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FACTORS AFFECTING ALTITUDE RELIGHT PERFORMANCE OF A DOUBLE-ANNULAR RAM-INDUCTION COMBUSTOR

by Donald F. Schultz and Edward J. Mularz

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16. Abstract

A test program was conducted to evaluate the altitude relight capabilities of a short-length, double-annular, ram-induction combustor which was designed for Mach 3 cruise operation. The use of distorted inlet-air flow profiles was tried to evaluate their effect on the relight performance. No significant improvement in altitude relight performance was obtained with this approach. A study was also made to determine the effects of the reference Mach number, the fuel temperature, and the fuel volatility (ASTM-A1 against JP-4) on the altitude relight performance. Decreasing the reference Mach number, increasing the fuel temperature, and using more volatile fuel all decrease the combustor pressure necessary for relight.

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SUMMARY

A test program was conducted to evaluate the altitude relight capabilities of a short-length, double-annular, ram-induction combustor which was designed for Mach 3 cruise operation. The combustor was modified by the placing of airflow distortion plates in the diffuser inlet to redirect the inlet airflow as well as removing air swirlers on the inner annulus while adding blockage to the swirlers in the outer annulus. The intent of these modifications was to reduce the airflow through the outer annulus by diverting the airflow toward the inner annulus. The resultant lower velocity in the outer annulus should facilitate altitude relight since decreasing velocity increases flame stabilization. In addition, two sets of fuel nozzles were used to improve relight performance by providing better atomization at low fuel flow. However, no significant improvement in altitude relight performance was obtainable with any of these modifications. The relatively high pressure loss of this combustor redistributed the distorted inlet-air profile in such a way that very little decrease in reference Mach number occurred in the outer annulus.

A study was also made relating the reference Mach number, the fuel temperature, and the fuel volatility with altitude-relight performance. Significant improvements in altitude relight performance were obtained by reducing the reference Mach number, by increasing the fuel temperature from 251 to 425 K (-8° to 305° F), and by using a more volatile fuel, JP-4 instead of ASTM-A1.

INTRODUCTION

This report presents the results of two efforts. One was an attempt to improve the altitude relight capability of a double-annular, ram-induction combustor by using distorted inlet-air flow profiles. The other shows the effects of reference Mach number, fuel

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temperature, and fuel volatility on altitude relight performance.

Previous testing of a short-length, double-annular, ram-induction combustor (ref. 1) indicated a serious altitude relight problem. Relight could not be obtained at inlet-air pressures and temperatures below ambient with reference Mach numbers above 0.05. In an effort to improve altitude-relight capability, several modifications to this combustor were undertaken in light of its otherwise fine performance.

The previous testing indicated that the altitude-relight performance was very sensitive to reference Mach number. Decreasing the reference Mach number improved relight performance. Because the double-annular combustor has the unique feature that combustion can be maintained in either annulus independent of the other, several methods were proposed to improve relight performance by reducing the reference Mach number in the outer annulus while maintaining the same diffuser inlet Mach number. Reduction of velocity in the outer annulus was chosen because the igniters are located there. Hence, the combustor modifications all involved attempts to lower the airflow (i.e., the reference Mach number) in the outer annulus by directing part of the airflow that would normally go to the outer annulus to the inner annulus while holding diffuser inlet conditions constant. In application, diffuser bleed (ref. 2) or variable combustor geometry have been proposed for use on engines to redirect the airflow during altitude relight. To determine if airflow redistribution would enhance relight capability, a flow distortion device was used to redirect the airflow.

Other factors that may affect relight performance are fuel temperature, fuel volatility, and ignitor location. Fuel temperature was varied from 251 to 425 K (-8° to 305° F) to evaluate its effect. A few tests using the more volatile JP-4 fuel were made to compare its performance with ASTM-A1 fuel. Igniter location and energy were not varied during the test program.

Combustor blowout and relight limits were obtained for several configurations. In addition, using the best relight configuration, maximum combustor average temperature rise was determined as a function of inlet-air temperature, total pressure, and combustor reference Mach number. These average temperature rise data are useful in determining how well the combustor could accelerate an engine.

TEST FACILITY

The altitude-relight capabilities of the combustor were studied in a closed-duct test facility. A flow path of this facility is shown in figure 1. Airflow rates for combustion from 2.3 to 136 kilograms per second (5 to 300 lbm/sec) at pressures from 1.7 to 103 newtons per square centimeters (2.5 to 150 psia), could be cooled to 260 K (8° F) or heated to 922 K (1200° F) without vitiation before entering the combustor.

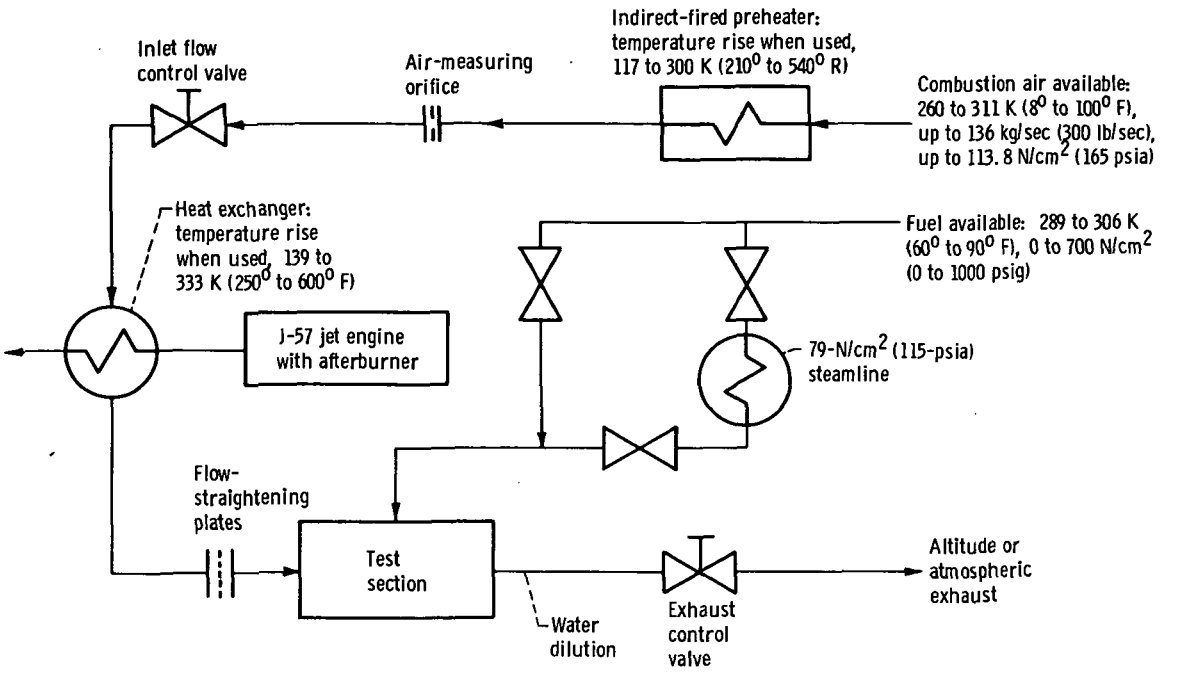


Figure 1. - Schematic of test facility combustion air and fuel.

Fuel was available for the tests at a wide range of temperatures. For desired fuel temperatures below ambient down to 251 K (-8° F), the fuel was supplied from a converted nitrogen trailer which was chilled off site.

For fuel temperatures from ambient to 425 K (305° F), the fuel was passed through a steam heated heat exchanger. Further description of the test facility is given in reference 3.

INSTRUMENTATION

Figure 2 shows the axial location of the instrumentation stations and the placement of the airflow distortion plates. Four, five-point pitot-static tube rakes at station 3.5 were used to measure the airflow profile at the diffuser inlet.

Combustor airflow passage instrumentation consisted of two rakes in each of the three passages to measure airflow distribution between the outer, inner, and center flow passages (fig. 3). Each rake consisted of three total-pressure tubes and a static-pressure tube. The rakes were located at the entrance to each flow passage.

Combustor-outlet total temperature and pressure were measured at 6° increments around the exit circumference. At each 6° increment, five temperature and pressure points were measured across the annulus. In addition, 17 randomly spaced chromel-

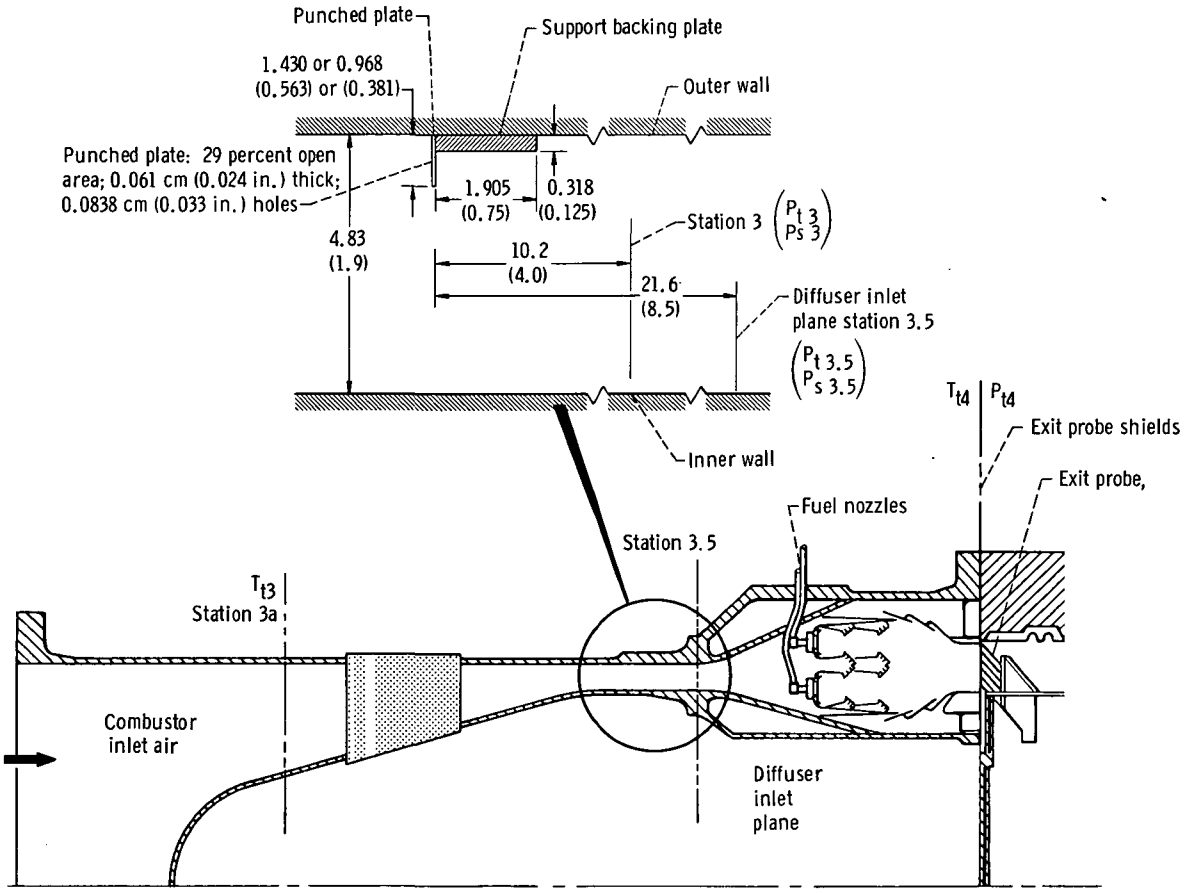


Figure 2. - Axial location of combustor instrumentation. (All dimensions are in cm (in.).)

