AFAPL-TR-70-82

INFLUENCE OF FUEL SLOSH UPON THE EFFECTIVENESS OF NITROGEN INERTING FOR AIRCRAFT FUEL TANKS

EDWIN E. OTT, CAPTAIN, USAF
ROBERT A. LILLIE

TECHNICAL REPORT AFAPL- 70-82

FEBRUARY 1971

This document has been approved for public release and sale; its distribution is unlimited.

AERO PROPULSION LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

32

NOTICE

200 - March 1971 - CO305 - 31-71-513

AFAPL-TR-70-82

INFLUENCE OF FUEL SLOSH UPON THE EFFECTIVENESS OF NITROGEN INERTING FOR AIRCRAFT FUEL TANKS

EDWIN E. OTT, CAPTAIN, USAF
ROBERT A. LILLIE

FOREWORD

This report covers work done by the Fire Protection Branch of the Air Force Aero Propulsion Laboratory during the period 1 April 1970 to 3 June 1970 and was submitted by the authors 13 Novermber 1970. This research was performed under Project 3048, Task 304807 "Aerospace Vehicle Hazard Protection," Work Unit 304807032.

This technical report has been reviewed and is approved.

Benito P Botteri

BENITO P. BOTTERI
Chief, Fire Protection Branch
Fuels and Lubrication Division

ABSTRACT

Tests were conducted to determine the influence of sloshing fuel within an aircraft fuel tank upon the effectiveness of nitrogen inerting. These tests were performed in a closed combustion chamber partially filled with JP-8 fuel. The fuel was severely agitated by a rocking motion of the chamber. The flammability of the tank ullage at various concentrations of air, nitrogen, and fuel vapor was tested by exposure to an electric arc. The sloshing fuel did not alter the maximum concentration of oxygen that could be allowed for inerting of all fuel vapor concentrations. For JP-8 fuel vapor exposed to an electric arc this maximum allowable oxygen concentration was found to be 12% by volume. Slosh did extend the flammable region for oxygen concentrations greater than the maximum allowable for inerting. These conclusions, it is believed, are valid for any mode or level of fuel agitation that may be experienced by aircraft fuel tanks.

TABLE OF CONTENTS

SECTION		PAGE
I	INTRODUCTION	1
II	SUMMARY	1
III	TECHNICAL DISCUSSION	2
	1. General Approach	2
	2. Apparatus and Setup	2
	3. Procedure	4
	4. Test Fuel	9
	5. Selection of Slosh Condition	9
IV	TEST RESULTS	11
V	CONCLUSIONS AND RECOMMENDATIONS	21
	1. Conclusions	21
	2. Recommendations	21
	REFERENCES	23

LIST OF ILLUSTRATIONS

FIGURE	TITLE	PAGE
1.	Instrumented Test Chamber	3
2.	Fuel Temperature Control System	5
3.	Ullage Pressure Control System	6
4.	Electric Arc Ignition Source	7
5.	Equilibrium Vapor Pressure for JP-8 Fuel Used in Nitrogen Inerting Tests	10
6.	Fire-No Fire Data as Influenced by Fuel Vapor-Oxygen Concentration	16
7.	Fuel Vapor-Oxygen Flammability Envelopes for JP-8 Fuel	17
8.	Peak Reaction Pressure Rise Data for Various Initial Oxygen Concentrations	19
9.	Peak Reaction Pressure Rise for JP-8 Fuel Ignited in a Sloshing Fuel Tank With no Vent and at Various Initial Oxygen Concentrations	20

SECTION I

INTRODUCTION

The USAF is presently considering nitrogen gas as an inertant for use in aircraft fuel tank ullages. Previous testing to determine the effectiveness of N_2 in this application has been performed under static test conditions, i.e., no liquid fuel agitation within the test vessel (References 1, 2). Recent fuel flammability tests by the Air Force (Reference 3) and the Navy (Reference 4) have shown that the lean flammability temperature limits of jet fuels are lowered by liquid agitation within the fuel tank. The shifting of flammable temperature limits by fuel agitation suggested the possibility that fuel agitation may affect the inerting capability of N_2. In order to assess more completely the effectiveness of N_2 inerting, the Fire Protection Branch of the Air Force Aero Propulsion Laboratory conducted an experimental program designed to study whether fuel slosh had any effect upon the inerting capability of N_2.

SECTION II

SUMMARY

Tests were conducted to determine the influence of sloshing fuel within an aircraft fuel tank upon the inerting effectiveness of N_2. These tests were performed in a closed combustion chamber partially filled with JP-8 fuel. The fuel was severely agitated by rocking the chamber. The flammability of the chamber ullage at various concentrations of air, nitrogen, and fuel vapor was tested by exposure to an electric arc.

It was determined that the sloshing fuel did not alter the maximum concentration of oxygen that could be allowed for inerting all fuel vapor concentrations. For JP-8 fuel vapor exposed to an electric arc the maximum allowable oxygen concentration was found to be 12% by volume. Slosh did extend the flammable region for oxygen concentrations above the maximum allowable for inerting. These conclusions, it is believed, are valid for any mode of fuel agitation experienced by aircraft fuel tanks.

SECTION III

TECHNICAL DISCUSSION

1. GENERAL APPROACH

A sealed combustion chamber was filled with approximately 10 gallons (12.5% volume) of jet fuel. The desired air-nitrogen ullage atmosphere was provided within the test vessel and the system heated to the desired temperature. The amount of fuel vapor in the ullage was determined by the fuel vapor pressure and assumed to be at the equilibrium value. An ignition source (electric arc) was formed within the ullage and the pressure of any ensuing reaction was measured. Comparison ignition tests were run between static and sloshing conditions. The sloshing condition used in the tests was the one at which maximum fuel agitation occurred.

2. TEST APPARATUS AND SETUP

The test vessel (Figure 1) used for these experiments has approximately an 80-gallon capacity, is constructed of stainless steel and is cylindrical in shape; it has a 20-inch outer diameter and is 60 inches in length. Its walls are 3/8 inch thick to withstand a 300 PSIA internal pressure at room temperature. An 8-inch viewing port is located at either end and a pressure relief burst disk is built into the top of the cylindrical wall. This disk, however, was converted into a view port for these experiments. One end of the tank is a rapid opening door.

This test chamber is mounted on a slosh-vibration table located in the Aero Propulsion Laboratory at Wright-Patterson Air Force Base. Vibration displacement is perpendicular to the surface of the table. Slosh is caused by a rocking motion of the table surface about and axis located in the table surface. The test chamber's cylindrical axis is parallel to the table surface and perpendicular to the sloshing axis, and centered above it. The table can vibrate at frequencies between 400 and 3200 cpm and double amplitudes up to 0.050 inch. It can slosh at frequencies between 10 and 20 cpm and double amplitudes between 16 and 30 degrees. The slosh amplitude not readily adjustabl , was set at 30 degrees. Slosh and vibration frequencies and amplitudes can be varied independently.

