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EVALUATION OF AN AUTOMATED SMOKE ABATEMENT SYSTEM FOR JET ENGIN--ETC(U)
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NAVAL AIR PROPULSION TEST CENTER

TRENTON, NEW JERSEY 08628

NAPTC-PE-108 JULY 1977

EVALUATION OF AN AUTOMATED SMOKE ABATEMENT SYSTEM FOR JET ENGINE TEST CELLS

By: A. F. Klarman

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An Automated Smoke Abatement System (ASAS) which injects a smoke abatement fuel additive into the fuel system of a gas turbine engine was developed for reducing test cell exhaust stack plume opacity caused by engine operation. The ASAS contains three major components: (a) transmissometer to monitor plume opacity, (b) logic/control unit which determines if opacity exceeds the standard, and (c) variable speed pump which injects the optimum quantity of the smoke abatement additive. The difference between the plume

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opacity and standard regulates the speed of the pump and quantity of additive injected. The System maintained test cell plume opacity to a visual opacity of 20 percent or less during evaluation tests at two Naval Air Rework Facilities (NARF's). It is recommended that the ASAS be used to control plume opacity from those engines compatible with smoke abatement additives.

NAVAL AIR PROPULSION TEST CENTER
TRENTON, NEW JERSEY 08628

PROPULSION TECHNOLOGY AND PROJECT ENGINEERING DEPARTMENT

NAPTC-PE-108 JULY 1977

EVALUATION OF AN AUTOMATED SMOKE ABATEMENT SYSTEM FOR JET ENGINE TEST CELLS

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CONVERSION FACTORS: SI TO U.S. CUSTOMARY UNITS

Convert From	To	Multiply by
metre (m)	inch (in)	$3.937\,007 \times 10^{1}$
pascal (Pa)	pound per square inch (psi)	$1.450\,377 \times 10^{-4}$

INTRODUCTION

On the basis of its effectiveness and lack of detrimental effect on engines during short periods of injection, the Naval Air Systems Command (NAVAIR) has approved the use of ferrocene during overhaul performance checks of five engine models at Naval Air Rework Facility (NARF) Alameda. Small concentrations of this additive in fuel are effective in reducing test cell exhaust stack smoke to a level accepted by the Bay Area Air Pollution Control District (BAAPCD). The recommended procedures for injecting the additive are as follows: (1) the test cell operator observes the exhaust plume and, if it exceeds the local opacity regulation, ferrocene is added; and (2) ferrocene concentration is increased by the test operator until the smoke plume meets the local opacity regulation. Steps (1) and (2) are repeated for each engine power setting employed during the performance check-run. The disadvantages of these procedures are as follows: (1) personnel who are not trained in smoke plume density determination (test cell mechanics) are making the decisions as to whether the smoke plume exceeds the BAAPCD regulation and (2) test cell mechanics are busy checking engine performance and do not have the time to regulate the injection of the additive and monitor test cell exhaust smoke. As a result of these problems, the additive flow rate is usually set for the worst exhaust stack smoke condition during the entire engine performance check and the additive injection is not reduced for the less smoky engine conditions.

The injection of too much additive can cause a deposit build-up problem on hot section components which will result in serious deterioration in engine performance. One way of overcoming these deficiencies would be by assigning a separate individual to each test cell to perform the above additive injection steps, but this additional cost to have the procedures performed properly would be unacceptable to a NARF. Another way to eliminate the smoke problem with the minimum use of ferrocene and without increasing the number of test cell personnel would be by developing an electronic system to perform the procedures properly and automatically. The latter way appears to be the most cost effective method for controlling the test cell exhaust smoke and at the same time safeguarding engine performance and components from deterioration.

A prototype Automated Smoke Abatement System (ASAS) was developed under work authorized by reference 1. Reference 2 authorized the evaluation of this System at NARF's Alameda and North Island. The objectives of these tests were to demonstrate the feasibility of the ASAS concept and applicability of the System for NARF use.

CONCLUSIONS

1. The ASAS is simple in design and inexpensive to purchase, and its use will not interfere with normal test cell operations.

2. The System can maintain the exhaust plume opacity from a jet engine test cell at a visual opacity of 20 percent or less while an engine is operated at various power conditions.

3. The "fail safe" systems incorporated into the ASAS are satisfactory in that the no additive can be injected into the engine outside of the operating range selected.

RECOMMENDATIONS

1. Improvements in the motor/pump combination, especially the pump, as tested in this program are required to increase the useful life of the System.

2. An ASAS should be used in jet engine test cells to control exhaust smoke levels from those engines compatible with the smoke abatement additive ferrocene.

DESCRIPTION

1. The Robert H. Wager Co., Incorporated, Chatham, New Jersey, under contract to the Naval Air Propulsion Test Center (NAPTC) developed an electronic ASAS which would control test cell exhaust plume opacity by regulating the quantity of a smoke suppressant fuel additive injected into a gas turbine engine fuel system. The ASAS contains the following components: (a) a transmissometer, (b) a logic/control unit, and (c) an additive injection device. A schematic of the System is shown in figure (1). The ASAS described below is the model employed during the NARF's evaluation.

