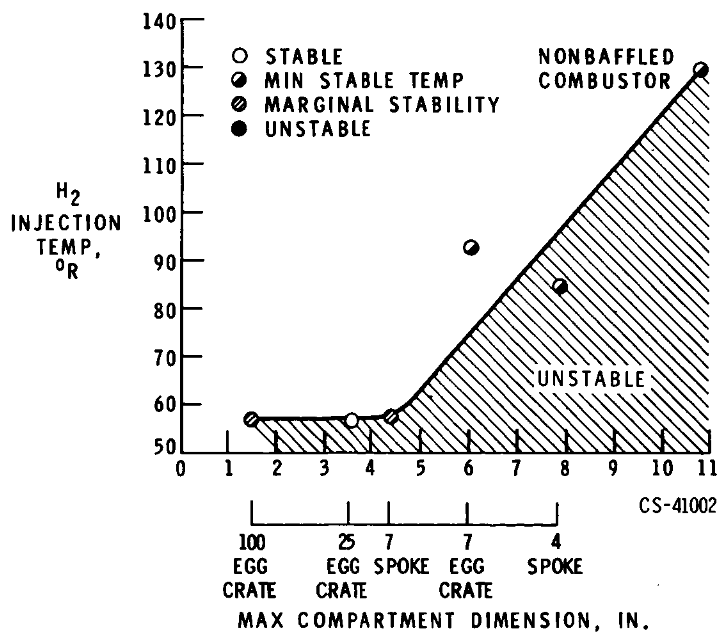

Figure 8.

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CORRELATION RELATING BAFFLE LENGTH AND MAXIMUM COMPARTMENT DIMENSION

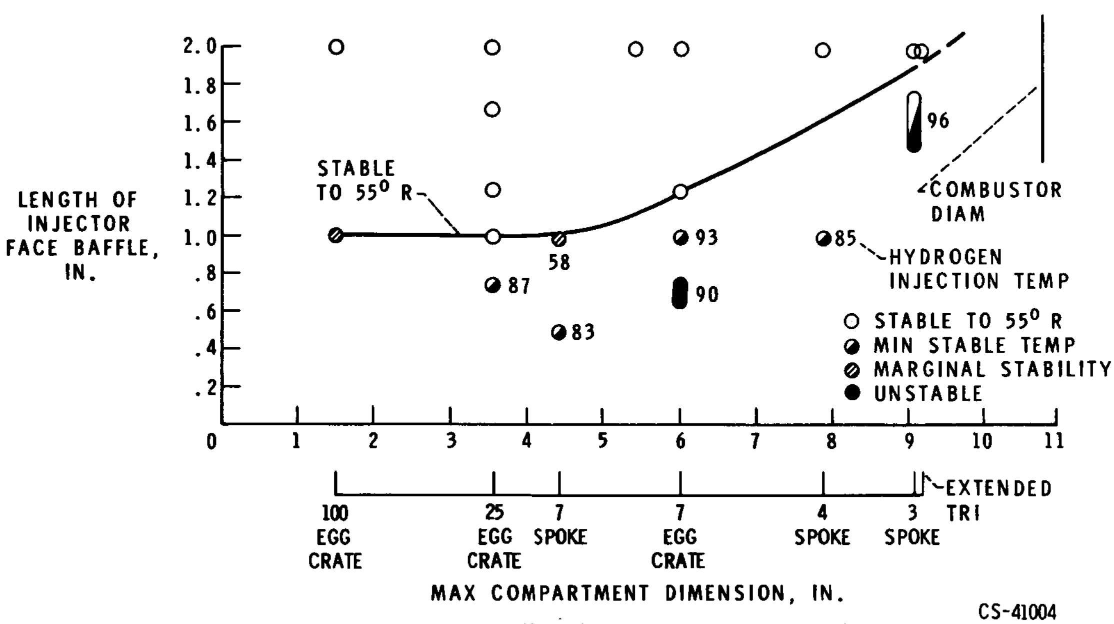

Figure 9.

RECESS-ONE ELEMEMT/COMPARTMENT

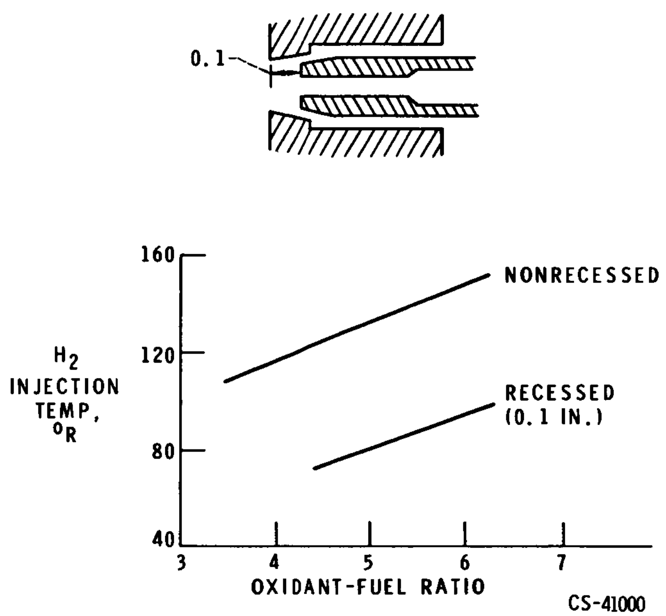

Figure 10.

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SUMMARY

FOR TESTS CONDUCTED WITH:

CHAMBER PRESSURE - 300 PSIA
THRUST/ELEMENT - 50 LB
CHAMBER DIAM - 10.77 IN.
CONTRACTION RATIO - 1.89

IT WAS FOUND THAT:

1. INJECTOR FACE BAFFLES 2 IN. LONG PRODUCED STABLE OPERATION DOWN TO 55° R WITH AS FEW AS THREE BAFFLE COMPARTMENTS
2. STABILITY CHARACTERISTICS OF SEVERAL BAFFLE CONFIGURATIONS COULD BE CORRELATED WITH THE MAX DIMENSION IN A SINGLE BAFFLE COMPARTMENT
3. INJECTOR FACE BAFFLES 1 IN. LONG PRODUCED MARGINAL STABILITY DOWN TO 55° R WHEN THE MAX BAFFLE CAVITY DIMENSION WAS LESS THAN 4 IN.

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Figure 11.