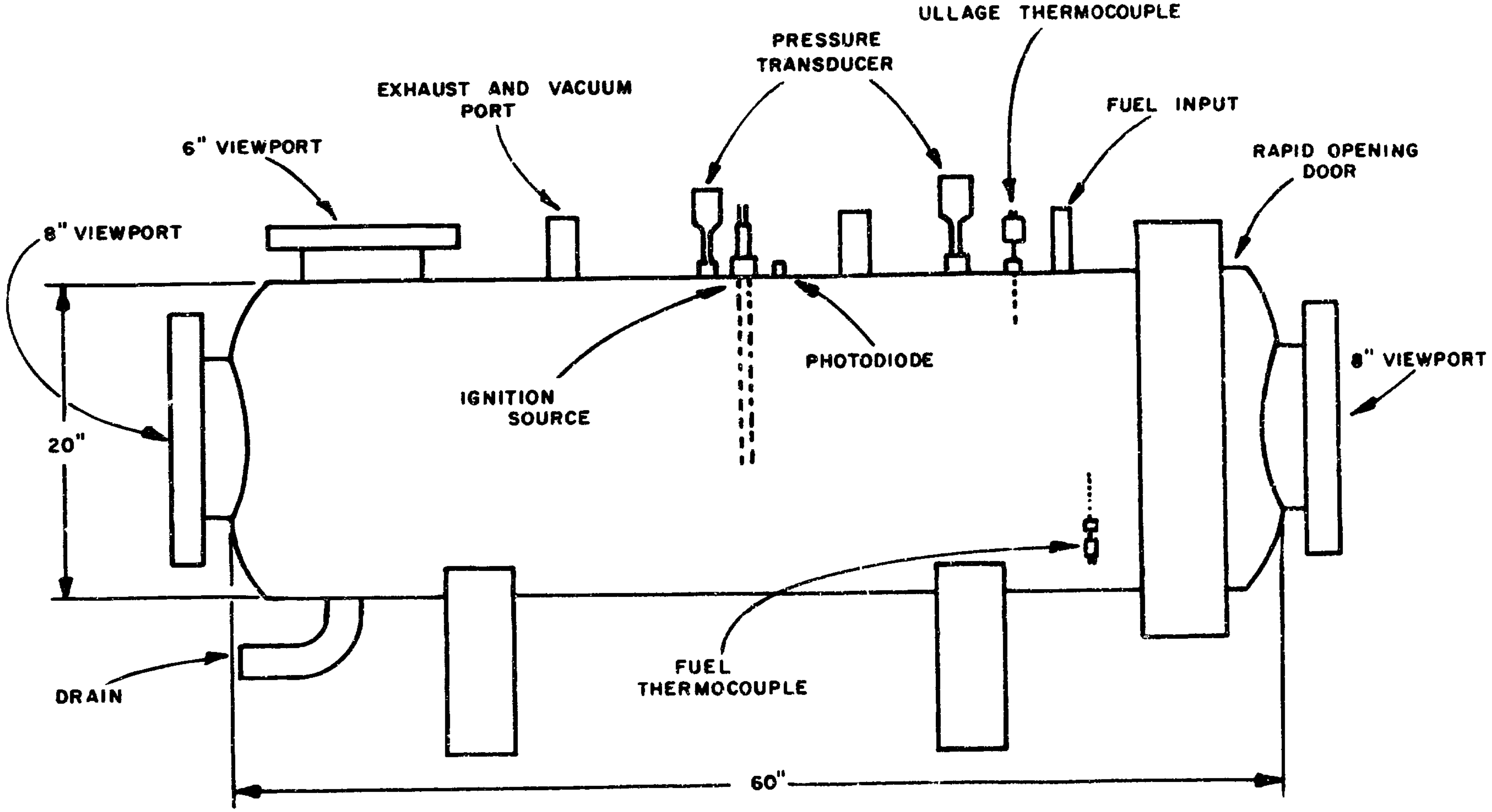

Figure 1. Instrumented Test Chamber

Fuel is heated by means of a steam heat exchanger and cooled by storage in a specially adapted commercial food freezer (Figure 2). Air entering the test chamber passed first through a chemical air dryer (Figure 3). Evacuation was accomplished by oil vacuum pumps.

The test chamber is instrumented with two copper-constantan thermocouples: one mounted in the ullage and one submerged in the fuel. Thermocouple outputs were recorded by a strip chart recorder (Brown "Electronik"). Pressure was measured by two strain gauge transducers mounted in the ullage (CEC 4-326-003, 0 to 75 PSIA; CEC 4-311, 0 to 200 PSIA). An uncalibrated photodiode was also mounted in the chamber so that it viewed the vicinity of the ignition source. The pressure transducers and photodiode outputs were recorded on a light beam oscillograph (CEC model 5-124). Also recorded on the oscillograph was the output of an uncalibrated accelerometer which sensed the rocking motion of the table.

The ignition source (Figure 4) consisted of two 1/16 inch stainless steel rods mounted 1/4 inch apart and nearly parallel, and vertically from the top center of the test chamber. A standard furnace type fuel oil ignition transformer rated at 12,000 volts AC and 250-volt-amperes was used to apply voltage to the rods. These rods mounted in the chamber through ceramic insulators, dipped 12 inches into the ullage. The bottom ends of the rods were mounted closer together than the top ends so that when the high voltage was applied an arc formed at the bottom ends. The convective air currents formed by the hot arc carried the arc up the rods to a point at which the separation was too great to sustain it. Here the arc was broken and a new one formed at the bottom.

3. PROCEDURE

Testing procedures are summarized as follows:

1. Evacuate tank to less than 1 PSIA.
2. Pressurize tank to atmospheric pressure using dry air.
3. Add fuel to tank and heat.
4. Evacuate tank to 5 PSIA.
5. Pressurize tank to atmospheric pressure using dry air.

