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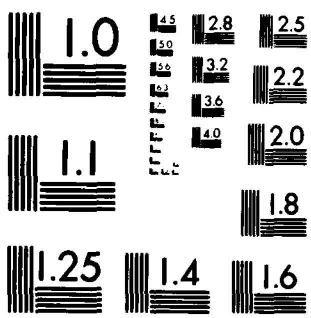

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SERVICE TEST OF TWO FUEL CONDUCTIVITY ADDITIVES

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May 1980

TECHNICAL REPORT AFWAL-TR-80-2051

Final Report for Period April 1977 - January 1980

Approved for public release; distribution unlimited.

AERO PROPULSION LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
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This technical report has been reviewed and is approved for publication.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFWAL-TR-80-2051	2. GOVT ACCESSION NO. AD-A088 046	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SERVICE TEST OF TWO FUEL CONDUCTIVITY ADDITIVES.		5. TYPE OF REPORT & PERIOD COVERED Final - April 77 - Jan 80
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Charles R. Martel, Frank P. Morse		8. CONTRACT OR GRANT NUMBER(s) 3048 05
9. PERFORMING ORGANIZATION NAME AND ADDRESS Aero Propulsion Laboratory, Wright-Patterson AFB, Ohio 45433 and San Antonio Air Logistics Center (SFQH), Kelly AFB, TX 78241		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Prog. Element 62203F Work Unit 304805FL
11. CONTROLLING OFFICE NAME AND ADDRESS Aero Propulsion Laboratory (POSF), Air Force AF Wright Aeronautical Laboratories, AFSC Wright-Patterson Air Force Base, Ohio 45433		12. REPORT DATE May 1980
		13. NUMBER OF PAGES 86
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Final rept. 1 Apr 77-Jan 80		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

JP-4
Jet Fuel
Fuel Conductivity
Fuel Additives
Anti-Static Additive
Service Test

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A service test of two fuel conductivity (anti-static) additives was conducted from April 1977 to May 1979 at eight Air Force bases. Since bases have continued to use the additive, a portion of the data reported herein extends to January 1980. The two candidate fuel additives were Shell Chemical Company's ASA-3 and E.I. duPont de Nemours and Company's Stadis 450. The additives were injected into the JP-4 aviation turbine fuel at either the refinery or terminal supporting the base. The conductivity of the JP-4 delivered to the service test base was to be maintained between 200 and 600 pS/m. The minimum and

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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maximum fuel conductivity limits for servicing to aircraft was 100 to 700 pS/m. The effects of the additives on the air base fuel systems, filter separator elements, and on aircraft were monitored.

FOREWORD

This report describes the results of an Air Force service test of two candidate electrical conductivity additives for JP-4 turbine fuel. The service test was jointly conducted by the Directorate of Energy Management, San Antonio Air Logistics Center, Kelly AFB, Texas, and the Aero Propulsion Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio. The Technical Services Division of the Defense Fuel Supply Center was the office of prime responsibility for fuel contractor involvement. Test equipment was funded by the Propulsion Laboratory under Project 3048, "Fuels and Lubrication," Task 304805, "Aero Propulsion Fuels". The Defense Fuel Supply Center funded the additive used by contractors under account code F 6.99.

The work reported herein was performed during the time period 1 April 1977 to 1 January 1980. Aero Propulsion Laboratory personnel involved were Mr. Arthur Churchill, Mr. Charles Martel and Major James Morgan (deceased). San Antonio Air Logistics Center personnel included Mr. Nick Makris, Mr. Frank Morse, Mr. Arnold Clegg, Mr. James Doster (retired) and Major James Colvig (retired). The report was released by the authors in February 1980.

The authors wish to thank the Fuels Management staff at each test site and Quality Assurance Representatives of the Defense Contract Administration Service for their valuable assistance in the test program.

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SECTION I

INTRODUCTION

Electrostatic charges are generated whenever two dissimilar materials come into physical contact and are then separated. Aviation turbine fuels are electrostatically charged as the fuel passes through pumps, piping and particularly filtration equipment. Normally these charges bleed rapidly to ground, but due to the poor electrical conductivity of aviation turbine fuels, charges can require several seconds to several minutes to relax. If the fuel becomes highly charged, spark and corona discharges may occur with some discharges having sufficient energy to be incendive; i.e., the discharges are capable of igniting flammable fuel/air mixtures.

Fuel electrical conductivity additives have been used successfully in other countries to prevent electrostatically initiated fires. The additives, which are easily ionized in the fuel, function by increasing the electrical conductivity of the fuel so that charges present bleed rapidly and safely to ground.

JP-4 fuel typically has a conductivity in the range of 1 to 5 picosiemens per meter (pS/m) which gives charge relaxation times of 18 to 3.6 seconds, respectively. One picosiemen per meter is equivalent to 10^{-12} ohm^{-1} meter^{-1}, also referred to as a conductivity unit (CU). Charge relaxation time is the time required for an electrical charge to decrease to about 37% of the original value. With the addition of about 1 ppm of a conductivity additive to JP-4, the conductivity of the fuel normally increases to between 200 to 500 pS/m. This increase in conductivity results in a decrease in the charge relaxation time to approximately

0.1 to 0.04 seconds, respectively. Thus, under these circumstances electrostatic charges in the fuel bleed to ground about as fast as they are generated, thereby preventing charge build-up.

In the military and commercial sectors, numerous fires and explosions involving tank trucks, bulk tanks, and other fuel handling equipment have occurred as a result of static electricity. Several aircraft have also been damaged or destroyed by electrostatic discharges within the fuel tanks or cells of aircraft. Personnel injury or death has often accompanied these static initiated incidents.