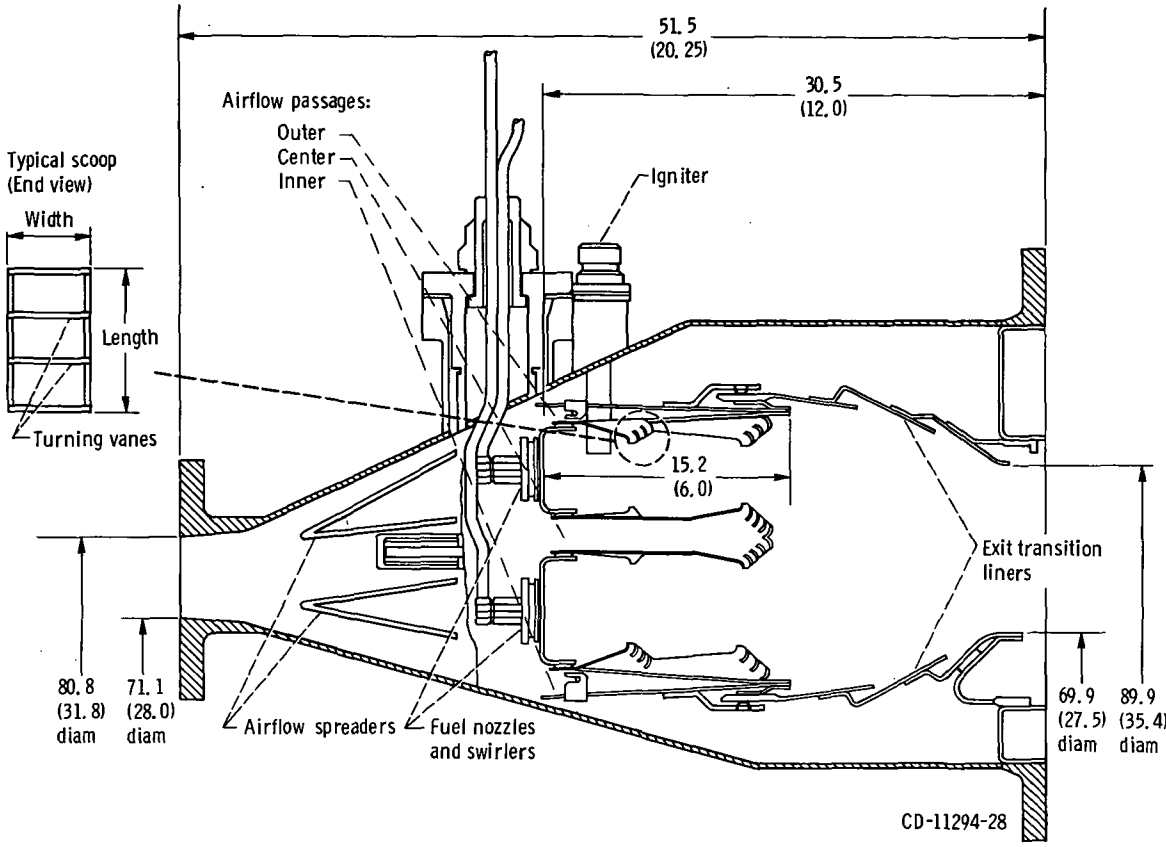


Figure 3. - Cross section of double-annular ram induction combustor. (All dimensions are in cm (in.).)

alumel thermocouples, five near the outer wall, were used to determine when ignition or blowout had occurred.

CALCULATIONS

Reference Mach Number

The reference Mach number was computed from the total airflow, air density at the diffuser inlet, and reference area. The actual combustor reference area is 0.428 square meter (662.8 in.^{2}), the minimum cross-sectional area into which the combustor will fit. However, this combustor was designed to operate in an engine that had a combustor reference area of 0.448 square meter (695 in.^{2}). The reference Mach number was computed using the larger area. Therefore, all pressures, temperatures, and airflows were consistent with the altitude windmill operation of that engine.

Units

The U.S. Customary system of units was used for primary measurements and calculations. Conversion to SI units (System International d'Unites) is done for reporting purposes only. In making the conversion, consideration is given to implied accuracy and may result in rounding off the values expressed in SI units.

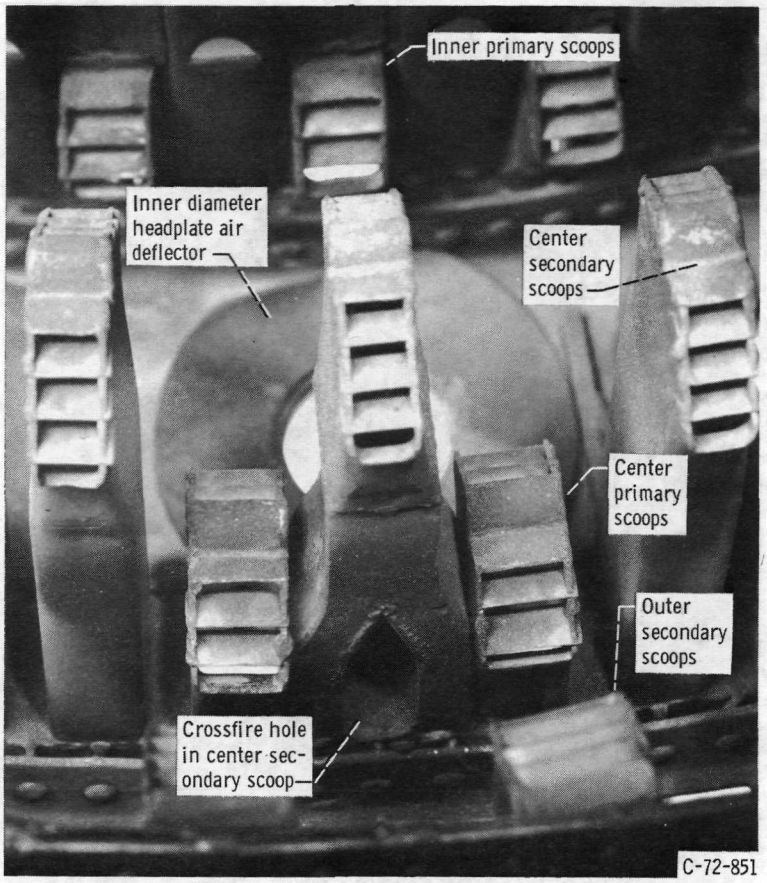
TEST COMBUSTOR

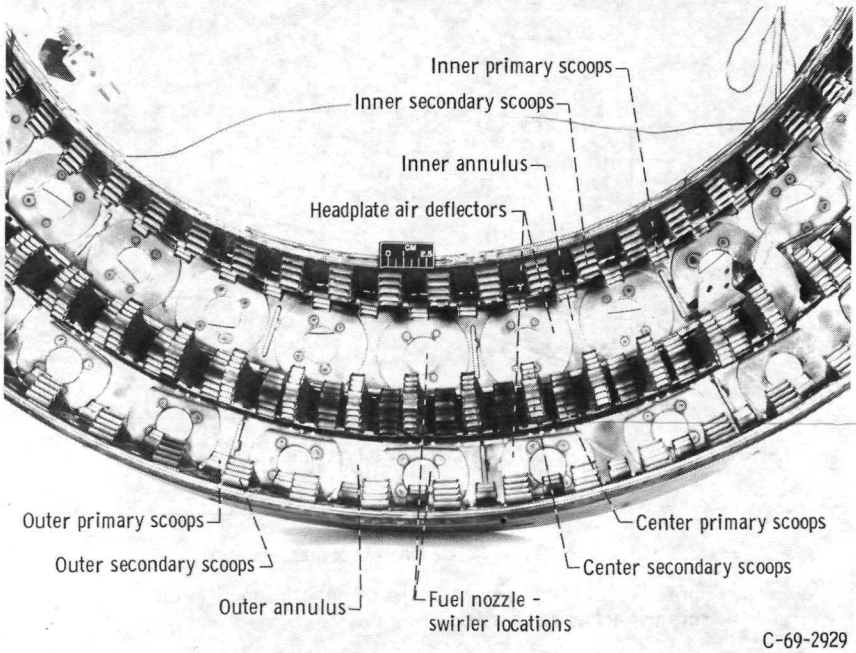
Combustor Design

The combustor is referred to as a double-annular, ram-induction combustor. The double-annular design permits a considerable reduction in combustor length while maintaining an adequate ratio of length-to-annulus height. The ram-induction principle utilizes the kinetic energy of the inlet air to provide rapid mixing both in the primary zone and in the secondary zone. The advantages of this combustor are a shorter combustor length, a shorter diffuser length, and a reduction in the film-cooling-air requirement. A cross section of the combustor may be seen in figure 3. Figure 4 shows photographs of the combustor.

The combustor has 64 fuel nozzles, 32 in each annulus. Two sizes of fuel nozzles were used to better tailor fuel atomization for high- and low-fuel flow operation requirements. Figure 5 shows the fuel flow against fuel nozzle differential pressure for the two sizes of fuel nozzles used. Simplex fuel nozzles were used in this test program.