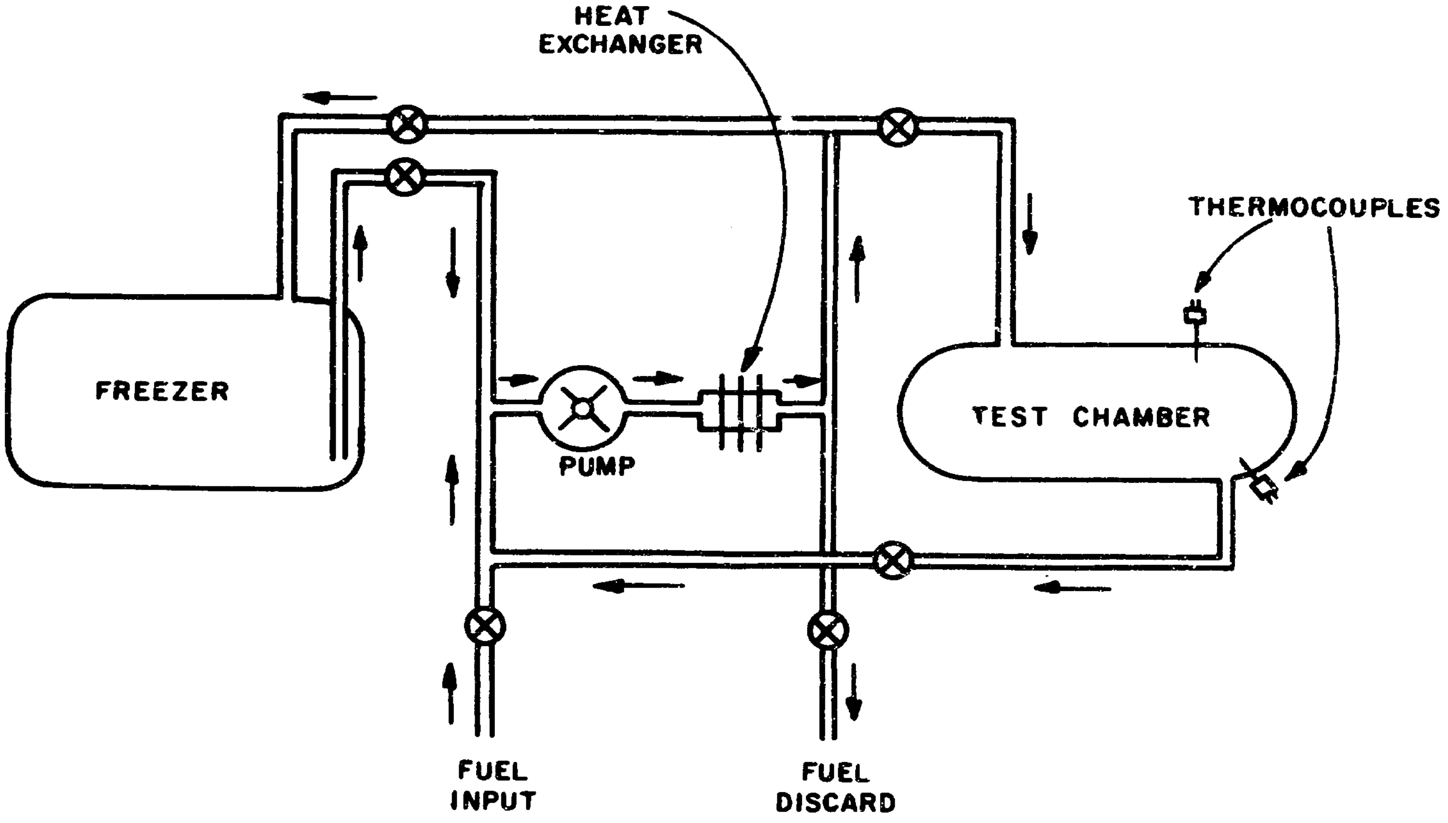

Figure 2. Fuel Temperature Control System

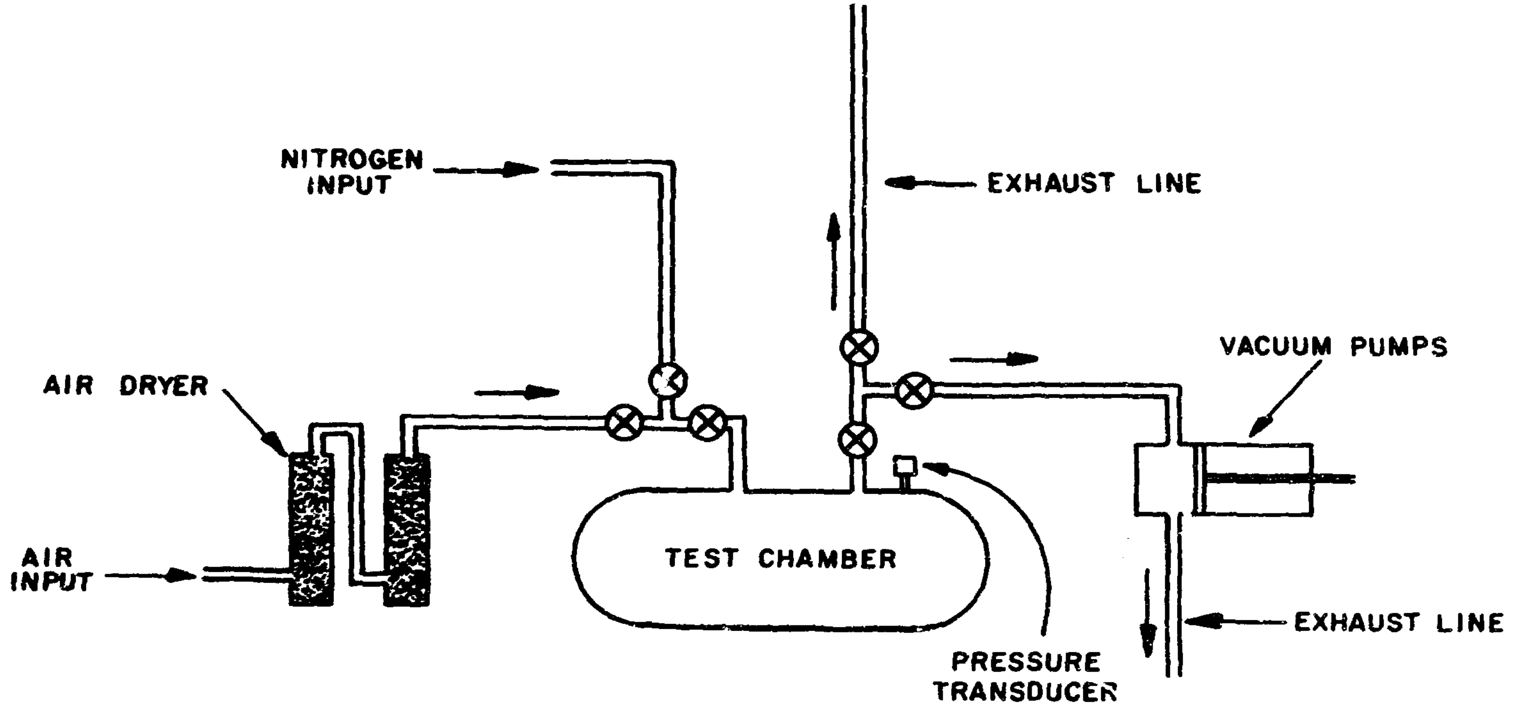

Figure 3. Ullage Pressure Control System

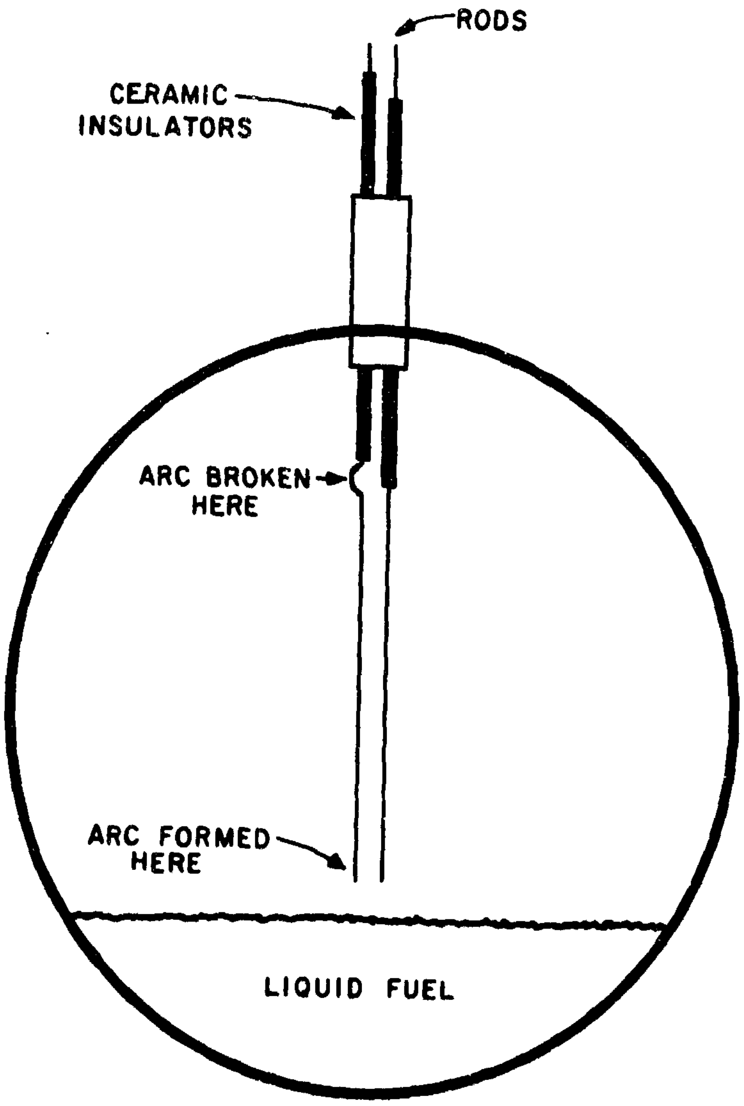

Figure 4. Electric Arc Ignition Source

6. Evacuate tank to 5 PSIA.
7. Pressurize tank using dry air to a value desired from Table 1.
8. Pressurize tank with N_2 to value desired from Table 1.
9. Exhaust excess pressure to atmosphere.
10. Slosh for 5 minutes.
11. Continue sloshing and attempt ignition if a sloshing test is desired. If static test is desired, turn off slosh and allow table to stop moving before attempting ignition. Time for table to stop moving is approximately one minute.
12. Repeat steps 4 through 11 for next test.
13. Conduct two tests per fuel batch if temperature is greater than 100°F; four tests if temperature is 100°F or below.

TABLE I

MIXING PARTIAL PRESSURES FOR AIR AND NITROGEN

% Oxygen By Volume	Air Pressure (PSIA)	Nitrogen Pressure (PSIA)	Total Pressure Before Exhaust (PSIA)
21	14.7	0	14.7
15	27.5	11.0	38.5
14	24.0	12.0	36.0
13	21.3	13.0	34.3
12	20.0	15.0	35.0
11	20.0	18.2	38.2
10	14.7	16.2	30.9

The desired air-nitrogen ullage atmosphere was formed by mixing partial pressures of air and nitrogen as prescribed by the following equations:

$$P_{N_2}/P_A = 21/\%O_2 - 1 \equiv K \quad .....(1)$$

$$P_A \geq 21/(1+K)\left[43/42 + 1/(1+K)\right]..(2)$$

where P_A = partial pressure of air,

P_{N_2} = partial pressure of nitrogen, and

$\%O_2$ = final desired oxygen content.

Equation 1 defines the nitrogen - air ratio needed to obtain the desired oxygen content and Equation 2 sets the minimum value for the mixing partial pressure of air in order to obtain accuracy of ± 1/2% in oxygen content (with pressure measurement system accuracy of ±1/2 PSI).

4. TEST FUEL

JP-8 fuel was used in all tests. This fuel had a Pensky-Martens Closed Cup flash point of 118°F and an average bulk molecular weight of 163. Vapor pressure for this JP-8 fuel is shown in Figure 5.

5. SELECTION OF SLOSH CONDITIONS

The slosh or fuel agitation used in these tests was the most severe that could be developed by the test apparatus. At a frequency of 17.5 cpm and double amplitude of 30 degrees, the bulk of the fuel splashed against alternate ends of the vessel in resonance with the rocking motion of the tank.

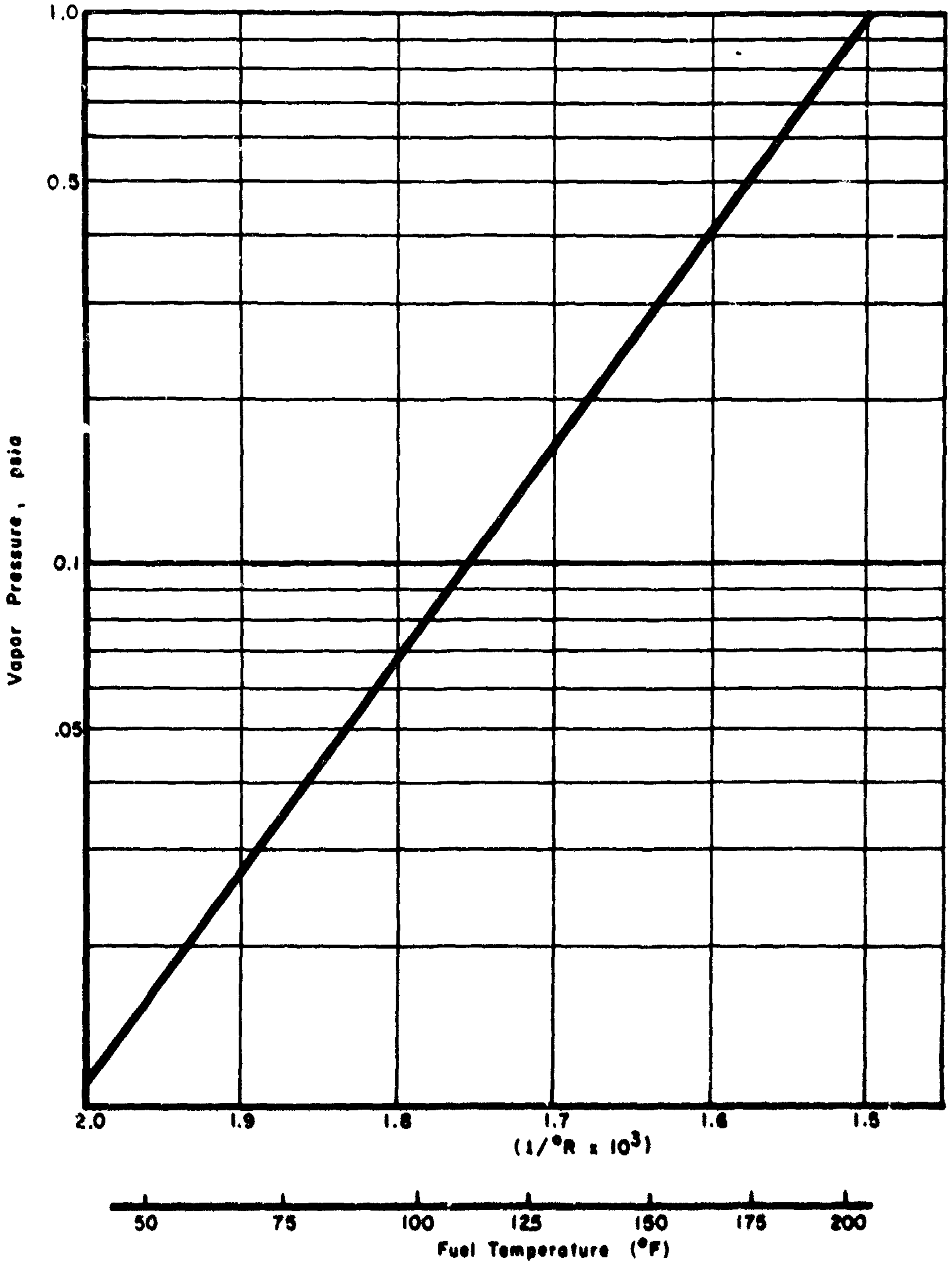

Figure 5. Equilibrium Vapor Pressure for JP-8 Fuel Used in Nitrogen Inerting Tests