During the winters of 1974 through 1977, eight USAF aircraft experienced fuel tank fires during refueling. Static electricity was the cause of these ignitions. In all eight cases, the fuel cells in the aircraft contained a polyester urethane, open-pore (i.e., reticulated) foam. This foam was installed to suppress fires and explosions that could result during combat conditions. The effectiveness of the foam in reducing flame propagation and overpressure within the fuel tanks was evident in that none of the eight aircraft suffered structural damage. The foam and in some cases the fuel tank liners were scorched and damaged. Aircraft involved in the mishaps were two UH-1 helicopters, two F-105s, two F-5s and two A-10s.

Previous to 1974, the Air Force had experienced and confirmed only one aircraft refueling fire caused by electrostatic ignition. However, there had been several other aircraft fires and explosions that may have been initiated by static electricity discharges. The use of the polyester urethane foam in the aircraft fuel tanks began on a large scale in the late 1960's, but until recently most of these aircraft were stationed in Southeast Asia where high temperature and humidity conditions were not conducive to electrostatic incidents.

As a result of these eight aircraft static-initiated fires, an Air Force Ad Hoc Committee on Static Electricity was formed in February 1977 to investigate the causes and recommend actions to correct the problem. One of the actions taken by the Ad Hoc Committee was to evaluate the use of an electrical conductivity additive in JP-4. This report covers the results of a service test of two candidate conductivity additives, ASA-3, a Shell Chemical Co. product and Stadis 450 produced by E.I. duPont de Nemours and Co. The service test sites were Carswell AFB, TX, Davis-Monthan AFB, AZ, Griffiss AFB, NY, McChord AFB, WA, Mountain Home AFB, ID, Myrtle Beach AFB, SC, Nellis AFB, NV, Travis AFB, CA and the Defense Fuel Supply Point, Searsport ME.

SECTION II

TEST OBJECTIVES

The objectives of the service test were to (1) identify the most feasible points in aviation turbine fuel supply systems to inject the conductivity additive so as to maintain sufficient conductivity levels at the time of refueling, (2) determine compatibility of the two additives with JP-4, (3) determine the additives' effect on ground handling systems with particular emphasis on the performance of filter separator elements, and (4) determine effects of the additives on aircraft fuel systems. Subsequent to the initiation of the test program, a fifth objective arose, i.e., to provide added protection for specific types of aircraft which were especially vulnerable to electrostatic charge hazards during refueling.

SECTION III

SUMMARY OF FINDINGS

1. The service test showed that ASA-3 or Stadis 450 can be injected into JP-4 at the refinery or terminal supporting the base with acceptable levels of fuel conductivity loss between the supplier and the aircraft. The service test did not include shipment of fuel containing conductivity additive by either multiproduct pipeline or ocean tanker since commercial experience with both modes and Air Force experience with tanker movements showed excessive conductivity losses would occur.

2. Addition of the two additives either singularly or in combination to increase the fuel conductivity to prescribed levels created no major compatibility problems with JP-4. Decrease of the water separation property of JP-4 caused by both additives did not significantly degrade the coalescence performance of filter separator elements. The adverse effect of the two additives on the filtration time property of JP-4, which occurred periodically at one test site, indicated this problem could be a concern with widespread use of the conductivity additives.

3. Both ASA-3 and Stadis 450 additives, when present at sufficient concentrations to increase the conductivity of JP-4 to about 200 pS/m, depressed the water separation value of JP-4 to about the same degree. The amount of decrease was dependent on the original water separation value of the product. The higher the WSIM number, the less the effect. The average WSIM value decrease was approximately 15 numbers.

4. No effect on the thermal oxidation stability of JP-4 was seen for either Stadis 450 or ASA-3 additive. However, JP-4 at several of the service test bases was found to fail this property both before and after the addition of conductivity additive.

5. The two additives at proper concentrations created no compatibility problems with aircraft performance. Test work conducted on JP-4 at Myrtle Beach AFB, SC , where the fuel conductivity level was higher than established limits, resulted in a 5.8% fuel quantity gage error in an A-7 aircraft. This same high conductivity fuel (approximately 1500 pS/m) did not significantly affect the capacitance type fuel quantity gage system in an A-10 aircraft. These findings indicated the need to identify the levels of conductivity which adversely affect fuel quantity gage systems in all military aircraft.

6. The reasons for the two episodes of high fuel conductivity (approximately 1500 pS/m) at Myrtle Beach AFB, SC, are unknown.

7. Three of the additive test sites were selected to provide added protection for aircraft especially vulnerable to electrostatic charge hazards. Myrtle Beach AFB and Davis-Monthan AFB were selected because of base assigned A-10 aircraft. Mountain Home AFB was placed on the additive after electrostatic incidents were reported with UH-1 helicopters. No fuel related, electrostatic incidents occurred at any of the service test bases except as noted in paragraph 9 below.

8. The concentration of ASA-3 or Stadis 450 required to maintain the conductivity of JP-4 fuel at desired levels varied considerably from one fuel to another and with temperature. For ASA-3, the concentration ranged from about 0.3 ppm to 1.5 ppm (wt/vol) with the average being 0.9 ppm. For a short period at one site, it was necessary to increase the concentration of ASA-3 to 1.8 ppm. For Stadis 450, the concentrations ranged from 1.0 ppm to 1.8 ppm with an average concentration of about 1.5 ppm. Although fuel conductivity changes significantly with temperature, the differences in additive response with different fuels were greater.

9. Two static incidents at one of the service test bases showed that conductivity additives were not effective in preventing static initiated internal filter separator fires. Special procedures for the filling of filter separator vessels after draining must continue to be used.

10. Use of conductivity additives will not eliminate the requirements to ground and bond fuel systems, servicing equipment and aircraft.

11. During long term static storage tests in bulk tanks at Searsport DFSP, neither ASA-3 nor Stadis 450 inhibited fuel showed excessive losses of conductivity.