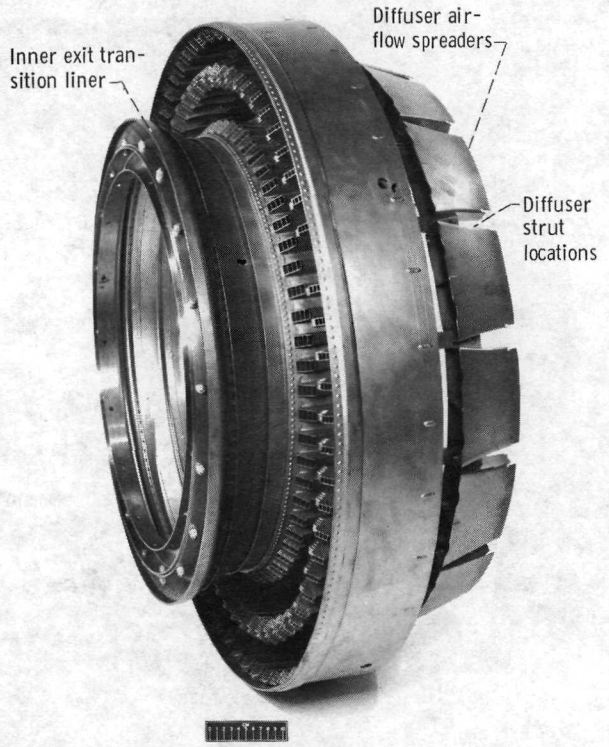
The combustor had two igniters located in the outer annulus, 180° apart. Each igniter was supplied by a 20-joule capacitance discharge power supply. A cross-fire tube located in a center air passage scoop adjacent to one of the igniters was used to assist ignition of the inner annulus. Figure 4(a) shows this crossfire tube. A more detailed description of this combustor and the ram-induction concept may be found in reference 1.





(a) Closeup view.

Figure 4. - Double-annular ram-induction combustor.



(b) Side view (outer transition liner removed).

Figure 4. - Concluded.

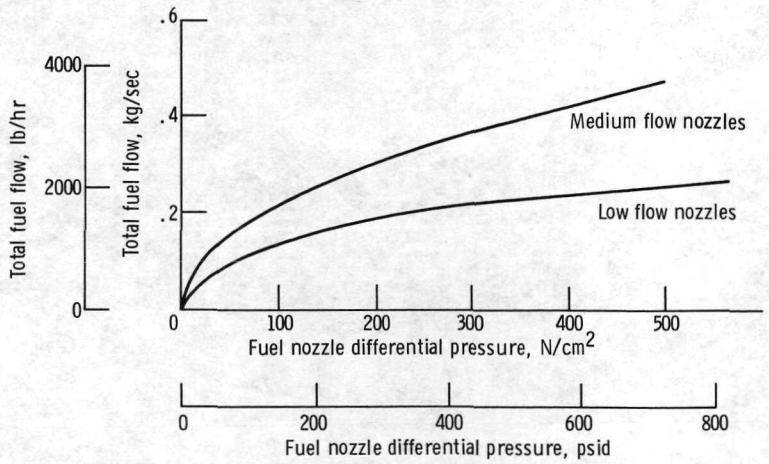


Figure 5. - Total fuel flow for 64 nozzles (32 on each annuli) as function of pressure drop across fuel nozzles.

Combustor Configurations

Previous tests (ref. 1) have shown that reducing the overall combustor reference Mach number usually improves the altitude-relight performance of a combustor. However, it may not be practical to reduce the overall reference Mach number of an engine (combustor) in flight. Since the double-annular combustor has two annuli for combustion, diverting airflow from the outer annulus to the inner annulus should reduce the effective reference Mach number in the outer annulus while maintaining the same overall reference Mach number. This reduction in effective reference Mach number in the outer annulus would then permit improvements in altitude relight performance.

One way to experimentally change the airflow distribution between the annuli is to install an airflow deflector upstream of the diffuser. The purpose of the deflector was to mechanically distort the airflow toward the inner annulus. A moderately hub peaked profile was obtained with a punched plate installed perpendicular to and mounted on the outer wall of the combustor housing. The location of this plate is shown in figure 2(a). A photograph of a plate segment is shown in figure 6.

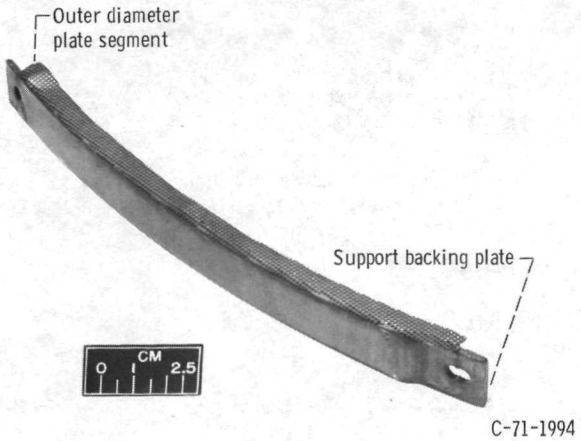


Figure 6. - Inlet airflow distortion plate.

In addition to airflow distortions in the inlet, the open-hole areas of the two combustor annuli were also changed in one case.

The five most significant combustor configuration designs are summarized in table I, and are described below:

Configuration 1 (fig. 7(a)) was essentially the original combustor design of reference 1. The inlet-air profile was flat, the low-flow fuel nozzles with radial air swirlers were used, as well as the original transition liners.

Configuration 2 (fig. 7(b)) was the same as configuration 1 except that the inlet-air

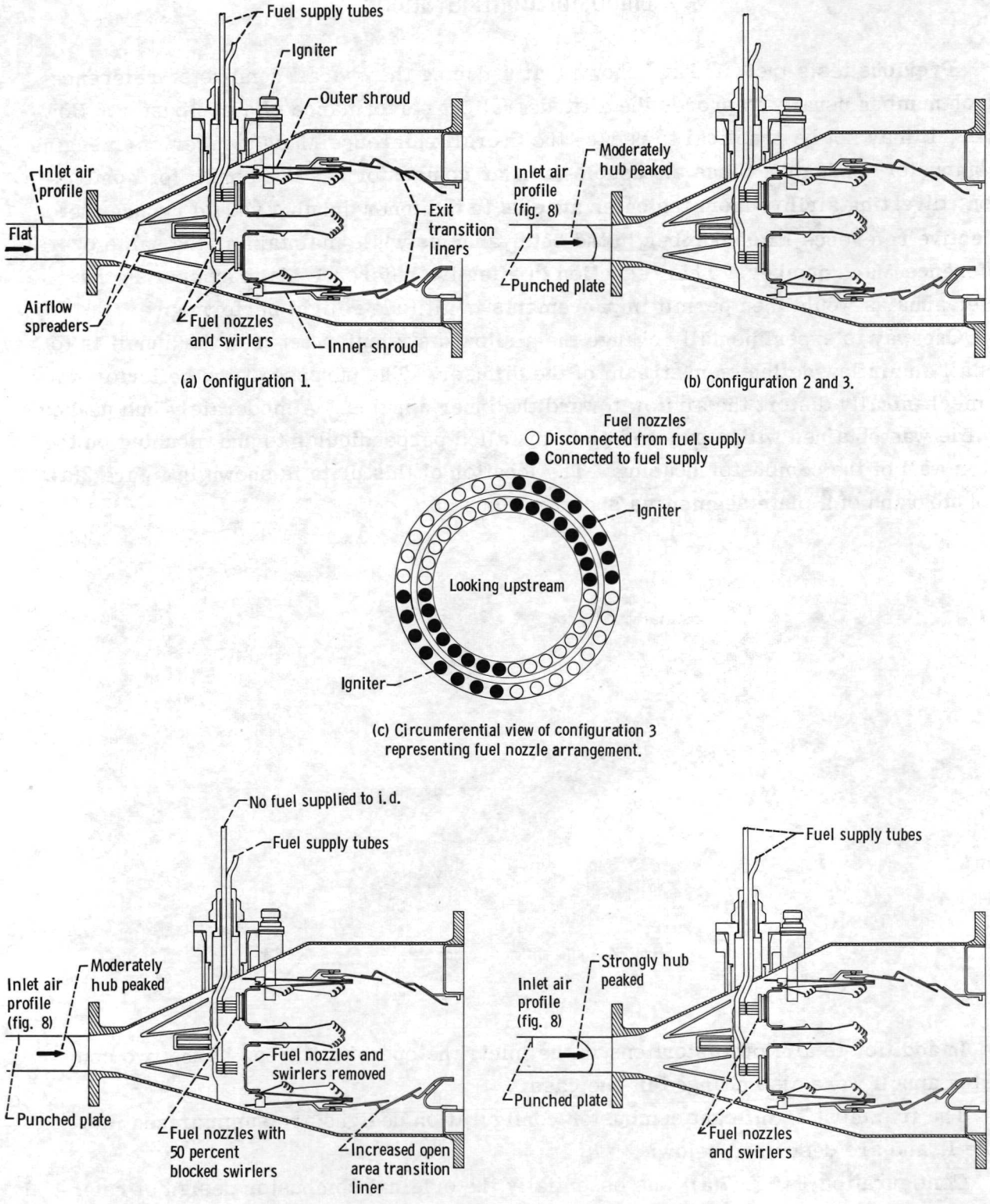


Figure 7. - Cross section of double-annular ram induction combustor.

profile was moderately hub peaked, as shown in figure 8.

Configuration 3 (fig. 7(b)) was exactly the same as configuration 2 except that fuel was not supplied to the two 90° sectors of fuel nozzles, which were located between the two opposed igniters. This fuel nozzle arrangement is detailed in figure 7(c). By using only half as many fuel nozzles it was thought that the increased fuel nozzle differential pressure for the same overall fuel-air ratio could improve relight performance by improving the fuel spray quality.