SECTION IV

TEST RESULTS

A total of 68 ignition tests were conducted. Initial conditions and resulting combustion pressure rises are given in Table 2.

Figure 6 shows the results plotted as either fire or no fire as a function of the initial oxygen and fuel vapor concentrations. Only one ignition took place for an oxygen concentration below 13%. This unique ignition occurred at 12% oxygen and simultaneous sloshing. It resulted in a pressure rise of only one PSI. Several other ignition tests were conducted at or very near this same fuel vapor-oxygen condition for both the sloshing and static cases with no resulting reaction. Therefore, 12% oxygen is the minimum oxygen concentration for flammability of JP-8 fuel vapors. Since ignition at 12% oxygen could not be made to occur again even for the sloshing case, the authors do not believe that this single fire point represents a real difference in the minimum oxygen concentration for flammability between the static and the sloshing conditions.

A difference does occur in the flammability envelopes between the static and the sloshing conditions. At 15% oxygen, nearly 1.25% fuel vapor was required for flammability under static conditions, while only 0.5% fuel vapor was needed under sloshing conditions. This extension of the flammability envelope under sloshing conditions is illustrated in Figure 7. The dashed lines in the figure represent the extrapolation of the envelopes to include the flammable limits at 21% oxygen as determined in previous AFAPL work (Reference 3).

The extension of the flammability envelope by sloshing fuel is not unexpected. The sloshing causes a spray of fuel droplets throughout portions of the ullage. These fuel droplets will burn in addition to the fuel vapors. Although droplets have different flammable characteristics from vapors, the addition of droplets to vapors can be viewed, for the purpose of gaining qualitative insight only, as an addition to the amount of fuel vapor. Thus the sloshing fuel tank with only a 15% oxygen concentration and a 0.5% fuel vapor concentration is still flammable because enough fuel droplets are scattered throughout the ullage to cause the ullage to behave as if it had a 1.25% fuel vapor concentration.

TABLE II

INITIAL TEST CONDITIONS AND COMBUSTION PRESSURE RISES

Test No.	Dynamic Condition	Initial Ullage Pressure (PSIA)	Fuel Temperature	Ullage Temperature	Oxygen Percent	Fuel Vapor Percent By Volume	Peak Reaction Pressure Rise (PSI)
4001	static	14.7*	127	115	10	1.17	0
4002	slosh	14.7	123	114	10	1.04	0
4003	static	14.7	125	113	15	1.10	65
4004	static	14.7	126	118	12	1.13	0
4005	slosh	14.7	95	90	15	0.49	7 ½
4006	slosh	14.7	98	93	12	0.53	0
4007	slosh	14.7	110	105	15	0.73	34
4008	slosh	14.7	93	unknown	15	0.46	1
4009	slosh	14.7	91	89	15	0.43	3
4010	slosh	14.7	125	118	15	1.10	63
4011	slosh	14.7	118	114	12	0.91	0
4012	static	14.7	119	114	12	0.93	0
4013	slosh	14.7	136	125	15	1.45	63
4014	slosh	14.7	127	121	14	1.17	37
4015	slosh	14.7	121	112	13	0.99	40
4016	static	14.7	116	110	13	0.86	0
4017	slosh	14.7	110	106	13	0.73	0

*Atmospheric pressure was always taken to be 14.7 PSIA.

TABLE II (CONTINUED)

Test No	Dynamic Condition	Initial Ullage Pressure (PSIA)	Fuel Temperature	Ullage Temperature	Oxygen Percent	Fuel Vapor Percent By Volume	Peak Reaction Pressure Rise (PSI)
4018	slosh	14.7	105	102	14	0.64	0
4019	slosh	14.7	128	120	12	1.18	0
4020	slosh	14.7	160	149	14	2.75	43
4021	static	14.7	150	141	15	2.13	1
4022	static	14.7	152	135	15	2.26	52
4023	slosh	14.7	135	129	14	1.43	43
4024	slosh	14.7	155	144	14	2.44	46
4025	static	14.7	146	137	13	1.89	0
4026	slosh	14.7	125	120	14	1.10	58
4027	static	14.7	154	137	14	2.38	36
4028	static	14.7	144	133	14	1.80	53
4029	slosh	14.7	143	132	14	1.78	51
4030	static	14.7	135	128	14	1.43	3
4031	static	14.7	126	121	14	1.13	57
4032	static	14.7	135	127	14	1.45	58
4033	static	14.7	126	122	14	1.13	53
4034	slosh	14.7	145	131	15	1.85	56

TABLE II (CONTINUED)

Test No.	Dynamic Condition	Initial Ullage Pressure (PSIA)	Fuel Temperature	Ullage Temperature	Oxygen Percent	Fuel Vapor Percent By Volume	Peak Reaction Pressure Rise (PSI)
4035	static	14.7	135	126	15	1.42	57
4036	static	14.7	145	135	15	1.85	50
4037	static	14.7	146	135	15	1.85	59
4038	slosh	14.7	146	137	13	1.89	39
4039	slosh	14.7	136	126	13	1.45	48
4040	static	14.7	144	127	13	1.80	49
4041	slosh	14.7	135	126	12	1.42	0
4042	static	14.7	126	119	13	1.13	11
4043	slosh	14.7	145	134	13	1.65	52
4044	static	14.7	136	129	12	1.45	0
4045	slosh	14.7	126	122	12	1.13	0
4046	static	14.7	132	124	13	1.33	49
4047a	static	14.7	126	120	15	1.13	61
4047b	slosh	14.7	148	130	14	2.01	55
4048	slosh	14.7	142	127	12	1.69	0
4049	static	14.7	132	117	13	1.33	0
4050	slosh	14.7	157	137	13	2.55	40

TABLE II (CONTINUED)