12. The additives were readily blended in JP-4 by a variety of injection techniques. While proportional injection of the additive into a flowing stream is the desired method, other less sophisticated blending methods proved satisfactory.

13. Evidence of a time delay was encountered in obtaining equilibrium fuel conductivity after additive injection. Up to 24 hours may be required after the fuel and additive are mixed before equilibrium fuel conductivity values are obtained. The method of injection and temperature were major factors in the time required to obtain maximum conductivity.

14. Conductivity measurements in sample containers should be made from two to five minutes after taking the sample. Under these conditions the type of sample container was not critical. Conductivity readings did not change appreciably after eight hours when samples were stored in epoxy coated or tin-plated steel one-gallon cans at the same temperature. Erratic fuel conductivity data were obtained on one-gallon correlation samples taken at the base and shipped to area Aerospace Fuel Laboratores.

SECTION IV

APPROACH

1. TEST SITE SELECTION

Several factors were involved in the selection of test sites. High fuel consumption, variety of aircraft, different fuel transportation modes, types of fuel dispensing systems, recent filter separator test data, and weather were prime considerations. Bases originally selected for the service test program were Carswell AFB, TX; Griffiss AFB, NY; McChord AFB, WA; Nellis AFB, NV; and Travis AFB, CA. The Defense Fuel Supply Point at Searsport, ME, was selected to determine the stability of the additive in fuel under prolonged dormant storage. Myrtle Beach AFB, SC, and Davis-Monthan AFB, AZ, were placed in the service test program at the request of Hq. Tactical Air Command to prevent possible recurrence of electrostatic problems in assigned A-10 aircraft. Mountain Home AFB, ID, was added six months after start of the test program when electrostatic discharges were audible during refueling of UH-1 helicopters.

While it was desired to obtain conductivity additive use experience in multiproduct pipeline shipments, efforts to establish a test site for this objective were not successful. However, since commercial experience had shown that up to 75 percent conductivity depletion can occur in multiproduct lines, this mode of transporting inhibited fuel was eliminated from consideration. (Reference 1) Also, there was no test program established for ocean tanker movements. In addition to industry experience, a limited USAF ASA-3 test program conducted in 1968 indicated that excessive additive depletion would occur in tanker shipments, requiring reinjection facilities at destination ports. The USAF program involved four tanker shipments of JP-4 from the Gulf Coast to an Air Force base in Maine (Reference 2). Conductivity loss was approximately 27 percent at the discharge port. Industry experience with ASA-3 involved monitoring of 17 ocean cargoes of aviation turbine fuel. In general, a loss of conductivity up to 60 percent was found with an average loss of 30 percent (Reference 1).

An important factor in the selection of test bases was the availability of base-line data of fuel effects on filter separator performance. In 1976 the Air Force POL Technical Assistance Team of the San Antonio Air Logistics Center's Directorate of Energy Management (SA-ALC/SFQH), Kelly AFB, Texas, conducted a study of fuel effects on filter separator performance at 17 bases. The objective of the study was to determine the effect of JP-4 having low or borderline Water Separometer Index, Modified, (WSIM) values on filter separator performance after continued exposure to these fuels for two to three years. On-site tests were performed on individual coalescer elements removed from filter separtor vessels by using a single element tester manufactured by Gammon Technical Products. Water was injected into the fuel flowing through the element, and the degree of coalescence was observed. Results of this study showed that the performance of both fixed and mobile filter separator coalescer elements was not significantly degraded by low WSIM fuel. These single element coalescence tests provided a baseline for determining the effects of fuel conductivity additives on filter separator performance.

2. ADDITIVE SELECTION

Two electrical conductivity additives were selected for the service test; ASA-3, a Shell Chemical Co. product, and Stadis 450, produced by E.I. duPont de Nemours & Co.

ASA-3 has been used in turbine fuels and other petroleum distillate products in Canada since 1964. In 1968, use of the additive became a mandatory requirement in the British aviation fuel specification D Eng. R. D. 2494. Shell reports that ASA-3 is used in over 95% of all civil turbine fuel supplied in the free world outside the United States. There have been no reports of electrostatic incidents from ASA-3 users. Chemically, ASA-3 is composed of equal parts of three active materials in a xylene carrier. These are the chromium salt of alkyl salicylic acid, the calcium salt of do-decyl sulfo succinic acid and a methacrylate-vinyl pyridine copolymer. Reference 3 is a selected literature survey that includes a summary of many papers and reports dealing with the use of and the effectiveness of ASA-3.

While there was no previous flight experience with Stadis 450 additive in turbine fuels, laboratory and field test data along with tests by several aircraft turbine engine manufacturers indicated the additive gave satisfactory results. Stadis 450 is an ashless, organic, clear amber liquid, manufactured under US Patent No. 3,917,466. Prior to and subsequent to the start of the service test, several aircraft engine manufacturers approved the use of Stadis 450 in their engines.

The type of additive used at each site was arbitrarily selected to approximate equal use. At two sites, both ASA-3 and Stadis 450 were used. JP-4 received into bulk storage at Carswell AFB TX contained a mix of approximately 70% Stadis 450 and 30% ASA-3. This mix was obtained by varying the type of additive used by the three supplying refineries. For the dormant storage stability test at Searsport DFSP, two tanks were allocated for additive tests, one for each additive.

During November 1977, approximately seven months after start of the test program, preliminary test results obtained by Mobil Research and Development Corp, under contract to the Air Force Aero Propulsion Laboratory, indicated a potential electrostatic problem with the use of Stadis 450 at temperatures below 30°F. As a precautionary move, use of Stadis 450 at the test sites was terminated in December 1977 and January 1978 and replaced with ASA-3. However, further laboratory test work with Stadis 450 showed the additive was satisfactory for use. Consequently, as of November 1979, the Air Force initiated action to approve Stadis 450 for use in JP-4 and JP-8 fuels.