Configuration 4 (fig. 7(d)) had the same hub peaked inlet air profile as configurations 2 and 3. In addition, the low-flow fuel nozzles were replaced with midrange nozzles on the outer annulus, and the nozzles were removed altogether from the inner annulus. The swirlers were also removed from the inner annulus. The fuel nozzle size change was necessary because 32 fuel nozzles would be carrying the flow previously handled by 64. On the outer annulus the radial swirlers were blocked 50 percent by running metal ribbon around the inlet of the vanes. Finally, the inner transition liner was replaced with one that had 230 percent greater open area. These modifications were made in an attempt to greatly increase the airflow to the inner annulus.

Configuration 5 (fig. 7(e)) was essentially the same as configuration 2 except that a wider punch plate was used in order to achieve a larger hub peaked distorted inlet-air profile. The strongly hub peaked profile is shown in figure 8. A more distorted flow

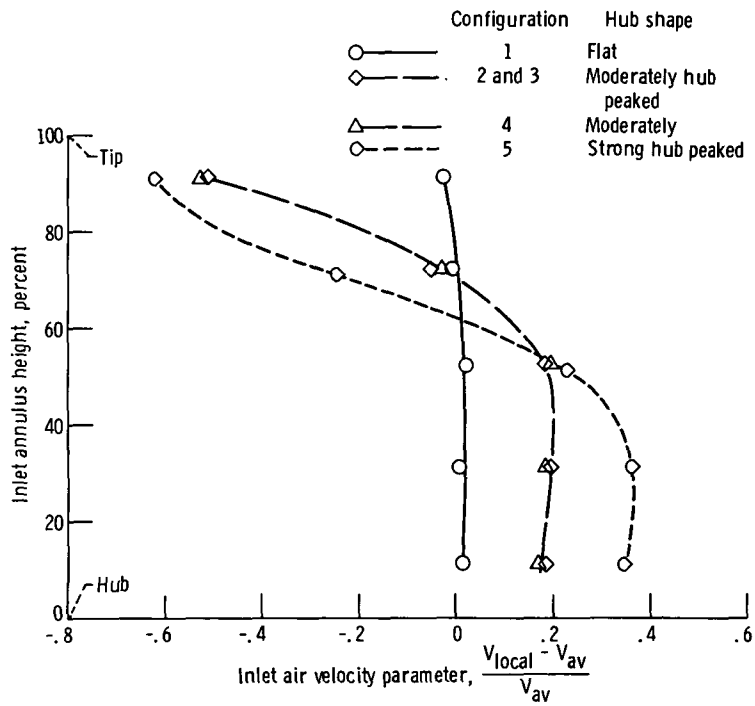


Figure 8. - Diffuser inlet annulus height versus inlet velocity parameter. Average velocity, 116 meters per second (381 ft/sec). (See table I and fig. 8.)

was tried in order to force maximum airflow to the inner annulus. The width of this punched plate was 1.425 centimeters (0.562 in.).

TESTING PROCEDURE

The data were obtained in the following sequence. First, the combustor was operated at a condition that insured ignition. Upon ignition the combustor fuel flow was adjusted to give the highest possible temperature rise up to 650 K (1170° R) differential temperature with airflow, inlet temperatures, and pressure remaining constant.

If a 650 K (1170° R) temperature rise was reached before it appeared that the maximum temperature rise had been obtained at that test condition, the airflow and pressure were reduced at constant reference Mach number and inlet-air temperature. At the new pressure level, the fuel-air ratio was again ranged to determine the maximum temperature rise. Data were taken at successively lower pressures at constant inlet-air temperature, reference Mach number, and fuel-air ratio giving the highest temperature rise until combustor blowout occurred. This fuel-air ratio is defined as the optimum fuel-air ratio. Then ignition was attempted at the conditions existing at blowout. The fuel flow was ranged about the fuel flow rate at blowout. If ignition was not achieved at that condition, the pressure was increased at constant reference Mach number and inlet-air temperature until ignition was obtained. This whole procedure was then repeated, but with a change in one of the basic parameters of inlet-air temperature, reference Mach number, or fuel temperature.

This procedure differs somewhat from that used in reference 1. Reference 1 used a single chromel-alumel thermocouple located near the outer diameter wall to determine when ignition and blowout had occurred. The new procedure required a temperature rise indication on one of 17 randomly spaced chromel-alumel thermocouples for ignition and loss of temperature rise indication on all 17 thermocouples for blowout.

RESULTS AND DISCUSSION

This altitude relight program was conducted in two phases. The first phase was a preliminary investigation, and the second phase was a performance evaluation. The preliminary investigation screened many combustor configurations to determine the best one for the performance evaluation.

All test data presented in this report are tabulated in table II.

Preliminary Investigation

To begin this investigation, a single test was made to determine the altitude relight potential of each combustor configuration. Experience has shown that the blowout point at ambient inlet-air temperature and moderately high reference Mach number (0.075) is a good basis for comparing different configurations of the same basic combustor design.

Figure 9 shows the effect of inlet total temperature on the combustor pressure at blowout. A dashed line has been drawn through the configuration 1, 3, and 5 points to illustrate that all these points likely represent the same blowout curve.

Table III shows how the airflow from the various inlet airflow profiles of figure 8 was distributed when entering the three main combustor airflow passages as shown in figure 3.

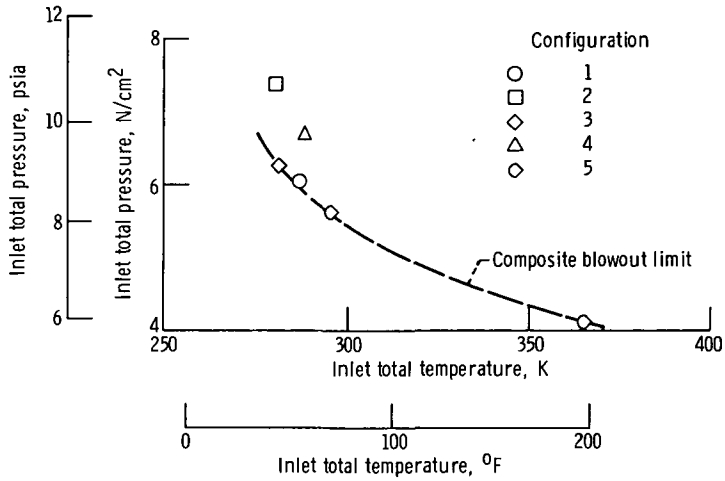


Figure 9. - Comparison of combustor blowout performance for configurations tested. Combustor reference Mach number, 0.075. (See table I.)

As can be seen in table III, with this relatively high-pressure-loss combustor (5.8 percent at a diffuser inlet Mach number of 0.25), the airflow redistributed itself in a manner that nearly nullified the effects of the peaked profiles. This was true even with the strongly hub peaked inlet profile of configuration 5. Therefore, these efforts to improve altitude relight performance were not successful. As configurations 1, 3, and 5 exhibit similar performance, configuration 5 was selected for the performance evaluation.

Performance Evaluation

The performance evaluation was conducted on configuration 5 to determine the effects of combustor reference Mach number, fuel temperature, and fuel volatility on altitude relight performance. Subsequent figures showing relight limit, blowout limit, and maximum temperature rise will be presented.

Effect of variation in combustor reference Mach number. - Figure 10(a) shows the effect of inlet-total temperature on minimum inlet-total pressure for relight at three different combustor reference Mach numbers. The curves indicate the lowest inlet-total pressure at any given inlet-air temperature at which relight can be obtained at the reference Mach number indicated. Thus, at a reference Mach 0.05 and an inlet-air tempera-