Test No.	Dynamic Condition	Initial Ullage Pressure (PSIA)	Fuel Temperature	Ullage Temperature	Oxygen Percent	Fuel Vapor Percent By Volume	Peak Reaction Pressure Rise (PSI)
4051	slosh	14.7	149	134	12	2.06	0
4052	static	14.7	141	123	13	1.64	40
4053	slosh	14.7	159	141	13	2.68	30
4054	static	14.7	151	136	12	2.20	0
4055	slosh	10.0	157	134	13	3.69	1.5
4056	slosh	10.0	141	124	12	2.53	1
4057	static	10.0	160	138	13	4.00	0
4058	slosh	5.0	120	103	12	2.86	0
4059	static	5.0	120	102	12	2.86	0
4060	static	5.0	126	108	13	3.45	0
4061	slosh	5.0	114	99	12	2.44	0
4062	static	5.0	125	111	13	3.30	0
4063	slosh	5.0	122	112	12	3.06	0
4064	slosh	5.0	135	117	13	4.35	0
4065	slosh	14.7	157	152	12	2.55	0
4066	slosh	14.7	157	153	11	2.55	0
4067	slosh	14.7	157	152	12	2.55	0

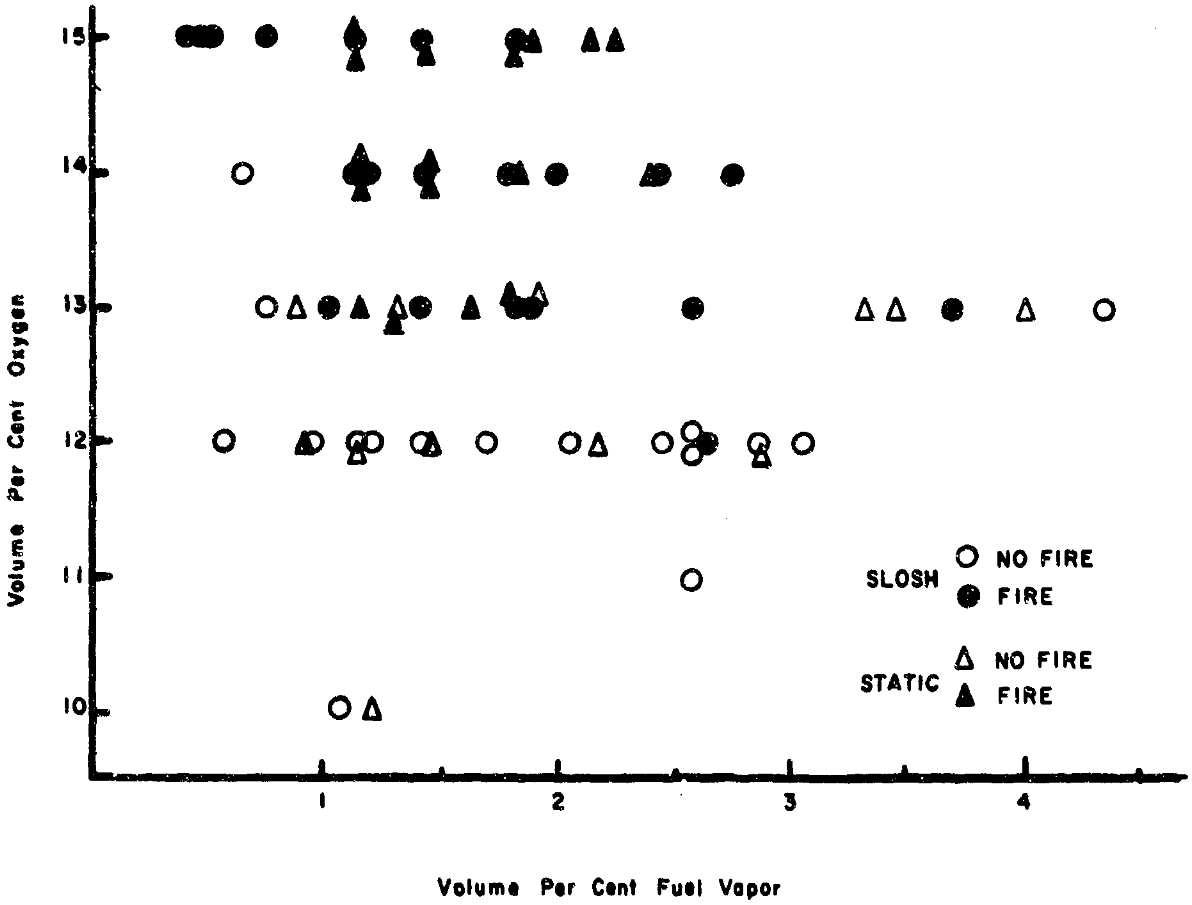

Figure 6. Fire-No Fire Data as Influenced by Fuel Vapor-Oxygen Concentration

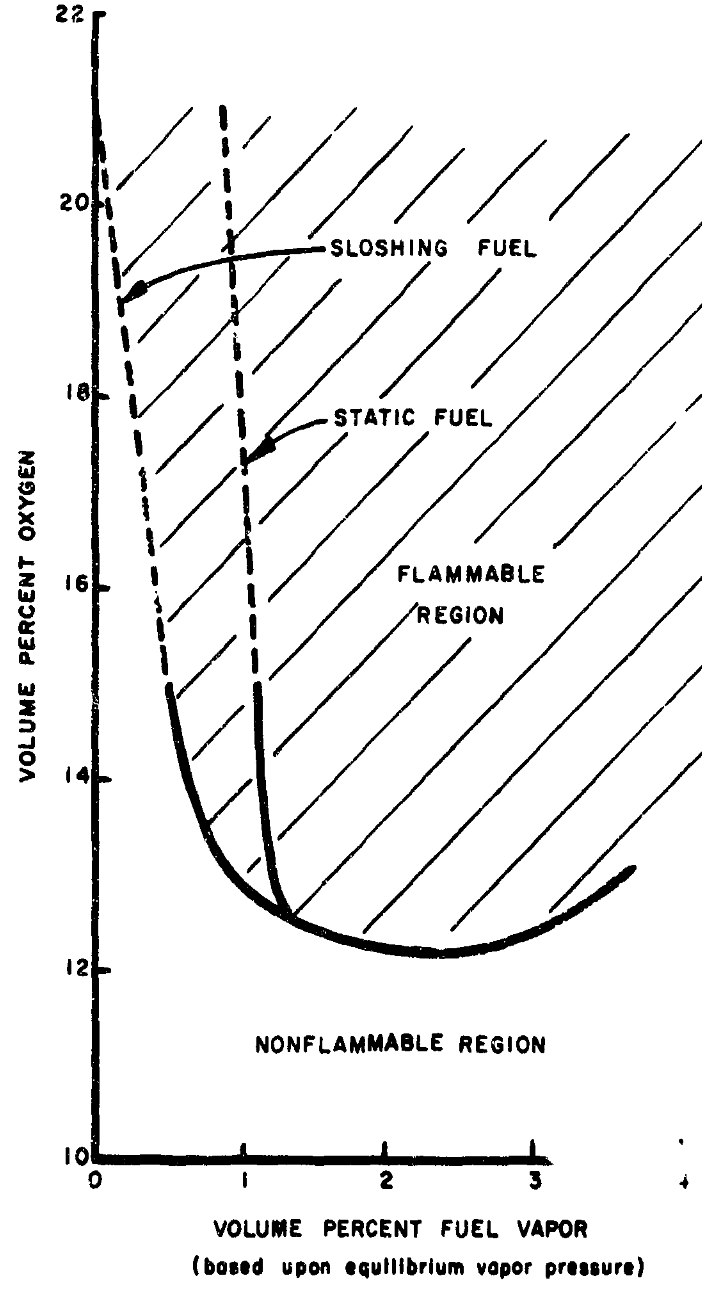

Figure 7. Fuel Vapor-Oxygen Flammability Envelopes for JP-8 Fuel

The amount of extension to the flammability envelope by sloshing decreases rapidly with decreasing oxygen concentration as shown in Figures 8 and 9. For 21% oxygen there is no lower flammability temperature limit (Reference 3). For 15% oxygen there is approximately 30°F lowering of the lean limit. At 13% oxygen there is essentially no extension to the limit.