Table 1 provides information at test sites including start dates, type of additive used at the start of the program, additive injection point, delivery mode to the base and distance from the base.

3. CONDUCTIVITY TEST EQUIPMENT

Each Air Force base and fuel supplying activity involved in the test program required a portable conductivity meter to permit periodic checks on the conductivity of the fuel. Only three types of fuel conductivity meters were identified by the American Society of Testing and Materials (ASTM) as satisfactory for field measurements of turbine fuel conductivity: the Maihak MLA Conductivity Indicator manufactured in West Germany; the Ethyl Corp. Distillate Conductivity Meter, Models 8150 and 8151; and the EMCEE Electronics Inc. Model number 1151. The ASTM method governing the field conductivity test is D 2624.

Approximate prices for the three field meters were $1600 for the Maihak, $1500 for the Ethyl and $500 for the EMCEE meter (with cable kit). For the service test, one Maihak meter was already available and was supplied to the San Antonio Air Logistics Center's POL Technical Assistance Team (SA-ALC/SFQH). Twenty-six of the EMCEE meters were procured and distributed to Base Fuels Management Officers, Quality

TABLE 1

SERVICE TEST SITES

INSTALLATION	START DATE	TYPE OF ADDITIVE	ADDITIVE INJECTION POINT	FUEL DELIVERY MODE	DISTANCE FROM ADDITIVE INJECTION POINT TO BASE
DFSP Searsport, ME	27 Apr 77	ASA-3	Bulk Tank	N/A	N/A
		Stadis 450	Bulk Tank		
Griffiss AFB, N.Y.	2 May 77	Stadis 450	Delivery Line From Terminal	Pipeline	11 Miles
Myrtle Beach AFB, S.C.	14 June 77	ASA-3	In Barge Tanks Prior To Offloading into Terminal	Pipeline From Terminal	6 Miles
Carswell AFB, TX	20 June 77	70% Stadis 450	Three Refineries	Tank Car	15 Miles
		30% ASA-3		Tank Truck	150 Miles
				Tank Truck	200 Miles
Travis AFB, CA	18 July 77	ASA-3	During Receipt Into Terminal Tanks	Pipeline	23 Miles
Davis-Monthan AFB, AZ	25 July 77	Stadis 450	During Receipt Into Terminal Tanks	Pipeline	6 Miles
Nellis AFB, NV	28 July 77	Stadis 450	During Receipt Into Terminal Tanks	Pipeline	1 Mile
McChord AFB, WA	29 July 77	Stadis 450	Into Barge Tanks At Refinery and Mukilteo DFSP.	Barge to Terminal	150 Miles (Ref) 45 Miles (Term)
				Pipeline From Terminal to Base	16 Miles
Mt. Home AFB, ID	19 Oct 77	ASA-3	During Receipt Into Terminal Tanks	Pipeline	13 Miles

Assurance Representatives from the Defense Contract Administration Service, SA-ALC/SFQH, and to four Aerospace Fuels Laboratories of the Directorate of Energy Management. Four Ethyl meters were procured and distributed to Carswell AFB, Griffiss AFB, Myrtle Beach AFB, and the Aerospace Fuels Laboratory at Wright-Patterson AFB, OH (SA-ALC/SFQLA).

The EMCEE fuel conductivity meter, Model 1151, was not officially approved by ASTM for use with test method D 2624 until June 1977, after the service test had started. However, this meter had a major price advantage over the Maihak and Ethyl meters, and its size and adaptability to conductivity measurement in most all types of sampling containers were major advantages. The size of the probe permits it to be inserted into narrow-mouth sample bottles and cans which are standard sampling containers at bases. Because of probe size, special large mouth sample containers greater than one quart were required when using either the Maihak or Ethyl meters.

4. ESTABLISHMENT OF LIMITS

The development and initial use of fuel conductivity additives in aviation fuels occurred when aircraft did not contain foam in the fuel cells or integral fuel tanks. The major sources of static charge were micronic filters and filter separators located in aircraft servicing systems. With refueling hoses 30 to 50 feet in length connecting the service unit to the aircraft, charge relaxation times of several seconds were normally available. Under these conditions, a minimum fuel conductivity of about 25 pS/m was found to prevent incendive sparks within aircraft fuel tanks. Thus, users of the additive adopted a minimum fuel conductivity of 50 pS/m, considering a safety factor of about 2. This factor of safety was added to compensate for fuel conductivity changes with temperature. A decrease in temperature of 40 to 50°F will result in a 50% reduction in fuel conductivity. The Air Force also adopted the 50 pS/m minimum limit in the JP-4 specification in November 1976. However, the use of ASA-3 was optional and in fact was not used by suppliers.

The record of eight electrostatic refueling incidents in aircraft filled with the reticulated urethane foams during the period 1974 through 1977 pointed directly to the foam as a primary source of static charging during tank filling. In such a fuel system, there is minimum time for the electrostatic charge to bleed ground. Thus, the minimum conductivity limit for fuel serviced to aircraft at the additive service test bases was initially established at 75 pS/m. When research studies (Reference 4) showed that the new blue, polyether urethane foams, scheduled to be used in several aircraft, were even more electrostatically active than the orange, yellow, and red polyester urethane foams already in use, the minimum fuel conductivity for test bases was increased to 100 pS/m, measured at the skin of the aircraft. Blue foam has been programmed for extensive use in some production aircraft as well as a replacement for the polyester urethane foams due to its better stability properties.