2. The transmissometer, a Robert H. Wager Co., Inc., Model P-5, was mounted on the test cell exhaust stack. This instrument meets the Environmental Protection Agency (EPA) specifications for smoke meters as described in reference 3. The Model P-5 transmissometer is a single pass light transmission system which employs a green light emitting diode (LED) as a source. The LED emits light in the wavelength region of 570 nanometres. The amount of light reaching the detector is proportional to the transmittance of the plume. Percent opacity is related to percent transmittance by the following equation: Opacity (%) = 100% - transmittance (%). The instrument internally makes this calculation and reports the data as percent opacity. This transmissometer does not have internal calibration capability and must be calibrated when no smoke exists in the exhaust stack. This is not a problem for test cell use because the calibration of the transmissometer can be checked before each engine test.

3. The logic/control unit compares the electrical signal developed by the transmissometer to a reference signal. If there is a difference between these signals, an error signal is sent to the additive injection device. The magnitude and sign of this signal will control the time rate of change in the pumps speed which in turn regulates the flow rate of the additive into the engines. When the reference and transmissometer voltage signals are equal, the smoke plume from the test cell has been reduced to the desired or target opacity. The reference signal can be adjusted by changing the setting (set point) of an arbitiary dial scale on the logic/control unit. The target opacity is the transmissometer opacity that is required

to give a visual opacity equal to the desired plume opacity. The target opacity, as established by the set point and measured by the transmissometer, can be set to meet any value specified by local smoke opacity regulations. These regulations can be expressed in either Ringlemann numbers or percent opacity. Each Ringlemann number is equivalent to 20 percent opacity, so Ringlemann No. 2 1/2 would be equal to 50 percent opacity. Most authorities limit smoke plume opacities to 20 percent or less (Ringlemann No. 1 or less). In this report, all smoke plumes will be described in percent opacity.

4. The additive injection device consists of a gear pump directly coupled to a variable speed motor. The flow rate of the additive injected by the pump into the engine's fuel system is regulated by the speed of the motor.

5. In order to protect the engine from receiving excessive additive either because of a malfunction in the System or additive being injected when not required, the following fail safe systems were added:

a. The variable speed motor which drives the pump does not have any electrical power until a preset threshold opacity level is measured by the transmissometer. The threshold level can be adjusted to meet the particular requirements of the installation. For this test series, a 10 percent transmissometer opacity was employed as the lower limit.

b. The variable speed motor which drives the pump is electrically shut off when an upper opacity limit is exceeded. This limit can be adjusted to meet the particular requirements of the installation and was designed to stop injection of the additive during afterburner operation when there is a steam plume and smoke abatement is not required. For this test series, an upper limit of 55 percent plume opacity as measured by the transmissometer was selected.

6. Detailed descriptions of components and wiring diagrams for the transmissometer, logic/control unit and additive injection device are contained in reference 4. During the program, improvements in the additive injection device and modification in the electronics of the System were made. Individual figures showing the evaluation of the System from the prototype design to the finalized System are not included in this report. The changes incorporated in the System are discussed in the Analysis of Results and Discussion Section.

METHOD OF TEST

Evaluation of Prototype System at NAPTC

1. The J57-P-8B engine was held at the Normal Rated power condition during this shake-down test. While the engine was operated at constant power, the set point (dial setting on the logic/control unit) was varied. This was done to cause the exhaust stack plume opacity and the quantity of ferrocene injected into the engine to vary. At each of the set points

tested, the resulting opacity was recorded. This test series employed a high pressure pump/electronic control valve combination as the additive injection device.

NARF Evaluation of Modified System

2. The evaluation of the System modified with gear pump/variable speed motor as the injection device was conducted in two parts: the preliminary check out of the System at a NARF and long term performance evaluation of the System. Steps a through c described below were employed in both parts.

a. Correlation of Transmissometer and Visual Opacity Measurements - Before the ASAS could be employed, it was necessary to establish a correlation between the transmissometer opacity readings and the visual opacity values. In this step, the test engine was operated at various power conditions between Idle and Military power ratings to provide a broad spectrum of plume opacities. At each power condition, a determination of visual opacity of the smoke plume was made and recorded and the corresponding transmissometer reading was also recorded.

b. Calibration of the Logic/Control Unit - Once the correlation between the transmissometer and visual methods was established, it was possible to determine the set point of the logic/control unit which would maintain the test cell smoke plume opacity within the limits established by the local authority. In this step, the test engine was maintained at the Normal Rated power rating and the set point from the logic/control unit was varied in a stepwise decreasing fashion. Each decrease in the set point caused a corresponding change in additive flow rate and plume opacity. Set point, additive flow rate, and plume opacity values (transmissometer method) were recorded.

c. Engine Performance Check-run - The set point on the logic/control unit was selected for a transmissometer reading which corresponded to a visual opacity of 20 percent. The engine was operated between power ratings of Idle and Military, simulating an overhaul performance check-run. The test also included accelerations and "chops" between Idle and Military power ratings. The smoke level was monitored by the transmissometer and recorded by a strip chart recorder.