Figures 8 and 9 also illustrate the effect of lowering the oxygen concentration to the maximum pressure rise. For 21, 15, 14, and 13% oxygen the maximum pressure rises (final pressure minus initial pressure) are 82, 65, 58, and 52 PSI, respectively. As would be expected, these decreases in maximum pressure rises are approximately proportional to the decreases in oxygen content. Thus in going from 21% to 13% oxygen, a decrease of 37% in oxygen content, the maximum pressure fell from 82 PSI to 52 PSI, a decrease of 38% in maximum pressure.

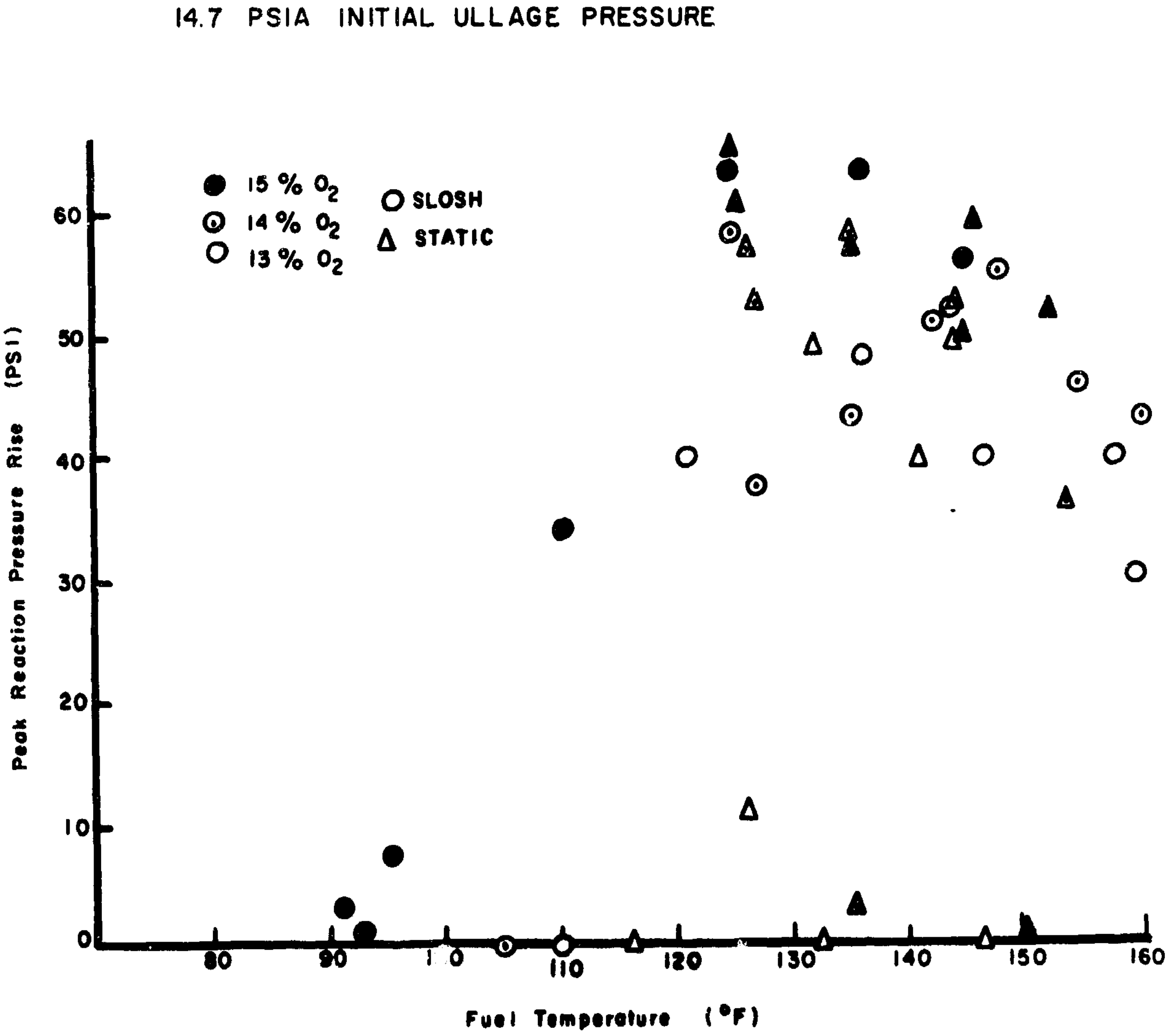

Figure 8. **Peak Reaction Pressure Rise Data for Various Initial Oxygen Concentrations**