The maximum limit on fuel conductivity was first set at 300 pS/m as a number of aircraft were equipped with uncompensated fuel tank capacitance quantity gages that were sensitive to fuel conductivity (Reference 1). After these older aircraft were phased out of service, the maximum limit was raised to 450 pS/m then to 600 pS/m by some users. For service test base fuel suppliers, a maximum conductivity limit of 600 pS/m was established. At the base, the maximum use limit was 700 pS/m.

Rationale for these upper limits was based primarily on permitting the suppliers sufficient latitude for blending error in addition to preventing use of high conductivity fuel which could cause erroneous readings in aircraft fuel quantity gage systems.

To insure that fuel delivered to service test bases met the minimum conductivity level of 75 pS/m (later raised to 100 pS/m) at time of servicing, the fuel conductivity requirement for the suppliers injecting the additive was established at 200 to 600 pS/m. No limit was placed on the quantity of additive necessary to obtain fuel conductivity within this range. The minimum conductivity level of 200 pS/m was established to prevent the fuel conductivity, as a result of fuel handling and temperature decreases, from falling below the minimum use limit at the time of servicing.

The minimum fuel conductivity in the Air Force base bulk tanks was set at 125 pS/m. If conductivity fell below this level, base personnel were instructed to increase the conductivity level by manually pouring diluted additive into the tanks or by increasing the amount of additive into fuel receipts.

5. TEST PLAN

a. Fuel Property Test Requirements

(1) Suppliers.

For contractors supplying fuel containing the conductivity additive, the test plan shown in Table 2 was established. Quality Assurance Representatives from the Defense Contract Administration Service (DCAS) were tasked with submitting the fuel test results as well as other requested information on a monthly basis to SA-ALC/SFQH. A blanket waiver was given to suppliers for the WSIM property since it was known the conductivity additives could reduce the WSIM below the minimum specification level of 70.

Thermal stability test results were also requested on both inhibited and uninhibited fuel to verify that the conductivity additives would not affect this property.

(2) Bases.

At the service test bases, fuel conductivity measurements and fuel temperatures were reported on samples taken at the locations and frequencies shown in Table 3. Results were submitted weekly by the base to SA-ALC/SFQH with an information copy to the Aero Propulsion Laboratory at Wright-Patterson AFB (AFWAL/POSF). Each month SA-ALC/SFQH summarized the results from each base and forwarded a progress report to AFWAL/POSF with information copies to HQ USAF/LEYF and the parent major command.

In addition to the above testing requirements, each test base submitted monthly, three one-gallon JP-4 samples to their respective area laboratory for selected specification tests. Tests performed at the area laboratory were thermal stability by the Jet Fuel Thermal Oxidation Tester (JFTOT), filtration time, water reaction, total solids, corrosion, fuel system icing inhibitor and the water separometer index by the standard WSIM (ASTM D2550), Minisonic Separometer (ASTM D 3602) and an early development version of the Micro Separometer (Microsep). Samples were obtained from bulk storage tanks under flow conditions. Conductivity level was also measured by the base on each of the one-gallon samples prior to shipment. The area laboratory receiving the sample also measured fuel conductivity to determine the effect of transient time.

TABLE 2

SERVICE TEST PLAN

LOCATION	INFORMATION REPORTED
DFSP Verona, NY Copeland Oil Co. (Griffiss AFB NY)	(1) Injection rate (ppm) (2) Conductivity & Temp each transfer (3) WSIM on uninhibited JP-4 (once per month 1-gal sample to be submitted with base correlation sample)
Myrtle Beach Pipeline, SC (Myrtle Beach AFB SC)	(1) Injection rate each barge (ppm) (2) Bulk tank conductivity reading weekly (3 levels) (3) Origin of Product (Hess, Exxon, etc.) (4) WSIM on uninhibited fuel (once per month from barge)
Winston Refining, Ft Worth, TX (Carswell AFB TX)	(1) Injection rate (ppm) (2) Conductivity & Temp (one tank car per five cars loaded) (3) WSIM & Thermal Stability of uninhibited JP-4 (each batch) (4) WSIM of inhibited JP-4 (one per week)
Longview Refining, Longview, TX (Carswell AFB TX)	Same as for Winston Refining above (tank trucks)
Pride Refining, Abilene, TX (Carswell AFB TX)	Same as for Winston Refining above (tank trucks) In addition run thermal stability on inhibited JP-4 once per week for four weeks
Southern Pacific Pipeline Co. Tucson, AZ (Davis-Monthan AFB AZ)	(1) Injection rate (ppm) (2) Conductivity & Temp-each batch-(3 levels) (3) WSIM before additive - each receipt (4) WSIM - after additive - each batch (5) Thermal Stability - before and after additive - on three batches
Southern Pacific Pipeline Co. Concord, CA (Travis AFB CA)	(1) Injection rate (ppm) (2) Conductivity & Temp - each batch (3 levels) (3) WSIM - after additive - each batch

TABLE 2 (CONCLUDED)

LOCATION	INFORMATION REPORTED
Cal Nev Pipeline, Las Vegas, NV (Nellis AFB NV)	Same as for Southern Pacific Pipeline, Tucson, AZ
Mobil Oil, Ferndale, WA Delivery to Buckeye Pipeline Terminal - Port of Tacoma, WA (McChord AFB WA)	(1) Injection rate (ppm) (2) Conductivity & Temp on four barge tanks - each loading (3) WSIM & Thermal Stability before additive - each batch (4) WSIM after additive - each barge (5) Thermal Stability after additive on three batches
Mukilteo DFSP, WA Delivery to Buckeye Pipeline Terminal - Port of Tacoma, WA (McChord AFB WA)	(1) Injection rate (ppm) (2) Conductivity & Temp on four barge tanks - each loading (3) WSIM before & after additive on each barge (4) Thermal Stability before & after additive on three barge loadings
Buckeye Pipeline Co., Tacoma, WA (McChord AFB WA)	(1) Conductivity & Temp on four barge tanks on each receipt (2) Conductivity & Temp on issue bulk tank one day prior to shipment to base (3 levels)
Searsport DFSP, ME Static Storage Test	(1) Conductivity & Temp on each bulk tank monthly (3 levels) (2) Samples from each tank submitted to SFQLB for specification analysis