ANALYSIS OF RESULTS AND DISCUSSION

Evaluation of Prototype System at NAPTC

1. The prototype ASAS with the electronic control valve/high pressure pump combination was installed in a test cell at the NAPTC Philadelphia Test Site for a check-out before shipping the System to NARF Alameda for evaluation. The purposes of this test were to make sure that all the components in the System were functioning and that the additive injection rate would be sensitive to changes in set point. The set point establishes the target plume opacity as measured by the transmissometer. The J57-P-8B engine was operated at the Normal Rated power condition during this test. Table I presents the results of this test series. The trends in the data show that test cell plume opacity can be controlled by set point selection.

2. Two problem areas were observed during this test program and they are interrelated: (a) excessive heating of the additive fluid and (b) high operating pressure of the control valve. The valve manufacturer recommends an inlet gage pressure of 3450 kPa (500 psi) to the control valve for its proper operation. To maintain this high operating pressure, a high capacity pump was required. The bulk of additive that passed through the pump was returned to the drum containing stock solution. The drum became hot to the touch after a half hour of testing because of the recirculation of the stock solution. Testing was ceased because of a possible fire hazard. Normally, a gage pressure of 480 kPa (70 psi) is sufficient to overcome the fuel pressure where the additive is injected.

3. No further evaluation of this design of the ASAS was made. The Robert H. Wager, Co., Inc. modified the additive injection device before the NARF test program by replacing the high pressure pump/electronic control valve combination with a variable speed motor coupled directly to a gear pump. In this configuration the flow rate of the additive is proportional to the speed of the motor and the difference (error signal) between the plume opacity (transmissometer signal) and the reference (set point signal) regulates the speed of the motor.

NARF Evaluation of Modified System

4. Preliminary Check-out of the System at NARF Alameda.

a. Correlation of Transmissometer and Ringlemann Measurements - The J57-P-10 engine, installed in test cell 15, was operated at various power conditions to present a broad spectrum of test cell exhaust plume opacities. The plume opacity was determined visually and by the transmissometer. The test results are presented in Table II. A transmissometer reading of 9 percent was measured when the visual plume opacity was 20 percent, but an examination of all the data indicates a transmissometer reading of 10 to be a better value, considering scatter.

b. Calibration of the Logic/Control Unit - The results of this test series are presented in Table III. During the test, the J57-P-10 engine was maintained at the Normal Rated power condition and the set point on the Logic/Control Unit was varied. The changes in the test cell exhaust plume opacity were recorded. A set point of 18 maintained the transmissometer monitored test cell plume opacity at 10 percent. This set point value was employed during the simulated engine performance step. The 10 percent transmissometer reading was selected because it would give a visual plume opacity of 20 percent.

c. Engine Performance Check-run - After establishing the set point necessary to maintain the test cell exhaust plume opacity within the smoke limits stipulated by the BAAPCD, a one hour endurance test was performed. During this test, the test cell operator performed the engine operating procedures employed in checking the performance of an engine after overhaul. Excerpts from the strip chart trace recorded during this test are shown in figure (2). The trace has been separated into the various engine performance conditions (test numbers). Test 1 represents the idle and military base line plume opacities without ferrocene in the fuel. During transient conditions the ASAS was not able to maintain the plume opacity to the desired value but the System quickly recovered in 5-6 seconds when the power condition stabilized (see test 2 in figure (2)). When the engine was held at constant power conditions for extended periods, the ASAS was capable of maintaining the desired opacity within ±1 percent opacity (see tests 5, 6, and 7 in figure (2)). In tests 3 and 4 in figure 5, the engine power condition was changed up and down too rapidly for the System to follow. The smoke levels resulting from transient maneuvers do not exist for periods long enough, however, to warrant consideration as violations by the BAAPCD. This agency allows the plume opacity to exceed the 20 percent opacity regulation for three minutes during each hour of operation.

d. General Discussion of Test Results - The concept of an Automated Smoke Abatement System was shown to be feasible. The modified system with the gear pump/variable speed motor combination is capable of controlling the test cell exhaust smoke level within the limits required by the BAAPCD. During this evaluation the following deficiencies were noted in the System: (a) there was no fail-safe mechanism to protect the engine from an excessive additive concentration in the fuel should the System malfunction, and (b) there were no means of discriminating between smoke and steam plumes which can occur during afterburning engine operation. The latter problem could cause an excessive amount of additive to be injected under the steam condition when no additive is required. The Robert H. Wager, Co., Inc. has made modifications to the logic/control unit to remedy the above deficiencies. These modifications were evaluated during the long term evaluation discussed below.