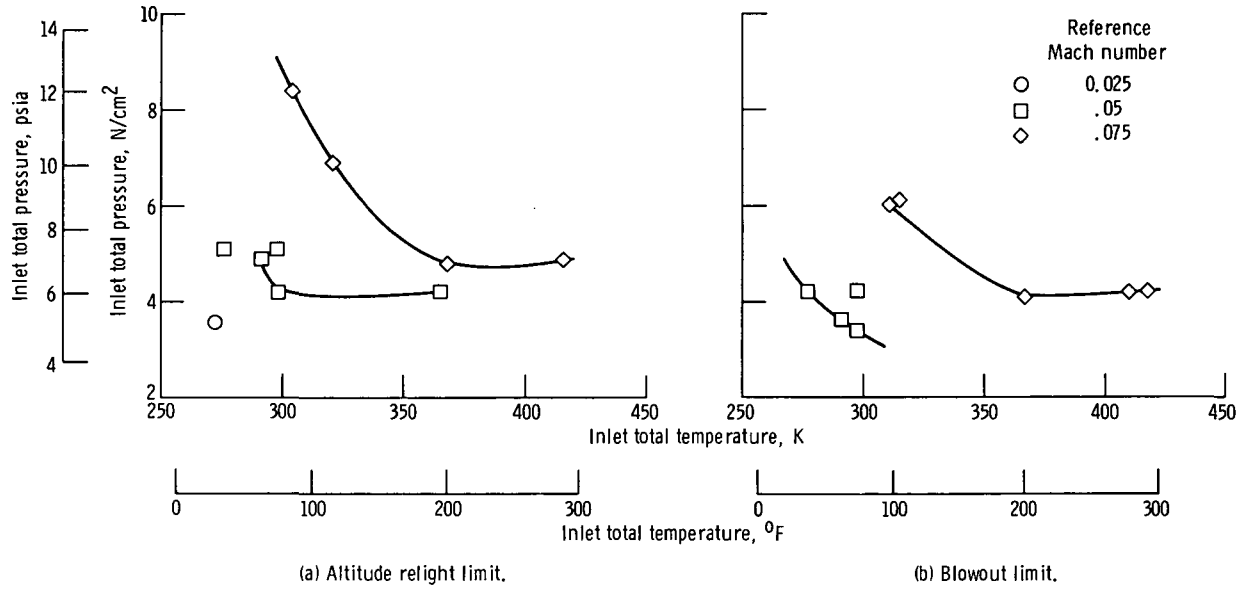


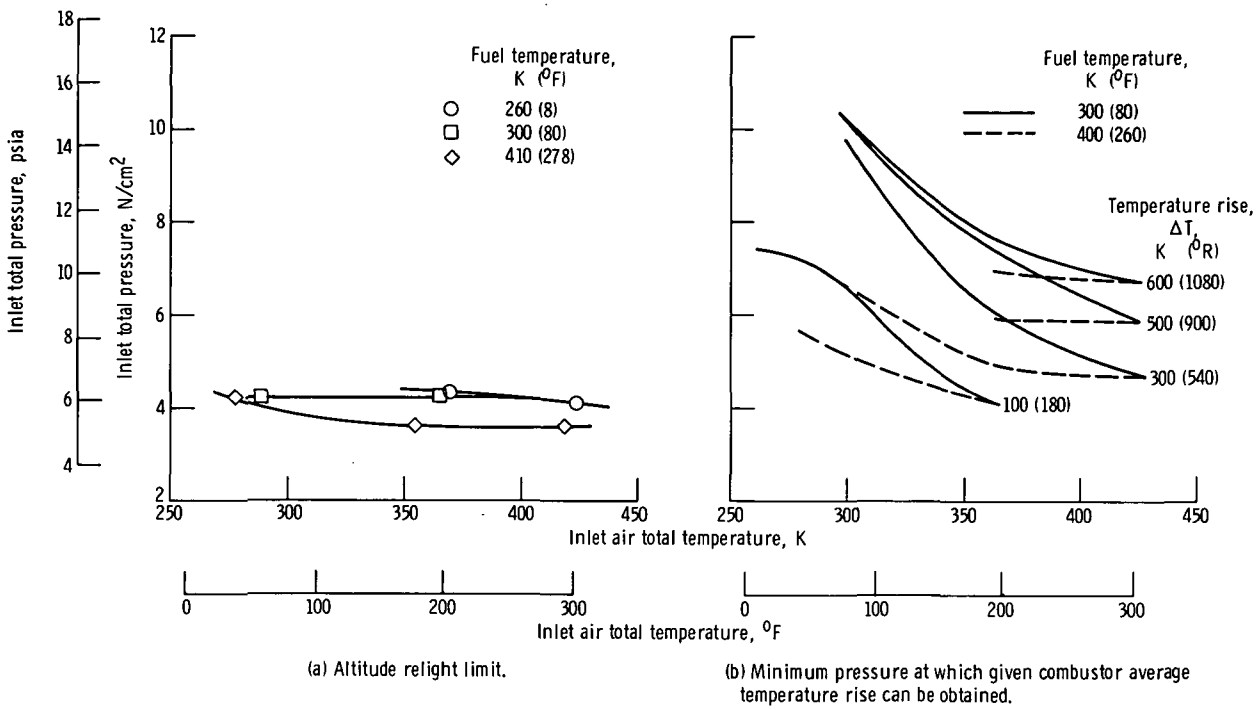
Figure 10. - Combustor performance showing variation with combustor reference Mach number. ASTM-A1 fuel at optimum fuel-air ratio and ambient temperature.

ture of 300 K (80^0 F), combustor ignition should occur at all inlet-total pressures above 4.1 newtons per square centimeter (6.0 psia). As expected, as reference Mach number decreases, altitude relight performance improves.

Figure 10(b) shows the effect of inlet-air temperature on maximum inlet-total pressure for blowout at two different reference Mach numbers. The curves indicate the limiting inlet-total pressure at any given inlet-air temperature at which blowout is likely to occur for a given reference Mach number. Thus, at a reference Mach 0.05 and an inlet-air temperature of 300 K (80^0 F), combustor blowout would likely occur at any inlet-total pressure below 3.3 newtons per square centimeter (4.8 psia). Above this pressure the

combustor should remain lit. Comparing figures 10(a) and (b) shows that combustor blowout occurs at about 0.6 to 1.6 newtons per square centimeter (0.9 to 2.3 psi) below the probable combustor ignition point. On a few occasions ignition was obtained at or very near the blowout point; however, the combustor was only lit in the areas adjacent to the igniters. This resulted in very little overall temperature rise, and blowout occurred when the igniters were turned off.

Effect of variation of inlet-fuel temperature. - Figure 11(a) shows the effect of inlet-air temperature on minimum inlet-total pressure for relight at three different



(a) Altitude relight limit.

(b) Minimum pressure at which given combustor average temperature rise can be obtained.

Figure 11. - Combustor performance showing variation with fuel temperature. Combustor reference Mach number, 0.05; optimum fuel-air ratio.

ASTM-A1 inlet fuel temperatures. As can be seen there is little difference in relight ability between 260 and 300 K (8° and 80° F) temperature fuel.

The effect of inlet-air temperature on minimum inlet-total pressure for average temperature rises of 500, 300, and 100 K (900°, 540°, and 180° R, respectively) at inlet-fuel temperatures of ambient and 400 K (260° F) are shown in figure 11(b) using ASTM-A1 fuel. Figure 11(b) shows that, as fuel temperature increases, the pressure necessary to obtain a particular temperature rise decreases. For example, at a 300 K (80° F) inlet-air temperature, a 9.7-newton-per-square-centimeter (14.1-psia) inlet-air total pressure is necessary to obtain a 300 K (540° R) temperature rise with ambient temperature fuel, while only 6.5 newtons per square centimeters (9.4 psia) is necessary to obtain this temperature rise with 400 K (260° F) temperature fuel. This is due to the

improved fuel atomization resulting from the increase in fuel temperature. However, as inlet-air total temperature increases, a point is reached when there is no longer any improvement in temperature rise with increasing fuel temperature. Apparently optimum fuel vaporization is achieved by acquiring heat from the warmer air so no further improvement can be obtained by having warmer fuel.

Comparison of ASTM-A1 and JP-4 fuels. - JP-4 was selected for this comparison to determine if a fuel more volatile than ASTM-A1 would make a significant improvement in altitude relight performance. Table IV compares various fuel properties of ASTM-A1 and JP-4. The initial boiling point is the most important feature of these fuels. ASTM-A1's initial boiling point is 433 K (320° F), and JP-4's is only 342 K (154° F). Also, table IV shows that about 60 percent of JP-4 is boiled off at the same temperature as the initial boiling point of ASTM-A1 fuel.

Figure 12 shows the effect of inlet-air temperature on minimum inlet total pressure for relight using ASTM-A1 and JP-4 fuels at a combustor reference Mach number of

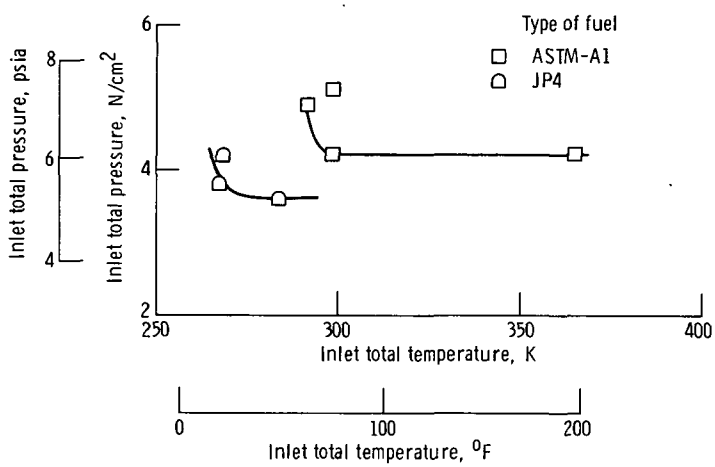


Figure 12. - Altitude relight limit showing variation with type of fuel. Combustor reference Mach number, 0.05; optimum fuel-air ratio.

0.05. Figure 12 indicates that relights are obtainable at lower inlet-air temperature and pressures with JP-4 fuel than with ASTM-A1 fuel.

SUMMARY OF RESULTS

A test program was conducted to evaluate the factors that might improve the altitude relight performance of a double-annular ram-induction combustor. Several methods of distorting inlet-airflow to the inner annulus to reduce the effective reference

Mach number in the outer annulus were tried. It was thought that a reduction in outer annulus effective reference velocity would improve altitude relight performance. However, due to the relatively high pressure loss of this combustor it is unlikely that a significant reduction in outer annulus reference velocity was obtained with any of the configurations tested. As a result no significant improvement in blowout was obtained with these tests.

Also investigated were the effects of combustor reference Mach number, fuel temperature and fuel volatility on relight performance. The following trends were found:

Decreasing the combustor reference Mach number, increasing the fuel temperature, and using a more volatile fuel all decrease the pressure necessary to obtain relight and increase the maximum obtainable temperature rise at any air condition. Much greater pressure decreases are obtainable at ambient temperatures than at higher 365 to 423 K (200° to 300° F) inlet-air temperatures.

CONCLUDING REMARKS

In the preliminary investigation, many attempts were made to improve the altitude relight capability of this relatively high-pressure-loss double-annular combustor by making diffuser and combustor modifications. Among those modifications were a moderate and severe distortion of the diffuser inlet airflow. It was thought that improvements in altitude relight could be made if most of the airflow could be directed to the inner annulus, thus creating a "sheltered" zone in the outer annulus conducive to altitude relight. However, it was found that the air always redistributed itself in such a manner that prevented the creation of the desired sheltered zone. This is likely due to the relatively high combustor total-pressure loss which tended to redistribute the distorted inlet-airflow to the more uniform airflow of configuration 1, the original configuration. Thus no improvement in altitude relight performance was obtainable by the geometric means attempted. It seems likely that a lower combustor pressure loss might allow such an airflow redistribution scheme to successfully improve the combustor relight limits.

Lewis Research Center,
National Aeronautics and Space Administration,
and
U.S. Army Air Mobility R&D Laboratory,
Cleveland, Ohio, June 8, 1972,
764-74.