TABLE 3

BASE SAMPLING PLAN

SAMPLING LOCATION	FREQUENCY	READING FROM
Tank Truck Receipt	a. 1st week-all trucks b. After 1st week, one truck daily from each source	Tank Truck
Rail Car Receipt	As above	Rail Car
Pipeline Receipts	Each receipt - 15 minutes after start and approximately 15 min before end of tender. This applies to 1st month after start of test. After 1st month sample each receipt - 15 minutes after start only.	One gallon coated can. On five samples during the 1st month run conductivity from both coated and uncoated sample cans.
Bulk Tanks	Daily from each tank for 2 weeks. Each tank weekly after the 2nd week.	Tank gage hatch. For 1st two weeks, in addition to reading from hatch, obtain reading from 1 gallon coated can sample from one tank daily. Alternate sampling tanks. This shall be a sample taken during transfer.
Operating Tanks	a. After operating storage tank has been filled twice from bulk storage, obtain reading on each tank. b. Thereafter one active tank from each pumphouse system weekly. Alternate tanks so that all tanks are sampled.	Tank
Refuelers	a. All units after second fill. b. Each unit weekly thereafter.	One gallon coated can. Sample taken from quick disconnect.
Hose Carts	a. During the first refueling from each lateral after operating storage tanks have been filled twice. b. Thereafter, weekly on each cart.	One gallon coated can. Sample taken from quick disconnect.

Within one week prior to start of using additive, each test base submitted three one-gallon samples of JP-4 from one bulk storage tank to the area laboratory for fuel specification testing. When SA-ALC/SFQH personnel visited each base at the start of additive use, samples from the selected base bulk tank that contained the additive were again shipped to the area laboratory for complete specification tests. This provided "before and after" test analyses.

At Searsport DFSP, where the dormant storage test was conducted on each additive, samples were submitted monthly to the Searsport Aerospace Fuels Laboratory for full specification tests.

While the submission of periodic reports required of DCAS and base personnel was terminated as of April 1978, additive use at these sites has continued. SA-ALC has maintained a reporting requirement only when problems were encountered.

b. Effect on Filter Separator Performance

The frequency for monitoring solids and water content of samples taken downstream of filter separator vessels was not altered for the test sites. These requirements, as specified in Technical Order 42B-1-1, "Quality Control of Fuel and Lubricants", are weekly for each fillstand, hose cart, and refueler and monthly for hydrant system pumphouse filter separators. Solids are determined by filtering a one-gallon sample through an in-line Millipore sampler containing a single membrane filter housed in a monitor. The membrane is visually compared to a Color and Particle Assessment Guide, NSN 6640-00-326-7684. The membrane must not exceed the particle rating of 'marginal' and must be less than a color of '5'. Should the solids exceed the limit,a recheck one-gallon sample is taken and a gravimetric analysis is determined from a matched weight membrane monitor. The limit is 4.0 mg/gal. Water analysis is conducted by the AEL method. Free water limit is 10 ppm.

The procedure for determining the effects of the additives on coalescer elements was to compare the water removal capability of individual elements before and after use of the conductivity additives. The instrument used was a single element tester manufactured by Gammon Technical Products, Model Number GTP 359-36.

c. Effect on Aircraft

Aircraft maintenance organizations at the service test bases were tasked with reporting any unusual maintenance action which might be related to the use of the two conductivity additives. Air Logistics Centers were required to report the condition of the fuel tank foam in aircraft undergoing programmed depot maintenance. These reports were forwarded to the responsible Air Logistics Center System Managers (MM), compiled, and forwarded to the Office of DCS/Logistics Operations, HQ AFLC/LOA, Wright-Patterson AFB, OH.

SECTION V

ADDITIVE INJECTION LOCATION AND TECHNIQUE

1. JP-4 SUPPLIERS

JP-4 was supplied to all service test bases with the conductivity additive already injected. The methods of additive injection and the location of the additive injection system within the fuel supply system are discussed below for each service test base.

a. Carswell AFB TX

JP-4 was delivered to the base by tank car or tank truck from three refineries. Tank car shipments were made from Ft Worth, a distance of approximately 15 miles. Tank truck deliveries were made from Longview, TX, and Abilene, TX, distances of 150 and 200 miles, respectively. Additive diluted with JP-4 was poured into individual tank cars or tank trucks during loading. This was accomplished by filling the vessel approximately 1/4 full, pouring the additive in, and completing the filling operation. Fuel-additive mixing occurred during the completion of loading and during transport to the base.

b. Davis-Monthan AFB AZ

Additive was injected into Southern Pacific Pipeline Company's bulk storage tank at Tucson, AZ, during receipt of JP-4. This was initially accomplished by pouring neat additive into the downstream side of a filter vessel that was used to filter the incoming JP-4. The required amount of additive for each receipt was added to the head end of the tender. Later in the test program, a proportioning pump on the upstream side of the terminal tank was used to inject the additive. The receiving tank was equipped with a floating fill line. Fuel was subsequently transferred to Davis-Monthan AFB via a 6 mile, 6" dedicated pipeline.

c. Griffiss AFB NY

At the Verona, NY terminal, Stadis 450 additive was diluted 1 part additive to 50 parts JP-4 in a 55-gallon drum. The diluted additive was injected by a positive displacement proportioning pump into JP-4 as fuel was transferred from the Verona terminal to Griffiss AFB through an 11 mile, 6" pipeline. When ASA-3 additive replaced Stadis 450, the same dilution ratio and method of injection were used.