5. Long Term Evaluation of the System.

a. This phase of the program was conducted jointly with another program to extend the time limit for the use of ferrocene in gas turbine engines during test cell performance check runs. This report will be limited to the performance of the ASAS, only. Five engines (J52-P-6B, J57-P-10, J79-GE-8B, TF30-P-6C and TF41-A-2A) were included in the extended ferrocene program.

b. Table IV contains the visual and transmissometer monitored opacities for four of the five engines included in the ferrocene program. No data were obtained on the J57-P-10 engine because the test was conducted at a time when it was impossible to make visual observations of the plume opacity. The plume opacity data for each engine were plotted (transmissometer versus visual). The desired or target opacity was estimated where the transmissometer reading was equivalent to a visual opacity of 20 percent. The target opacity varied from 16 for the TF41-A-2A to 30 for the J52-P-6B. The J52-P-6B target opacity was unexpected and appears to be high relative to the other three engine tests. A target opacity of 22 percent was used during the J52-P-6B engine test to insure adequate smoke reduction.

c. In order to evaluate the causes of variation in target opacity, all the data were plotted together (see figure (3)). The data for each engine test was consistent within that test. The most probable explanation for the variations in target opacity is a combination of effects due to different readers, time of day and sky conditions. There appeared to be an overall trend in the data and the best straight line passing through the data and (0,0) point was determined by the method of least squares analysis. The following equations were obtained:

(a) transmissometer reading as a function of visual opacity

$t = 0.99\,v + 0.18$, correlation coefficient = 0.95

(b) visual opacity as a function of transmissometer reading

$v = 0.90\,t + 3.93$, correlation coefficient = 0.95

where t = transmissometer reading (percent)

v = visual opacity (percent)

Both these equations give a good correlation to a straight line, and provide a means of converting one opacity value to the other for these two methods of measuring plume opacity. Based on the data obtained from all the engines, the transmissometer is a valid means of estimating test cell exhaust plume opacity. A target opacity of 20 percent will be sufficient to control the test cell exhaust smoke to the BAAPCD opacity requirement. This target opacity (20 percent) is in agreement with the ones employed during the tests (16-24 percent). The only plausible explanation as to why the target opacities for the series of tests (16-24 percent) differed from the one employed during the preliminary check-out of the System (10 percent) is that the visual opacities in the preliminary check-out test were made by non-certified readers and could have been in error.

d. Before initiating the engine performance simulation tests, the set point which would give the required target opacity was determined using the same procedures as in the first NARF test. The following set points were determined for the engines used during the extended ferrocene evaluation: J52-P-6B (18), J57-P-10 (18), J79-GE-8D (20) and TF30-P-6C (18). For practical purposes, these set points can be considered the same. During the TF41-A-2A engine test, a problem was encountered with the transmissometer and the ferrocene was injected based on concentrations employed in past TF41 engine tests (reference 5). In the establishment of the J57 set point, an instability in the ASAS was observed (see figure 4). The System called for additive but the quantity of additive injected exceeded that required to control the smoke plume to the target opacity. As the set point value was lowered, (causing the target opacity to be lower) the magnitude of the cycling of the opacity and additive flow rate increased. At even lower set point values, the magnitude of the cycling decreased and the System eventually stabilized, but the transmissometer opacity (12 percent) was well below the 22 percent target opacity. It was possible to tune out this instability in the System by making adjustments to decrease the System's gain setting and the initial speed of the pump motor. After these adjustments were made, a set point of 18 maintained the target opacity at 22 percent. These adjustments are easily made on the Logic/Control Unit. This demonstrates the flexibility of the ASAS. The trim dials are provided on the ASAS to adjust the gain setting and the intial pump speed so that the mix of engines operated in the test cell is unlimited.

e. The fail-safe and smoke/steam plume discriminating modifications were adjusted for a lower limit of 10 percent opacity and an upper limit of 55 percent opacity. This means that the pump motor is electrically inoperative until the exhaust plume opacity exceeds 10 percent and when the opacity exceeds 55 percent. This feature gives the ASAS an operating range of 10 to 55 percent opacity. These limits were checked-out by varying the engine from idle to military power rating very rapidly. When the J79 engine was "popped" in to the afterburner mode, a steam plume (60 percent opacity) from the test cell quench water appeared and the system quickly shut-off the pump motor. Even though the TF30-P-6C engine, at military rating, has an exhaust plume opacity greater than 55 percent without additive, this did not cause a problem for the System because ferrocene was injected into the fuel as soon as the plume opacity exceeded 22 percent and there was enough additive in the fuel so that the plume opacity never reached 55 percent to turn the pump motor off. For all the engines except the J79 (idle opacity = 12.5 percent) the pump motor was deactivated during idle operations.

f. The ASAS was operative for 61.6 hours during these tests. This time includes the TF41 test when a problem with the source and receiver of the transmissometer was noted. During this problem with the transmissometer, the Logic/Control Unit and pump/motor injection system were still used to inject the ferrocene. Table V summarizes the operation of the System and the problems that were encountered. Of the problems/failures experienced, none of them (except the blown fuse) were related to the electronics of the ASAS. The two major failures (drive gears (between the motor and pump), and the pump) were mechanical in nature and can easily be corrected by driving the pump directly by the motor and by replacing the brass pump with a steel gear pump such as a small gas turbine engine fuel pump.