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TABLE I. - SUMMARY OF COMBUSTOR CONFIGURATIONS

Configuration		Description		
Number	Inlet air velocity profile	Type of fuel nozzle	Swirler type	Transition liners
1	Flat	Low flow	Standard radial	Standard
2	Moderately hub peaked 0.95 cm (3/8 in.) o.d. plate	Low flow	Standard radial	Standard
3	Moderately hub peaked	Low flow with fuel nozzle in two 90° sectors only	Standard radial	Standard
4	Moderately hub peaked	Midrange o.d. manifold only; no nozzles on i.d.	Standard radial 50 percent blocked; no swirlers on i.d.	Inside diameter transitions liner has 230 percent greater open area than standard
5	Strongly hub peaked 1.42 cm (9/16 in.) o.d. plate	Low flow	Standard radial	Standard

TABLE II. - DATA TABLE

Run	Configuration	Inlet air conditions								Combustor operating conditions									Combustor performance				
		Velocity profile	Total pressure		Total temperature		Air flow		Diffuser Mach number	Reference Mach number	Fuel	Fuel-air ratio	Average outlet temperature		Inlet fuel temperature		Fuel nozzle differential pressure		Combustor average temperature rise		Combustor efficiency, percent	Relight obtained	Blowout occurred
			N/cm^2	psia	K	^oF	kg/sec	lb/sec					K	^oF	K	^oF	N/cm^2	psid	K	^oF			
479	4	Moderately hub peaked	6.7	9.7	289	60	9.5	21.0	0.321	0.0775	ASTM-A1	0.0081	310	98	290	63	49	71	---	----	----		Yes
482	4		6.1	8.8	290	62	8.7	19.2	.320	.078		------	---	----	---	----	---	---	---	----	----		
616	2		7.3	10.6	282	48	10.4	22.8	.309	.076		------	---	----	---	----	---	---	---	----	----		Yes
618	2		7.2	10.5	282	48	10.5	23.1	.317	.0778		.0140	---	----	289	61	103	150	---	----	----		Yes
624	3		6.2	9.0	282	47	8.8	19.4	.307	.076		.008	---	----	287	58	100	145	---	----	----		Yes
641	1	Flat	6.0	8.8	287	58	8.2	18.1	.288	.074		.0149	---	----	290	62	89	129	---	----	----		Yes
657	5	Strongly hub peaked	4.8	6.9	287	56	6.0	13.2	.277	.068		.0219	---	----	289	61	83	121	---	----	----	No	
715			8.1	11.7	278	41	7.7	16.9	.200	.053		.0139	423	302	280	44	47	68	145	261	----		
716			7.0	10.2	277	39	6.5	14.3	.194	.052		.0164	415	287	287	57	48	70	138	248	----		
717			5.7	8.2	278	41	5.5	12.1	.205	.054		.0186	344	160	287	57	44	64	66	119	----		
721			6.7	9.7	367	201	8.4	18.5	.331	.077		.0199	466	380	286	55	152	221	99	178	----		
722			8.4	12.1	369	205	9.8	21.7	.304	.0725		.0197	643	697	288	59	209	303	274	492	----		
728			6.3	9.1	371	208	7.5	16.4	.306	.0732		.0142	431	316	278	41	48	69	60	109	----		
729			6.1	8.8	370	206	7.5	16.5	.323	.076		.0195	427	310	283	50	114	165	57	103	----		
732			4.8	6.9	368	202	6.0	13.2	.326	.077		.0160	405	270	283	50	40	58	37	67	----		
733			4.1	5.9	367	202	4.8	10.5	.298	.0721		.0220	---	----	283	50	49	71	---	----	----		Yes
734			4.8	7.0	368	202	5.4	12.0	.285	.069		.0191	411	281	282	48	48	69	44	79	----	Yes	
735			4.2	6.0	365	198	4.0	8.8	.236	.059		.0202	421	298	283	50	26	38	56	100	----	Yes	
736			3.7	5.3	364	196	3.8	8.5	.259	.0637		.0213	---	----	284	52	26	38	---	----	----		Yes
737			4.5	6.5	367	201	4.4	9.6	.238	.060		.0294	529	493	287	57	82	119	162	292	----		
738			4.8	6.9	366	200	4.3	9.4	.217	.055		.0226	821	1019	394	250	62	90	455	819	----	Yes	
745			6.9	10.0	320	117	9.3	20.5	.328	.078		.0167	354	178	283	50	127	184	34	61	----	Yes	
746			6.1	8.9	315	107	8.8	19.3	.348	.0811		.0154	---	----	286	55	85	123	---	----	----		Yes
747			6.0	8.7	311	101	8.7	19.2	.349	.0815		.0149	---	----	286	55	79	114	---	----	----		Yes
760			4.9	7.1	291	64	3.8	8.4	.165	.043		.0309	321	119	285	53	61	88	31	55	----	Yes	
763			7.6	11.0	300	80	6.0	13.2	.169	.044		.0212	869	1104	289	61	76	110	569	1024	71.5		
764			8.2	11.8	296	73	9.4	20.7	.256	.064		.0176	457	363	290	62	148	214	161	290	----		
765			10.3	15.0	304	87	11.3	24.9	.245	.061		.0188	686	775	289	61	268	389	382	688	----		
766			7.1	10.3	298	76	6.5	14.3	.200	.050		.0151	434	322	287	57	40	58	136	245	----	Yes	
767			5.1	7.4		77	4.8	10.6	.207	.052		.0217	329	132	285	53	46	67	31	55	----	Yes	
768			5.1	7.4			4.8	10.7	.207	.052		.0174	334	142	287	57	27	39	36	66	----		
769			4.2	6.2			4.4	9.8	.234	.057		.0173	---	----	287	57	21	31	---	----	----		Yes
770			4.2	6.1			4.1	9.1	.217	.054		.0191	309	97	285	53	22	32	11	20	----	Yes	
771			3.4	4.9			3.6	8.0	.241	.059		.0177	---	----	286	55	13	19	---	----	----		Yes
774			5.0	7.2	291	64	4.4	9.7	.191	.048		.0192	---	----	283	50	25	36	---	----	----	Yes	
775			3.6	5.2	291	65	3.3	7.4	.210	.050		.0185	---	----	283	50	12	18	---	----	----		Yes

TABLE II. - Continued. DATA TABLE

Run	Configuration	Inlet air conditions							Combustor operating conditions									Combustor performance				
		Velocity profile	Total pressure		Total temperature		Air flow		Diffuser Mach number	Reference Mach number	Fuel	Fuel-air ratio	Average outlet temperature		Inlet fuel temperature		Fuel nozzle differential		Combustor average temperature rise		Combustor efficiency, percent	Relight obtained	Blowout occurred
			N/cm^2	psia	K	^oF	kg/sec	lb/sec					K	^oF	K	^oF	N/cm^2	psid	K	^oF			
778	5	Strongly	5.0	7.2	289	60	4.4	9.7	0.191	0.047	ASTM-A1	0.0201	361	190	399	259	50	72	72	130	----	Yes	
779		hub	8.3	12.0	262	11.1	7.9	17.5	.194	.050		.0127	----	----	288	59	41	59	---	----	----	Yes	
780		peaked	6.2	9.0	262	11.7	6.2	13.7	.206	.052		.0164	341	155	283	50	40	58	79	143	----		
781			4.9	7.1	261	10.3	5.0	11.0	.209	.053		.0180	302	83	284	52	30	43	40	73	----		
782			4.2	6.0	261	10.5	4.4	9.6	.215	.054		.0178	----	----	284	52	20	29	---	----	----		Yes
787			4.9	7.1	272	30	3.1	6.9	.128	.033		.0247	372	210	282	48	18	27	100	180	----	Yes	
789			3.6	5.2	272	29	2.7	6.0	.153	.040		.0264	288	59	282	48	9.1	13	17	30	----	Yes	Yes
791			5.6	8.1	270	26	3.6	7.9	.129	.033		.0211	409	276	281	46	20	29	139	251	----	Yes	
792			6.7	9.7	270	26	3.6	8.0	.110	.029		.0226	663	733	284	52	23	33	393	707	----		
793			7.1	10.3	269	25	4.1	9.1	.116	.030		.0217	700	801	284	52	29	42	431	776	----		
795			3.5	5.1	270	26	2.8	6.3	.162	.042		.0242	294	70	281	46	17	24	25	44	----	Yes	Yes
796			7.6	11.1	272	29	4.6	10.2	.122	.032		.0215	786	954	281	46	38	55	514	925	63.3	Yes	
797			5.1	7.4	276	38	4.7	10.5	.194	.049		.0191	372	210	338	149	49	72	95	172	----	Yes	
798			4.2	6.0	277	39	4.1	9.0	.208	.052		.0231	----	----	356	181	51	73	---	----	----	Yes	Yes
799			5.5	8.0	278	40	5.5	12.1	.209	.053		.0208	353	176	397	255	93	134	76	136	----	Yes	
800			5.6	8.1	278	40	5.5	12.2	.208	.053		.0206	363	194	404	268	91	132	85	153	----	Yes	
801			7.1	10.3	279	42	6.4	14.1	.188	.048		.0210	574	574	409	277	168	244	296	532	----		
803			5.7	8.3	287	56	5.3	11.6	.196	.05	JP-4	.0179	339	151	277	39	42	61	53	95	----		
806			4.8	7.0	285	54	4.9	10.8	.220	.055		.0147	359	186	278	41	30	43	73	132	----	Yes	
807			4.2	6.1	284	52	4.1	9.0	.206	.052		.0179	314	105	280	44	32	46	30	53	----	Yes	
809			3.5	5.0	283	49	3.8	8.3	.232	.059		------	----	----	277	39	3.4	4.9	---	----	----	No	Yes
810			7.0	10.2	283	50	6.3	13.8	.189	.048		.0211	690	783	283	50	133	193	407	732	----		
812			7.8	11.4	284	51	6.7	14.7	.178	.046		.0183	816	1009	285	53	112	162	532	958	74.8		
813			3.6	5.2	283	50	3.7	8.2	.219	.055		.0154	300	80	280	44	18	26	17	30	----	Yes	
814			4.9	7.1	267	22	4.6	10.2	.194	.049		.0159	362	193	274	34	33	48	95	171	----	Yes	
816			4.2	6.0	268	23	4.2	9.2	.206	.053		.0176	299	78	276	37	33	48	30	55	----	Yes	
817			5.7	8.3	268	22	5.2	11.4	.183	.048		.0178	435	323	281	46	58	84	167	300	----	Yes	
818			7.0	10.2	267	22	6.3	13.9	.181	.047		.0166	491	424	284	52	78	113	224	403	----		
819			7.7	11.2	267	21	7.0	15.4	.183	.048		.0166	538	508	285	53	98	142	271	488	----		
820			8.4	12.2	266	19	7.6	16.8	.183	.047		.0226	623	662	286	55	237	344	357	643	----		
822			3.8	5.5	267	20	4.1	9.0	.221	.056		.0115	----	----	281	46	11	16	---	----	----	Yes	Yes
823			3.5	5.1	369	204	4.2	9.2	.312	.074	ASTM-A1	------	----	----	382	228	12	17	---	----	----	No	
824			4.2	6.1	365	197	3.7	8.1	.209	.053		.0199	----	----	375	183	20	29	---	----	----		
828			3.4	5.0	363	193	3.2	7.1	.225	.057		.0234	374	214	404	268	35	50	12	21	----		
830			6.7	9.7	369	204	6.0	13.3	.218	.055		.0158	732	858	323	122	51	74	363	654	60.2		