d. McChord AFB WA

Additive was poured into individual tanks on barges, both prior to and during loading, at the supplying refinery or terminal. JP-4 destined for McChord AFB was loaded on barges at either Mobil Oil, Ferndale, WA, a distance of 150 miles from McChord AFB, or from Mukilteo DFSP, a distance of 45 miles from McChord AFB. Product was received at the Buckeye Terminal at the Port of Tacoma, WA, and transferred via a 16 mile, 6" pipeline to the base.

e. Mt. Home AFB ID

In the initial stages of the test program, additive was diluted 1 part additive to 5 parts JP-4 and poured into several openings on floating roof tanks after pipeline receipt of JP-4 into the contractor terminal tanks. After March 1978, the proper quantities of neat conductivity additive and corrosion inhibitor additive for each receipt were mixed in a small tank and injected by a positive displacement pump into the tank receipt line.

f. Myrtle Beach AFB SC

ASA-3, diluted 1 part additive to 9 parts fuel, was poured into individual barge tanks on receipt at the Myrtle Beach Pipeline Co. dock.

The product was pumped ashore five miles to the contractor's 25,000 bbl tank and then transferred approximately 1/4 mile to base storage.

g. Nellis AFB NV

Additive was injected by means of a positive displacement proportioning pump into Cal-Nev's bulk storage tanks at Las Vegas, NV during JP-4 receipt. The additive supply was undiluted. Prior to installing the proportioning pump, undiluted additive was injected into the tanks through internal tank mixing nozzles during product receipt. After injection, tank contents were circulated for two hours. Deliveries to Nellis AFB were made via a one-mile pipeline.

h. Searsport DFSP ME

ASA-3 additive was diluted at a ratio of 1 part additive to 15 parts JP-4 in a 55-gallon drum. A hose was connected to the suction side of a 500 gpm transfer pump, and during recirculation of the JP-4 contents of an 80,000 bbl tank, the diluted additive was slowly injected into the pump suction. The pump suction port and the tank discharge port on the tank were located 18 inches from the tank bottom and about 90° apart. Product was circulated an additional three hours after all additive was injected.

Stadis 450 additive was injected in the same manner into a 125,000 bbl tank. However, the dilution ratio was 1 part additive to 50 parts JP-4.

Dispersion of the additive throughout each tank required approximately two weeks. Injecting near the bottom of the tanks caused this long dispersion time. Additive injection was performed only once since the Searsport test was designed to determine additive stability in JP-4 under prolonged storage conditions.

i. Travis AFB CA

ASA-3 was injected into Southern Pacific Pipeline Company terminal bulk storage tanks at Concord, CA, during receipt. This was accomplished using a 90 bbl sump tank equipped with a 100 gpm pump. The required amount of additive for each receipt was poured into the sump tank. Contents of the entire sump tank were then transferred to the receiving tank prior to or at the beginning of the receipt. JP-4 was then transferred through a dedicated 23 mile, 8" pipeline to Travis AFB.

2. BASES

Additive injection into JP-4 at the service test bases was performed only at the start of the service test and whenever the conductivity of the fuel in the base tanks fell below specified limits.

At the start of the service test, the contents of the base bulk and hydrant system operating tanks were treated with the appropriate concentration of ASA-3 or Stadis 450 immediately prior to the first receipt of conductivity additive treated fuel from the supplier. To aid mixing a dilution of one part additive to 9 parts JP-4 was used.

For cone roof tanks the prediluted additive was poured through all available openings (gauging hatches, vents, etc.). For floating roof tanks the prediluted additive was poured through the gauging hatch, overflow ports, and between the floating roof seal and tank sidewall. Cone roof floating pan tanks were most difficult to inhibit due to the lack of openings. Pouring the additive into the product recovery system and pumping back through the tank water drain was used with minor success. In most cases, these types of tanks had to be inhibited by adding diluted additive through the hatch immediately before the tank was filled.

Generally, there was no difficulty obtaining proper mixing of the additive regardless of the method used. Whenever physical doping of bulk tanks was performed by pouring diluted additive through several openings on top of the tank, consistent conductivity readings of the fuel at all levels of the tank were obtained within 24 hours without circulating the fuel.

SECTION VI
DISCUSSION OF FINDINGS

1. CONDUCTIVITY LEVEL

The conductivity and temperature of JP-4 were measured regularly throughout the service test at all bases (Table 2). Summaries of these data can be found in Appendix A. Results at four of the service test bases are presented in more detail below, to illustrate conductivity losses between the injection point, bulk storage, and the refuelers and to illustrate the temperature changes encountered and the temperature effects on conductivity levels. These results are typical for the other service test bases except for specific problems encountered at Myrtle Beach and Mt. Home AFB. These specific problems are discussed under Section VI.

a. Travis AFB CA

Travis AFB used ASA-3 additive throughout the service test. The additive was injected into bulk storage tanks at Southern Pacific Pipeline Co's. terminal, Concord CA during fuel receipt. Fuel conductivity measurements reported in column two of Table 4 were averages of measurements from the tanks made about one day after additive injection.

Fuel is transferred through a 23 mile, 8" diameter, dedicated pipeline to five bulk tanks on Travis AFB. Column 3 of Table 4 records the averages of measurements from these five tanks. The final set of averages of conductivity measurements (Column 4 of Table 4) were made at the aircraft servicing units.