FIGURE I. AUTOMATED SMOKE ABATEMENT SYSTEM

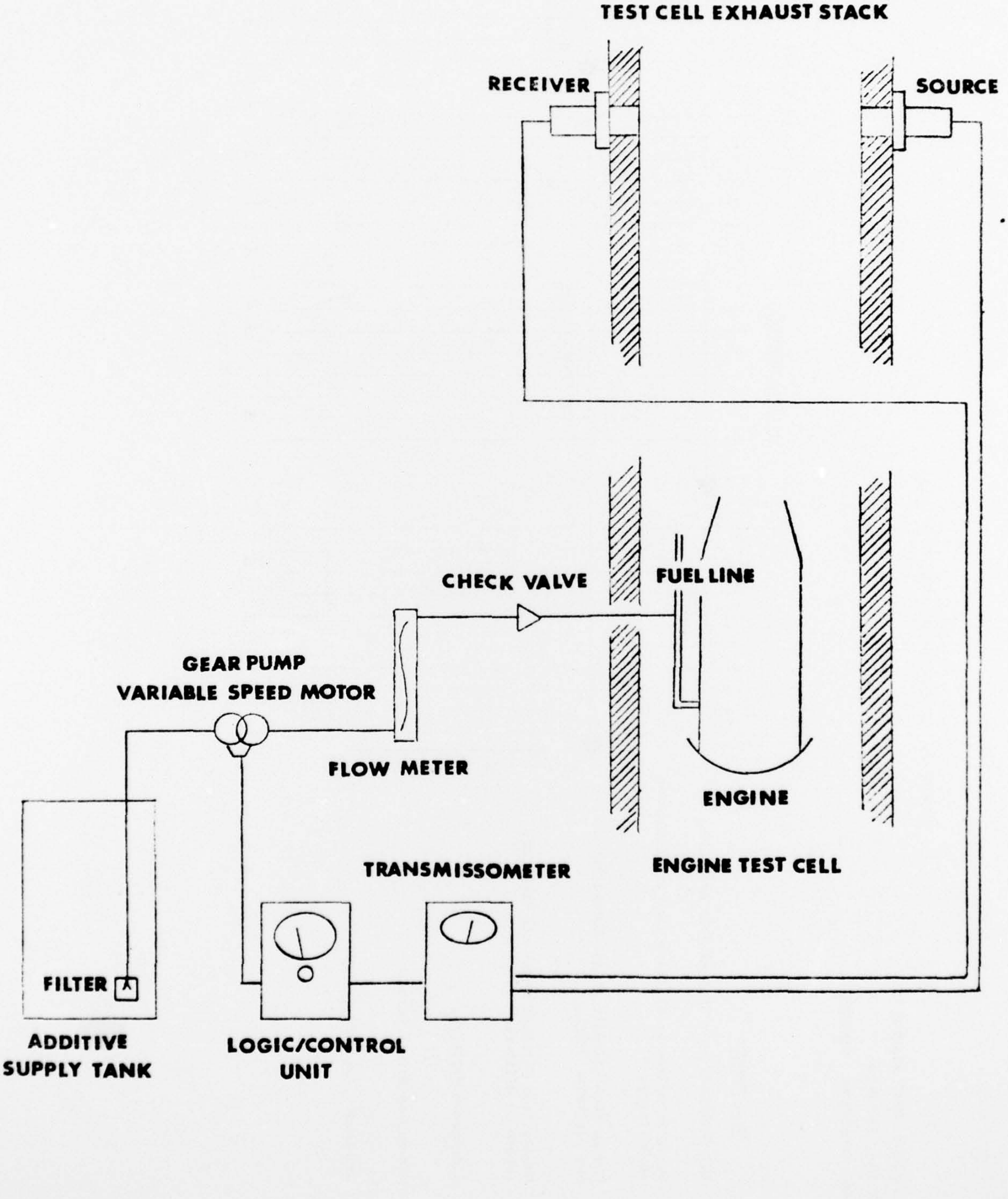

FIGURE 2. ENGINE PERFORMANCE TEST DATA

LOCATION: NARF ALAMEDA
ENGINE: J57-P-10
POWER CONDITION: VARIOUS

TEST NUMBER

1. Idle/Military base line without additive.
2. Burst from Idle to Military with stabilization at Military.
3. Change from Military to 75% Normal Rated and return to Military.
4. Change from Military to Normal Rated and return to Military
5. Continuous Military.
6. Continuous Normal Rated.
7. Continuous 75% Normal Rated.