TABLE II. - Continued. DATA TABLE

Run	Configuration	Velocity profile	Inlet air conditions							Combustor operating conditions									Combustor performance				
			Total pressure		Total temperature		Air flow		Diffuser Mach number	Reference Mach number	Fuel	Fuel-air ratio	Average outlet temperature		Inlet fuel temperature		Fuel nozzle differential pressure		Combustor average temperature rise		Combustor efficiency, percent	Relight obtained	Blowout occurred
			N/cm^2	psia	K	°F	kg/sec	lb/sec					K	°F	K	°F	N/cm^2	psid	K	°F			
833	5	Strongly hub peaked	8.4	12.2	369	205	7.2	15.9	0.212	0.053	ASTM-A1	0.0210	1066	1460	413	284	193	279	697	1255	89.3		
835			6.9	10.0	359	186	5.9	13.0	.206	.052		.0206	996	1334	397	255	115	167	638	1148	83.0		
836			5.7	8.3	356	182	5.1	11.3	.220	.055		.0227	728	850	409	277	103	149	371	668	----		
837			4.2	6.0	356	182	4.4	9.8	.267	.065		.0211	----	----	407	273	63	92	---	----	----		Yes
838			4.1	6.0	355	180	3.7	8.1	.217	.054		.0231	467	380	395	251	48	70	111	201	----	Yes	
839			3.6	5.2	354	177	3.0	6.7	.206	.051		.0250	384	232	378	221	35	51	31	55	----	Yes	
842			5.8	8.5	415	288	5.0	11.1	.229	.056		.0224	752	894	401	262	98	142	337	606	----	Yes	
843			4.1	6.0	422	299	3.6	7.9	.233	.057		.0238	779	942	364	196	48	70	357	643	----	Yes	
844			3.6	5.2	418	292	3.0	6.7	.224	.055		.0252	590	601	382	228	38	55	172	310	----	Yes	
845			4.1	5.9	417	291	3.0	6.6	.192	.049		.0260	----	----	409	277	35	51	---	----	----		
849			7.2	10.4	362	192	5.7	12.6	.191	.049		.0227	1007	1354	270	26	76	110	645	1161	77.5	Yes	
850			5.7	8.3	385	232	5.0	11.0	.220	.055		.0260	678	762	270	26	77	112	294	529	----		
857			5.7	8.2	367	201	6.4	14.1	.298	.069		.0152	417	290	293	68	47	68	50	89	----		
859			5.8	8.3	375	215	6.4	14.1	.296	.069		.0152	427	309	293	68	47	68	52	94	----		
861			6.5	9.4	374	213	7.1	15.7	.294	.069		.0198	441	334	294	70	114	166	67	120	----		
862			6.2	9.0	370	206	5.3	11.7	.215	.052		.0210	696	793	295	71	88	127	326	587	----		
864			5.7	8.2	368	202	3.0	6.5	.126	.032		.0303	968	1283	295	71	38	55	600	1080	----	Yes	
866			5.6	8.2	365	197	2.9	6.3	.123	.031		.0222	1028	1390	398	257	25	36	663	1193	80.9	Yes	
867			6.3	9.1	363	195	3.2	7.1	.123	.031		.0238	1152	1614	403	266	38	56	789	1420	90.5		
868			7.1	10.1	365	197	5.8	12.9	.203	.050		.0213	944	1239	307	93	86	124	579	1042	73.6	Yes	
869			5.6	8.1	434	321	4.7	10.4	.232	.056		.0231	1052	1434	296	73	65	94	619	1113	74.3	Yes	
870			5.5	8.0	431	317	4.8	10.6	.242	.058		.0177	867	1102	399	259	50	73	436	785	66.2		
871			6.3	9.2	418	293	5.1	11.2	.214	.052		.0186	994	1330	409	277	65	94	576	1036	83.2		
872			5.5	8.0	410	279	6.4	14.2	.339	.076		.0180	478	401	340	152	80	116	68	122	----		
873			6.3	9.1	404	268	6.9	15.3	.310	.071		.0198	568	564	301	82	111	161	164	296	----		
874			5.0	7.2	412	282	5.5	12.1	.314	.072		.0196	477	399	297	75	63	92	65	116	----		
875			4.2	6.0	418	293	5.0	10.9	.357	.078		.0207	----	----	297	75	54	78	---	----	----		Yes
877			4.9	7.2	416	289	5.5	12.0	.315	.072		.0175	----	----	297	75	50	73	---	----	----	Yes	
878			4.2	6.1	410	278	5.0	11.0	.348	.0772		.0199	----	----	297	75	50	73	---	----	----		Yes
879			5.7	8.3	407	273	3.0	6.7	.135	.034		.0287	1291	1864	296	73	37	54	884	1592	87.6	Yes	
881			5.8	8.4	296	73	2.7	6.1	.103	.026		.0304	1096	1513	297	75	29	42	800	1441	73.6	Yes	
882			8.4	12.1	304	88	10.8	23.9	.312	.073		.0136	354	177	296	73	122	178	49	89	----	Yes	
883			9.0	13.0	303	86	11.8	26.0	.318	.073		.0163	352	174	299	79	232	337	49	88	----		
884			9.7	14.0	303	85	12.6	27.7	.310	.073		.0166	361	191	304	88	287	417	59	105	----		
886			7.6	11.0	368	203	9.1	20.0	.321	.075		.0190	432	317	300	80	194	282	63	114	----	Yes	
887			7.1	10.2	373	212	8.3	18.4	.314	.073		.0169	458	364	300	80	119	173	85	152	----		
892			7.7	11.2	367	201	9.3	20.5	.319	.075		.0186	463	374	298	77	185	269	96	172	----		
893			8.4	12.2	368	203	10.1	22.3	.318	.074		.0176	558	545	300	80	208	302	190	342	----		
895			8.4	12.2	368	203	10.1	22.2	.318	.074		.0176	559	546	301	82	203	295	191	343	----		
896			8.9	12.9	368	203	10.5	23.1	.311	.073		.0181	595	611	302	84	236	341	227	408	----		

TABLE II. - Continued. DATA TABLE

Run	Configuration	Velocity profile	Inlet air conditions						Diffuser Mach number	Combustor operating conditions								Combustor performance				
			Total pressure		Total temperature		Air flow			Reference Mach number	Fuel	Fuel-air ratio	Average outlet temperature		Inlet fuel temperature		Fuel nozzle differential pressure		Combustor average temperature rise		Combustor efficiency, percent	Relight obtained	Blowout occurred
			N/cm^2	psia	K	^oF	kg/sec	lb/sec					K	^oF	K	^oF	N/cm^2	psid	K	^oF			
897	5	Strongly hub peaked	11.0	15.9	369	204	13.5	30.0	0.331	0.075	ASTM-A1	0.0173	608	635	303	86	379	550	240	431	----		
901			8.4	12.1	421	299	6.5	14.3	.204	.051		.0178	1028	1391	420	296	108	157	607	1092	91.4		
902			8.5	12.3	381	227	6.8	15.0	.200	.050		.0208	1063	1454	425	305	164	238	682	1227	88.5	Yes	
903			7.8	11.3	378	222	6.2	13.8	.199	.050		.0186	985	1313	425	305	108	156	607	1092	86.7		
904			9.6	13.9	374	214	11.8	26.1	.333	.077		.0181	571	568	301	82	309	448	196	353	----		
905			9.6	13.9	374	213	11.7	25.8	.324	.075		.0164	646	704	303	86	243	353	273	491	----		
906				14.0	373	212	11.7	25.8	.324			.0136	612	643	304	88	159	231	239	431	----		
907				14.0		212	11.6	25.7	.322			.0110	539	511	303	86	97	140	167	300	----		
908				14.0		211	11.7	25.8	.324			.0080	451	352	302	84	47	68	78	141	----		
909				13.9		211	11.7	25.8	.324			.0202	557	543	301	82	383	555	185	332	----		
937			6.3	9.1	295	71	5.5	12.1	.189	.048	JP-4	.0161	499	439	289	61	46	67	204	368	----	Yes	
939			7.1	10.3	295	71	5.9	13.0	.180	.046	JP-4	.0143	636	685	290	62	49	71	341	614	60		
940			7.6	11.1	295	72	6.5	14.3	.183	.048	JP-4	.0166	718	833	291	64	89	129	423	761	64.9		
941			10.2	14.8	298	77	7.8	17.2	.166	.042	ASTM-A1	.0160	818	1013	290	62	96	140	520	936	83.9	Yes	
943			9.3	13.4	376	216	8.6	19.1	.232	.058		.0090	----	----	266	19	27	39	---	----	----	Yes	
946			9.5	13.8	374	213	8.6	19.0	.224	.056		.0165	867	1101	252	-6	88	128	493	888	78.7		
947			8.3	12.0	372	210	7.3	16.1	.216	.054		.0193	970	1287	252	-6	84	121	598	1077	83.1		
948			8.3	12.1	371	208	7.3	16.1	.215	.054		.0191	967	1281	251	-8	81	117	596	1073	83.4		
949			5.5	7.9	423	302	4.5	9.9	.217	.054		.0179	835	1044	265	17	30	43	412	742	61.9	Yes	
950			4.2	6.1	423	302	3.4	7.5	.211	.053		.0195	729	852	266	19	19	27	306	551	----		
951			4.1	6.0	423	302	3.4	7.5	.214	.054		.0203	----	----	267	21	20	29	---	----	----	Yes	
952			6.0	8.7	424	304	4.8	10.5	.205	.052		.0185	926	1206	264	16	33	48	502	903	73.3		
953			6.8	9.9	367	201	5.2	11.5	.185	.047		.0135	----	----	270	26	20	29	---	----	----	Yes	
954			6.9	10.0	365	197	5.2	11.4	.180	.046		.0179	776	937	264	16	35	51	411	741	61.0		
955			5.5	7.9	362	191	4.5	9.9	.199	.050		.0191	620	657	264	16	29	42	259	465	----		
956			4.1	6.0	362	192	3.7	8.2	.220	.055		.0178	448	347	266	19	16	24	86	155	----		
957			7.6	11.0	366	199	5.8	12.8	.185	.047		.0203	971	1288	262	12	58	84	605	1089	80.2		
958			4.3	6.3	369	205	3.7	8.1	.208	.052		.0186	----	----	268	23	18	27	---	----	----	Yes	
961			7.1	10.3	295	72	6.2	13.6	.189	.047	JP-4	.0141	559	546	257	2	50	73	263	474	----		
962			10.0	14.5	296	74	8.5	18.7	.184	.047		.0155	792	966	248	-13	122	177	496	892	81.1		
963			10.6	15.4	296	73	9.1	20.1	.186	.048		.0144	751	892	251	-8	123	178	455	819	79.6	Yes	
964			9.1	13.3			7.9	17.4	.187	.048		.0157	745	882	251	-8	109	158	449	808	72.6		
965			5.7	8.3			5.1	11.2	.193	.049		.0171	487	417	256	1	50	72	191	344	----		
966			4.9	7.1			4.6	10.1	.205	.051		.0161	397	255	256	1	34	49	101	182	----		
967			4.3	6.3		72	4.0	8.9	.204	.051		.0138	369	204	262	12	18	27	73	132	----		
968			3.5	5.1	295	72	3.6	7.9	.224	.055		.0125	299	78	266	19	12	17	3	6	----		
969			2.8	4.1	295	72	3.0	6.7	.241	.060		.0145	----	----	268	23	12	17	---	----	----		Yes
970			10.7	15.5	296	74	9.1	20.0	.184	.047		.0144	756	901	257	2	126	183	460	827	80.6	Yes	
971			10.4	15.1	297	74	9.1	20.0	.189	.048		.0151	784	952	255	-1	141	204	488	878	81.7		
975			11.1	16.0	299	78	9.8	21.5	.192	.049		.0152	788	959	258	5	170	247	489	881	81.6	Yes	