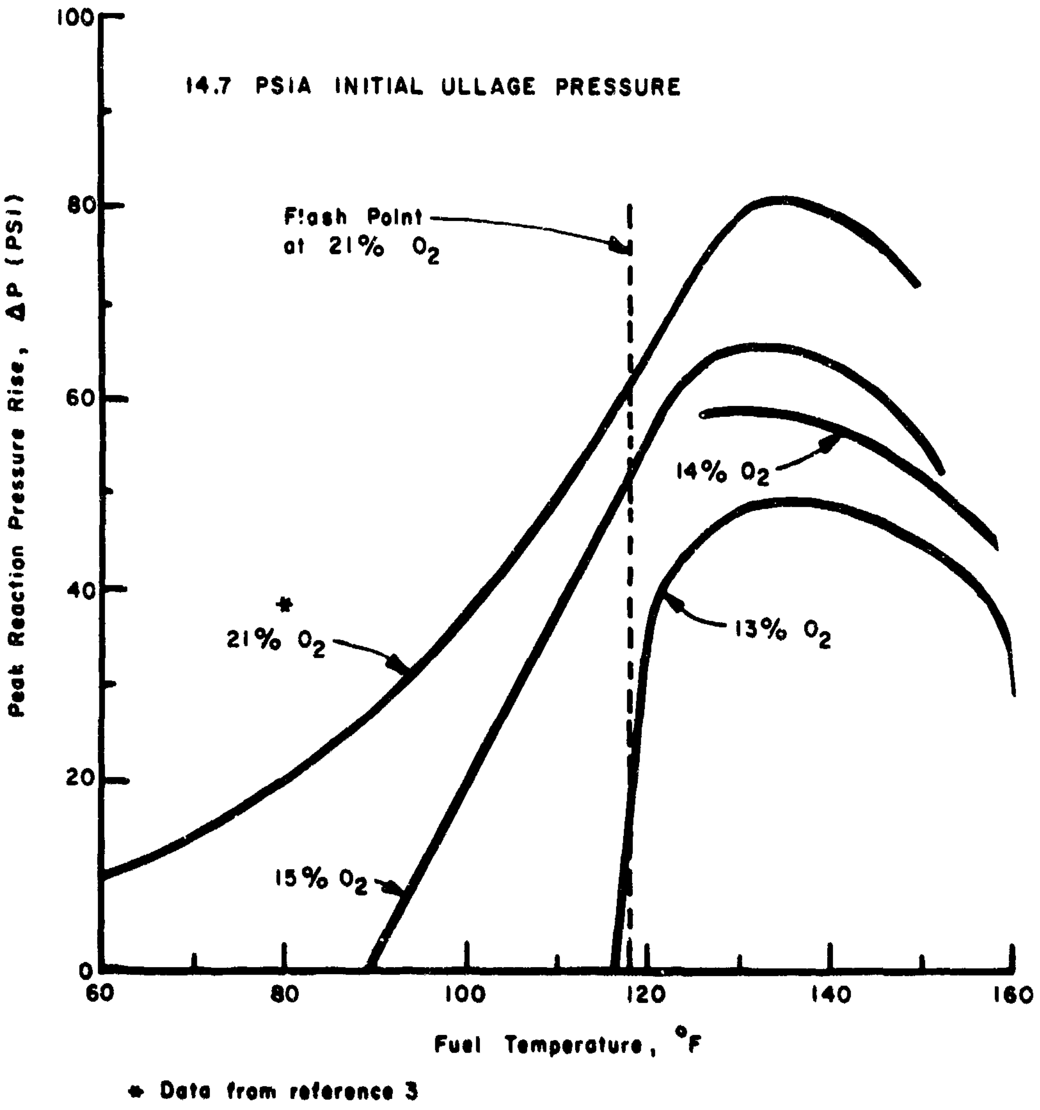

Figure 9. Peak Reaction Pressure Rise for JP-8 Fuel Ignited in a Sloshing Fuel Tank With no Vent and at Various Initial Oxygen Concentratio

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

The technical objective of this effort, the determination and measurement of the influence of severe agitation of liquid fuel upon the effectiveness of nitrogen inerting, has been successfully completed. Conclusions are summarized as follows:

1. Sloshing of the fuel does not change the maximum allowable percentage of oxygen for total inerting with nitrogen, i.e., maximum allowable concentration of oxygen for inerting of all fuel vapor concentrations.

2. The maximum allowable percentage of oxygen for the total inerting with nitrogen of JP-8 fuel vapors is 12% by volume.

3. Except for conditions very near the flammable limit, reaction-pressure rises will not be significantly affected by reduced oxygen concentration in any way other than to limit the amount of oxygen available for combustion.

Although only one mode and one level of fuel agitation (slosh at 17.5 cpm) was used in this testing, the authors feel that the only effect of using different modes or levels of agitation would be to change the magnitude of the extension to the flammability envelope by creating more or less fuel droplets; but not change the minimum flammable oxygen concentration.

2. RECOMMENDATIONS

Fuel slosh did not change the maximum allowable oxygen concentration for total nitrogen inerting. Therefore no special concern for the effect of fuel slosh is required in the application of a nitrogen inerting system for aircraft which maintains the oxygen content below this maximum limit.

Because fuel slosh did extend the flammability envelope for fuel vapor concentrations on the fuel lean side of the stoichiometric condition, it would be very precarious to apply nitrogen inerting at an oxygen concentration higher than the maximum allowable for inerting of all fuel vapor concentrations.

It is therefore recommended if nitrogen inerting is utilized for fuel tank protection, that the oxygen concentration be maintained below the maximum allowable for total inerting of all fuel vapor concentrations.

Several areas in the aircraft fuel tank inerting field require further investigation. Briefly these areas are:

(1) Influence of the Ignition Source Upon the Maximum Allowable Oxygen Concentration

The ignition source used in this program was an electric arc. Higher energy, more dispersed ignition sources such as gunfire incendiary ignition would lower the maximum allowable oxygen concentration. Stewart and Starkman (Reference 1) found the maximum allowable oxygen concentration under gunfire conditions to be close to 10% by volume for JP-4 and JP-5 type fuels.

(2) Influence of Dissolved Gases in the Fuel

Liquid fuels contain varying amounts of dissolved oxygen, nitrogen, and carbon dioxide which could be released into the fuel tank ullage upon certain temperature and altitude changes. These evolved gases could alter the safety provided by an inerting system during actual aircraft flight.

(3) Effectiveness of Other Inerting Gases

Although nitrogen appears the most attractive as the inertant gas, other gases such as carbon dioxide and carbon monoxide also have shown potential. A combination of several gases may also be useful.

(4) Influence of Fuel Type

The maximum allowable oxygen concentration for inerting should be determined as a function of fuel characteristics.

REFERENCES

1. P. B. Stewart and E. S. Starkman, "Inerting Conditions for Aircraft Fuel Tanks." WADC-TR-55-418, September 1955.

2. H. F. Coward and G. W. Jones, U. S. Bureau of Mines, Bull. No. 503 (1952).

3. E. E. Ott, "The Effects of Fuel Slosh and Vibration on the Flammability Hazards of Hydrocarbon Turbine Fuels Within Aircraft Fuel Tanks." AFAPL-TR-70-65, November 1970.

4. L. J. Nestor, "Investigation of Turbine Fuel Flammability Within Aircraft Fuel Tanks." FAA, ADS 67-7, July 1967.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Fuel, Lubrication, and Hazards Division Air Force Aero Propulsion Laboratory Wright-Patterson Air Force Base, Ohio	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE
INFLUENCE OF FUEL SLOSH UPON THE EFFECTIVENESS OF NITROGEN INERTING FOR AIRCRAFT FUEL TANKS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Technical Report, 1 April 1970 to 3 June 1970

5. AUTHOR(S) (First name, middle initial, last name)
Edwin E. Ott, Captain, USAF
Robert A. Lillie

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
February 1971	31	4

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. 3048	AFAPL-TR-70-82
c. Task No. 304807	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT
This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	AFAPL/SFH Wright-Patterson AFB, Ohio 45433

13. ABSTRACT

Tests were conducted to determine the influence of sloshing fuel within an aircraft fuel tank upon the effectiveness of nitrogen inerting. These tests were performed in a closed combustion chamber partially filled with JP-8 fuel. The fuel was severely agitated by a rocking motion of the chamber. The flammability of the tank ullage at various concentrations of air, nitrogen, and fuel vapor was tested by exposure to an electric arc. The sloshing fuel did not alter the maximum concentration of oxygen that could be allowed for inerting of all fuel vapor concentrations. For JP-8 fuel vapor exposed to an electric arc this maximum allowable oxygen concentration was found to be 12% by volume. Slosh did extend the flammable region for oxygen concentrations greater than the maximum allowable for inerting. These conclusions, it is believed, are valid for any mode or level of fuel agitation that may be experienced by aircraft fuel tanks.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Inerting						
Aviation Fuels						
Flammability Limits						
Combustion						
Aircraft Fuel Tank Safety						