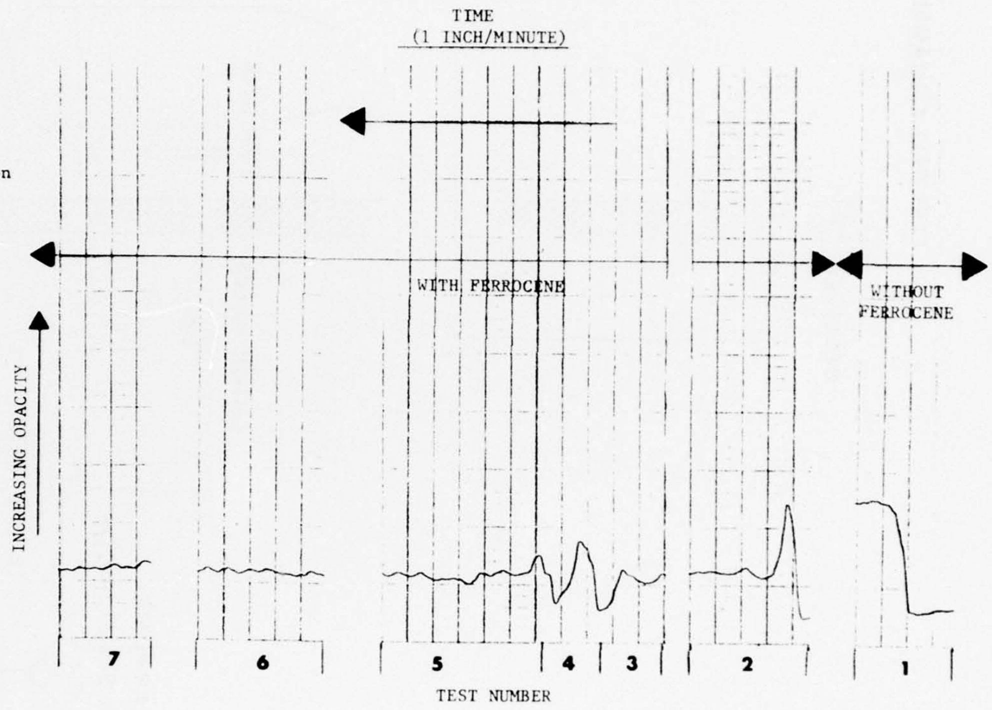

FIGURE 3. TEST CELL PLUME OPACITY CORRELATION

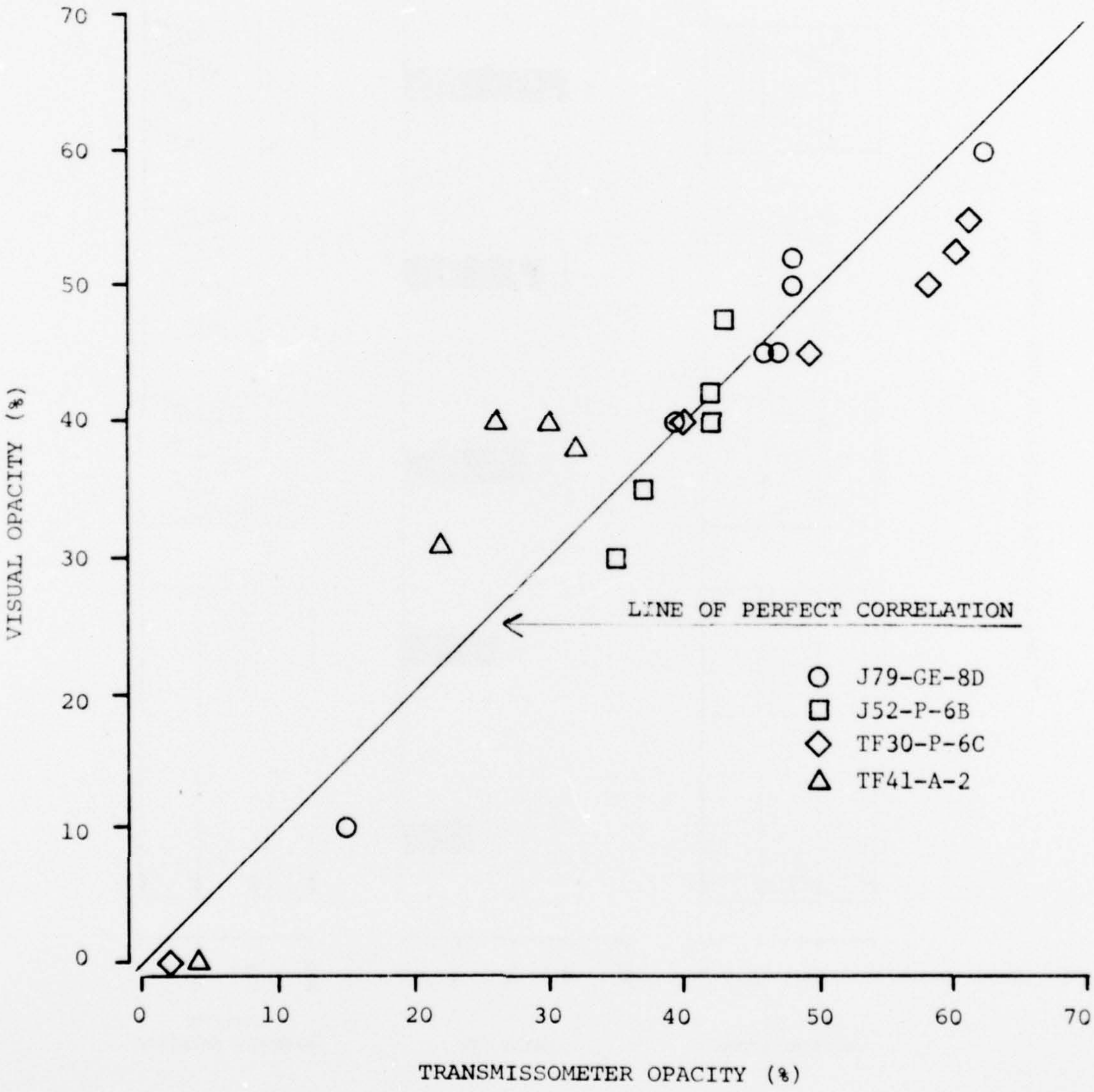

FIGURE 4. J57-P-10 MILITARY POWER RATING DATA

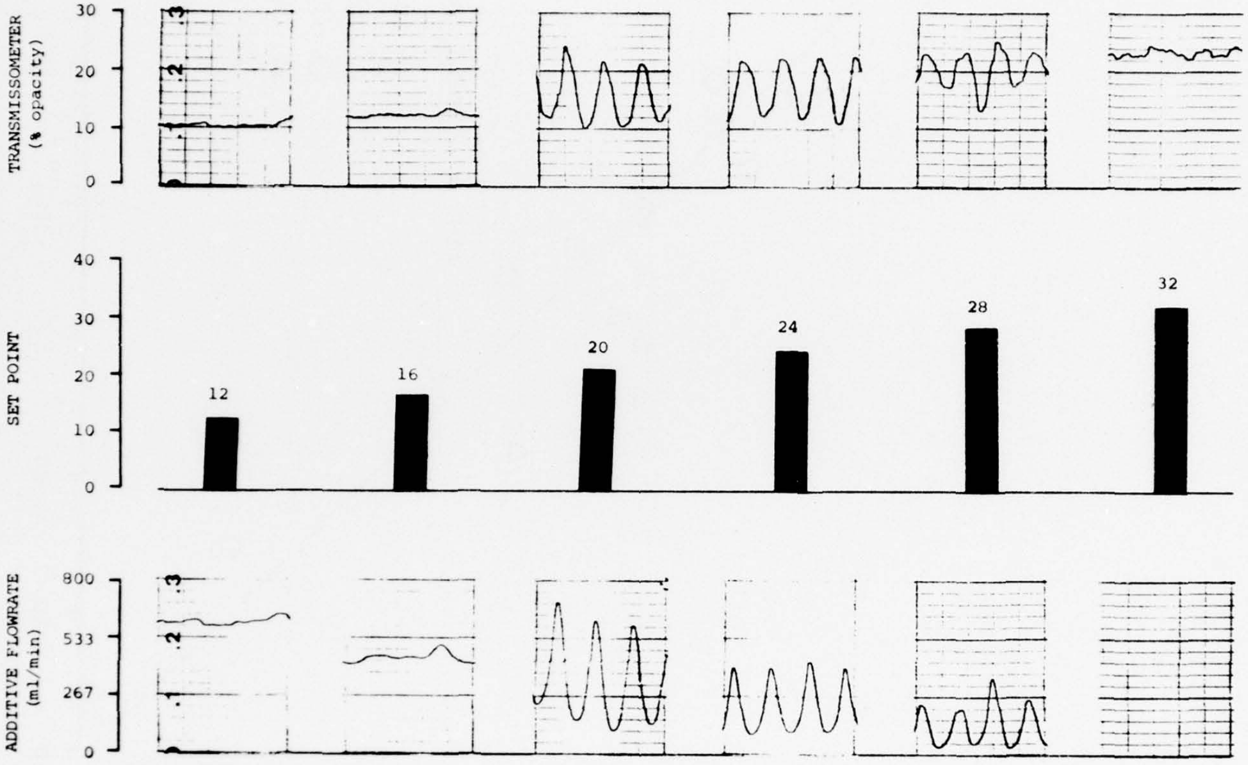

TABLE I

CALIBRATION OF THE LOGIC/CONTROL UNIT

Transmissometer Reading (% opacity)	Logic/Control Unit, Set Point
8.4	30
8.0	24
5.4	20
4.6	18
3.4	12
2.8	10
2.9	8
2.1	2

NOTES:
1. Location: NAPTC, Philadelphia Test Site
2. Engine: J57-P-8B
3. Power Condition: Normal Rated
4. Prototype high pressure pump/electronic control valve combination.