TABLE II. - Concluded. DATA TABLE

Run	Configuration	Velocity profile	Inlet air conditions							Combustor operating conditions									Combustor performance				
			Total pressure		Total temperature		Air flow		Diffuser Mach number	Reference Mach number	Fuel	Fuel-air ratio	Average outlet temperature		Inlet fuel temperature		Fuel nozzle differential pressure		Combustor average temperature rise		Combustor efficiency, percent	Relight obtained	Blowout occurred
			N/cm^2	psia	K	°F	kg/sec	lb/sec					K	°F	K	°F	N/cm^2	psid	K	°F			
976	5	Strongly hub peaked	12.1	17.6	298	77	10.8	23.8	0.193	0.049	JP-4	0.0177	872	1111	256	1	295	428	574	1034	83.4		
977			7.0	10.2	296	73	9.3	20.6	.311	.073	ASTM-A1	.0142	325	125	285	53	93	135	29	52	----	Yes	
978			8.4	12.1		74	10.9	24.1	.306	.073		.0150	342	157	289	61	151	219	46	83	----		
979			9.8	14.2		73	12.7	27.9	.300	.071		.0151	362	193	292	66	229	332	66	120	----		
980			10.6	15.3		72	13.5	29.9	.295	.070		.0155	424	303	297	75	288	418	128	231	----		
981			10.2	14.7	299	78	8.4	18.4	.178	.046		.0096	421	298	295	71	29	42	122	220	----	Yes	
982			10.2	14.8	299	79	8.3	18.4	.177	.045		.0146	677	759	295	71	75	109	377	679	66.0		
985			10.4	15.1	298	76	15.0	33.1	.348	.080		.0148	340	152	296	73	124	180	42	75	----	Yes	
986			11.1	16.0	298	77	15.8	34.7	.342	.080		.0176	349	168	298	77	196	285	51	91	----		
987			11.2	16.2	298	76	15.0	33.2	.317	.075		.0185	370	207	299	79	199	288	73	131	----		
988			12.3	17.8	297	76	17.1	37.6	.330	.076		.0187	373	212	299	79	265	385	76	136	----		
989			13.9	20.1	297	75	18.7	41.2	.316	.075		.0149	441	334	299	79	202	293	144	259	----		
990			15.2	22.0	295	72	20.3	44.8	.312	.073		.0170	455	360	299	79	306	444	160	289	----		
991			16.6	24.0	296	73	21.9	48.3	.308	.073		.0191	479	403	301	82	468	679	183	330	----		
992			17.9	26.0	296	73	23.5	51.8	.304	.073		.0187	506	451	302	84	512	742	210	379	----		
993			19.1	27.8	296	73	25.1	55.3	.304	.073		.0175	517	471	302	84	510	740	221	398	----		
996			11.2	16.2	377	219	15.2	33.5	.380	.085		.0174	523	482	297	75	188	273	146	263	----		
997			10.9	15.9	372	210	13.8	30.4	.337	.078		.0157	577	579	297	75	122	176	205	369	----	Yes	
999			11.2	16.3	436	324	12.8	28.3	.329	.076		.0138	777	939	294	70	76	111	341	614	64.9	Yes	
1000			12.3	17.9	417	290	14.3	31.6	.326	.076		.0163	860	1089	295	71	137	198	444	799	72.5		
1002			12.5	18.1	374	214	14.8	32.5	.311	.074		.0171	761	911	297	75	164	230	387	697	60		
1005			17.8	25.9	304	88	24.1	53.2	.302	.075		.0163	523	482	300	80	21	30	219	395	----	Yes	
1006			19.2	27.8			26.8	59.0	.313	.078		.0162	536	505	298	77	25	37	232	417	----		
1007			20.6	29.9			28.4	62.7	.309	.077		.0163	576	577	295	71	29	42	272	489	----		
1008			22.1	32.0			30.1	66.3	.306	.076		.0155	583	589	294	70	29	42	279	501	----		
1009			23.5	34.1	304	88	32.4	71.4	.309	.077		.0145	578	581	294	70	30	43	274	493	----		
1010			26.1	37.8	308	94	36.0	79.3	.311			.0132	553	535	294	70	30	43	245	441	----		
1012			27.4	39.7	307	93	37.7	83.0	.310			.0114	545	522	302	85	25	36	238	429	----		
1013			28.8	41.8	307	92	39.9	88.0	.312			.0112	557	543	300	80	26	38	250	451	----		
1014			34.5	50.0	307	93	47.0	103.7	.306			.0098	537	506	297	75	28	40	230	414	----		
1015			37.9	54.9	308	94	50.8	112.0	.301	.075		.0090	528	490	296	73	28	41	220	396	60.6		
1016			41.6	60.3	306	91	55.2	122.0	.296	.074		.0093	540	512	295	72	35	51	234	422	63.0		
1027			13.6	19.7	430	315	15.0	33.0	.297	.073		.0136	781	945	302	84	4.9	7.0	350	631	68.7		
1028			15.8	22.9	430	315	17.8	39.2	.302	.075		.0118	769	925	301	83	5.1	7.5	339	610	75.7		
1029			17.7	25.7	428	311	20.5	45.2	.310	.077		.0131	821	1018	301	82	8.5	12	393	707	79.8		
1030			19.2	27.9	425	306	22.4	49.4	.310	.077		.0121	800	980	301	81	8.6	13	375	675	81.5		
1031			21.3	30.9	424	304	25.2	55.6	.315	.078		.0116	785	953	300	80	10	14	361	649	81.4		
1032			24.0	34.8	422	300	28.4	62.6	.315	.078		.0100	723	842	299	79	9.1	13	301	542	78.2		
1033			27.6	40.0	422	300	31.8	70.1	.306	.076		.0099	736	864	299	78	11	16	314	564	82.2		
1034			30.1	43.7	421	298	35.3	77.8	.310	.077		.0083	680	764	299	78	9.4	14	259	466	79.5		
1035			17.1	24.8	483	410	18.9	41.6	.316	.078		.0156	994	1329	299	78	10	15	511	919	89.7		
1036			20.6	29.9	483	409	22.7	50.1	.314	.078		.0119	878	1121			8.4	12	396	712	89.0		
1037			13.7	19.8	479	403	14.9	32.8	.310	.077		.0158	972	1290			6.5	9.4	493	887	85.2		
1038			15.5	22.5	480	405	17.3	38.1	.318	.079		.0155	986	1316			8.4	12	506	911	89.0		
1039			20.6	29.9	371	208	25.2	55.7	.305	.076		.0114	649	708	298	76	9.7	14	278	500	62.9		
1040			17.1	24.9	374	214	18.3	40.3	.262	.066		.0150	788	958	297	76	9.0	13	413	744	72.7		
1041			19.0	27.5	381	226	23.6	52.1	.315	.078		.0119	666	739	297	76	9.2	13	285	514	62.1		

TABLE III. - COMBUSTOR AIRFLOW PASSAGE DISTRIBUTIONS

Configuration		Percent inlet air measured	Percent flow in -		
Number	Inlet air velocity profile		Outer passage	Center passage	Inner passage
1	Flat	83.8	23.6	49.9	26.5
2 and 3	Moderately hub peaked	84.3	19.2	52.1	28.7
4	Moderately hub peaked	79.5	20.0	56.0	24.0
5	Strongly hub peaked	93.8	16.0	55.5	28.5

TABLE IV. - FUEL PROPERTIES

	ASTM-A1	JP-4
Gravity, ^{o}APL (D287)	43.1	56.05
ASTM distillation values:		
Initial boiling point, K (^{o}F)	433 (320)	342 (154)
Temperature at which following percentage of fuel is evaporated, K (^{o}F):		
5	444 (340)	362 (192)
10	455 (360)	372 (208)
20	----------	384 (230)
30	472 (390)	396 (252)
40	----------	409 (274)
50	483 (410)	420 (294)
60	----------	432 (317)
70	495 (431)	445 (342)
80	----------	460 (368)
90	519 (474)	483 (409)
95	533 (500)	502 (442)
Final boiling point, K (^{o}F)	547 (525)	518 (471)
Residue, percent	1.1	1.4
Loss, percent	0.9	0.7
Flash temperature (D56), K (^{o}F)	324 (124)	----------
Pour point temperature (D97), K (^{o}F)	223 (-58)	----------
Viscosity at 239 K (-30^{o} F), m^2/sec (cS)	9.2×10^{-6} (9.2)	----------
Net heat of combustion (D1405), J/kg (Btu/lb)	43.27×10^{6} (18 615)	43.6×10^{6} (18 794)

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