TABLE II

CORRELATION OF TRANSMISSOMETER AND VISUAL MEASUREMENTS

Power Condition	Visual Reading (% opacity)	Transmissometer Reading (% opacity)
MIL	35	19.5
NR	40	17.0
75% NR	37.5	17.0
50% NR	22.5	14.0
30% NR	20	9.0
IDLE	0	0

NOTES:
1. Location: NARF Alameda, Test Cell 15
2. Engine: J57-P-10
3. Military - MIL; Normal Rated - NR
4. The visual opacities reported are the average values of the readings obtained by C. Lastiri, NARF Alameda and A. Klarman, NAPTC, neither of whom were certified smoke readers at that time.

TABLE III

CALIBRATION OF THE LOGIC/CONTROL UNIT

Logic/Control Unit, Set Point	Transmissometer Reading (% opacity)
30	19.0
28	19.0
26	16.2
24	15.0
22	12.5
20	11.0
18	10.0
14	8.8
10	7.3
6	6.0

NOTES: 1. Location: NARF Alameda, Test Cell 15

2. Engine: J57-P-10

3. Power Condition: Normal Rated

4. Gear pump/variable speed motor combination.

TABLE IV

CORRELATION OF TRANSMISSOMETER AND VISUAL OPACITY MEASUREMENTS

Location	NARF North Island Test Cell No. 20			NARF Alameda Test Cell No. 15			NARF Alameda Test Cell No. 15			NARF Alameda Test Cell No. 15		
Engine	J79-GE-8D			J52-P-6B			TF30-P-6C			TF41-A-2		
Certified Reader	Longley-Cook			Michalec			Nalevanko			Michalec		
Weather Condition	Clear			Clear			Clear/Haze			Clear		
Wind Speed (kmph)	5			-			0-8			0-8		
Starting Time of Observations	1430			1330			1100			1227		
	PC[1]	V	T	PC[2]	V	T	PC[2]	V	T	PC[3]	V	T
	MIL	52.6	48.0	MIL	47.5	43.0	MIL	52.5	60.0	42.0	38.0	32.0
	92.0	50.0	48.0	NR	40.0	42.0	NR	55.0	61.0	37.0	40.0	30.0
	89.0	45.0	47.0	75 NR	42.0	42.0	75 NR	50.0	58.0	32.4	37.9	26.0
	85.0	45.0	46.0	50 NR	35.0	37.0	50 NR	45.0	49.0	27.4	31.3	22.0
	82.0	40.0	39.5	30 NR	30.0	35.0	30 NR	40.0	40.0	Idle	0.0	2.0
	Idle	10.0	12.5	Idle	-	-	Idle	0.0	4.0	-	-	-
	A/B	60.0	62.0	-	-	-	-	-	-	-	-	-
Target Transmissometer Opacity			22			30			24			16

NOTES:
1. % MIL RPM
2. % NR Thrust
3. P_{T_5} (inches of Hg)

ABBREVATIONS:

V = Visual opacity (%)

T = Transmissometer opacity (%)

PC = Power Condition

NR = Normal Rated

MIL = Military

A/B = Afterburner

TABLE V

LONG TERM EVALUATION

ASAS PERFORMANCE

Date	Location	Engine Under Test	System Operating Time (hrs.)	Problem	Solution
FEB 76	NARF Alameda	J57-P-10	approx. 4	No mechanical or electrical problems.	-
NOV 76	NARF North Island	J79-GE-8D	12.6	No mechanical or electrical problems.	-
DEC 76	NARF Alameda	TF41-A-2	10.8	1. Positioning screws for source and receiver vibrated loose. 2. Broken wire in the receiver unit at the stack.	1. Realigned source and receiver and epoxied positioning screws in place. 2. Repaired wire (not expected to be a recurring problem).
DEC 76	NARF Alameda	J57-P-10	12.0	Drive gears between motor and pump stripped.	Replaced gears.
DEC 76	NARF Alameda	J52-P-6B	10.5	1. No mechanical problems. 2. Cycling of ferrocene injection.	Adjusted gain control and initial speed of pump.
DEC 76	NARF Alameda	TF30-P-6C	11.7	1. Fuse blew. 2. Pump lost pressure and additive flow stopped due to excessive wear on the gear teeth in the pump. Possibly due to misalignment which also caused the drive gears between the motor and pump to fail (see J57-P-10).	1. Replaced fuse (not expected to be a recurring problem). 2. Test stopped, replacement not available.
		TOTAL - - - - - -	61.6		

REFERENCES

1. WORK UNIT ASSIGNMENT: NAVAIR Work Unit Assignment No. NAPTC-742-BP7-307 dated 16 July 1974

2. AUTHORIZATION: NAVFAC (WESTDIV) Project Order No. N62474-76-PO-00018 dated 26 January 1976

3. REGULATION: Code of Federal Regulations, Volume 40, Part 60, Appendix B

4. MANUAL: Automated Smoke Abatement System, Bulletin 460-A0001, Robert H. Wager Co., Inc., September 1976

5. REPORT: Klarman, A. F., "Evaluation of Smoke Suppressant Fuel Additives for Jet Engine Test Cell Smoke Abatement," Naval Air Propulsion Test Center Report No. NAPTC-PE-103, February 1977

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