TABLE 4

AVERAGE FUEL CONDUCTIVITY MEASUREMENTS - TRAVIS AFB

TIME	AT INJECTION	BASE BULK TKS	REFUELER	ADD. INJ. RATE (PPM)
Jul - Aug 77	260 @ 77°F	180 @ 71°F	150 @ 70°F	0.4
Sep 77	290 @ 78	187 @ 70	168 @ 69	0.4
Oct 77	222 @ 90	211 @ 70	184 @ 69	0.5
Nov 77	282 @ 78	293 @ 68	222 @ 66	0.6
Dec 77 - Jan 78	248 @ 60	238 @ 65	220 @ 64	0.6 - 0.7
Feb - Mar 78	289 @ 58	256 @ 62	227 @ 62	0.6 - 0.7
AVE	265 @ 74°F	228 @ 68°F	195 @ 67°F	

As seen in Table 4, an average decrease in fuel conductivity of 37 pS/m occurred between the terminal tanks where the ASA-3 is first injected and the base bulk tanks. The lower average fuel temperature at the base bulk tanks accounted for about 25 pS/m of the 37 pS/m average decrease in conductivity.

An additional average loss of 33 pS/m in conductivity occurred between the base bulk tanks and the refueling units. This slight loss was predictable due to absorption of the additive by filters, tanks, and piping in the base fuel system.

The data in Table 4 indicate that conductivity losses were decreasing with time. At the start of the service test in July 1977 through September 1977, the total decrease in conductivity between the contractor's terminal and the refuelers exceeded 100 pS/m. However, by the December 1977 to March 1978 time period, the loss in conductivity amounted to only about 45 pS/m. These decreasing losses with respect to time related directly to equilibration of the system with the additive.

b. Davis-Monthan AFB

JP-4 supplied to Davis-Monthan AFB is injected with conductivity additive as fuel is received into the Southern Pacific Pipeline (SPP) terminal bulk tanks. Fuel from the terminal is transferred to the base through a 6 mile, 6" pipeline. Base bulk storage consists of three 67,000 bbl floating roof tanks that supply fuel to the one active hydrant system. Initially Stadis 450 additive was used, but was replaced by ASA-3 in January 1978.

Table 5 lists average fuel conductivities measured at the SPP terminal tank, the base bulk storage tanks, and refuelers. Concentration and type of additive used are shown in the last column.

TABLE 5

AVERAGE FUEL CONDUCTIVITY AT DAVIS-MONTHAN AFB

TIME	AT INJECTION	BASE BULK TKS	REFUELERS	ADDITIVE CONC (PPM) & TYPE
Jul - Aug 77	235 @ 80°F	175 @ 85°F	143 @ 85°F	1.2 S-450
Sep 77	177 @ 84	130 @ 83	153 @ 80	1.5 S-450
Oct 77	158 @ 83	130 @ 77	130 @ 75	1.5 S-450
Nov 77	230 @ 72	140 @ 67	145 @ 64	1.8 S-450
Dec 77 -	233 @ 60	205 @ 59	174 @ 54	1.8 S-450
Jan 78				1.0 to 1.2 ASA-3
Feb - Mar 78	362 @ 57	312 @ 59	281 @ 58	0.6 to 1.0 ASA-3
AVE	233 @ 73°F	182 @ 72°F	171 @ 69°F	

Between the terminal and base storage tanks the average loss in conductivity was 50 pS/m. An insignificant loss occurred within the AF base fuel system between the bulk tanks and refuelers.

As seen in Table 5, Stadis 450 concentration was gradually increased from 1.2 to 1.8 ppm to compensate for the 20°F drop in fuel temperature during the last six months of 1977. This was required to maintain the fuel conductivity in the 130 - 150 pS/m range at the time of servicing.

The increased conductivity response of ASA-3 as compared to Stadis 450 was apparent at Davis-Monthan AFB. The 0.6 to 1.0 ppm of ASA-3 caused a significant increase in fuel conductivity as compared to 1.8 ppm of Stadis 450. This response comparison between ASA-3 and Stadis 450 was generally typical at sites where both additives were used. Section VI 1.e. further discusses this relationship.

c. Griffiss AFB

JP-4 is supplied to Griffiss AFB from the Verona, NY DFSP by an 11 mile, dedicated pipeline. Conductivity additive was injected into the fuel during transfer from the terminal using a proportioning pump. Although fuel samples were taken immediately downstream of the proportioning pump, the conductivity readings of these samples were probably not accurate due to the lack of time for the additive to react with the fuel.

Table 6 gives the average fuel conductivities and temperatures for the fuel in base bulk tanks and refuelers.

TABLE 6

AVERAGE FUEL CONDUCTIVITY AT GRIFFISS AFB

TIME PERIOD	BASE BULK TKS	REFUELERS	ADDITIVE CONC (PPM) & TYPE
May - Aug 77	312 @ 74°F	258 @ 73°F	S-450 1.0
Sep 77	323 @ 72	265 @ 65	S-450 1.0
Oct 77	280 @ 62	265 @ 54	S-450 1.0
Nov 77	208 @ 60	174 @ 50	S-450 1.0
Dec 77 - Jan 78	275 @ 50	203 @ 35	ASA-3 1.0
Feb - Mar 78	217 @ 51	179 @ 36	ASA-3 1.0
AVE	269 @ 62°F	224 @ 52°F	

The Griffiss AFB data of Table 6 are similar to that for Travis AFB in that minor decreases (considering temperature differences) in fuel conductivity occurred between base bulk storage and the refuelers. As at Travis AFB, the loss appeared to decrease with time, first for Stadis 450 and then for ASA-3.

For the Griffiss AFB fuel Stadis 450 was almost as effective at 1.0 ppm concentration as was ASA-3 at 1.0 ppm.

Griffiss AFB was particularly interesting as it generally experiences lower winter temperatures than the other service test bases. Figures 1 and 2 show the change in fuel temperature at the refueler versus time and the fuel conductivity at the refueler versus time, respectively. The drop in fuel temperature from the 32nd week to the 52nd week of 1977 (Figure 1) is reflected in the decrease in fuel conductivity over the same period

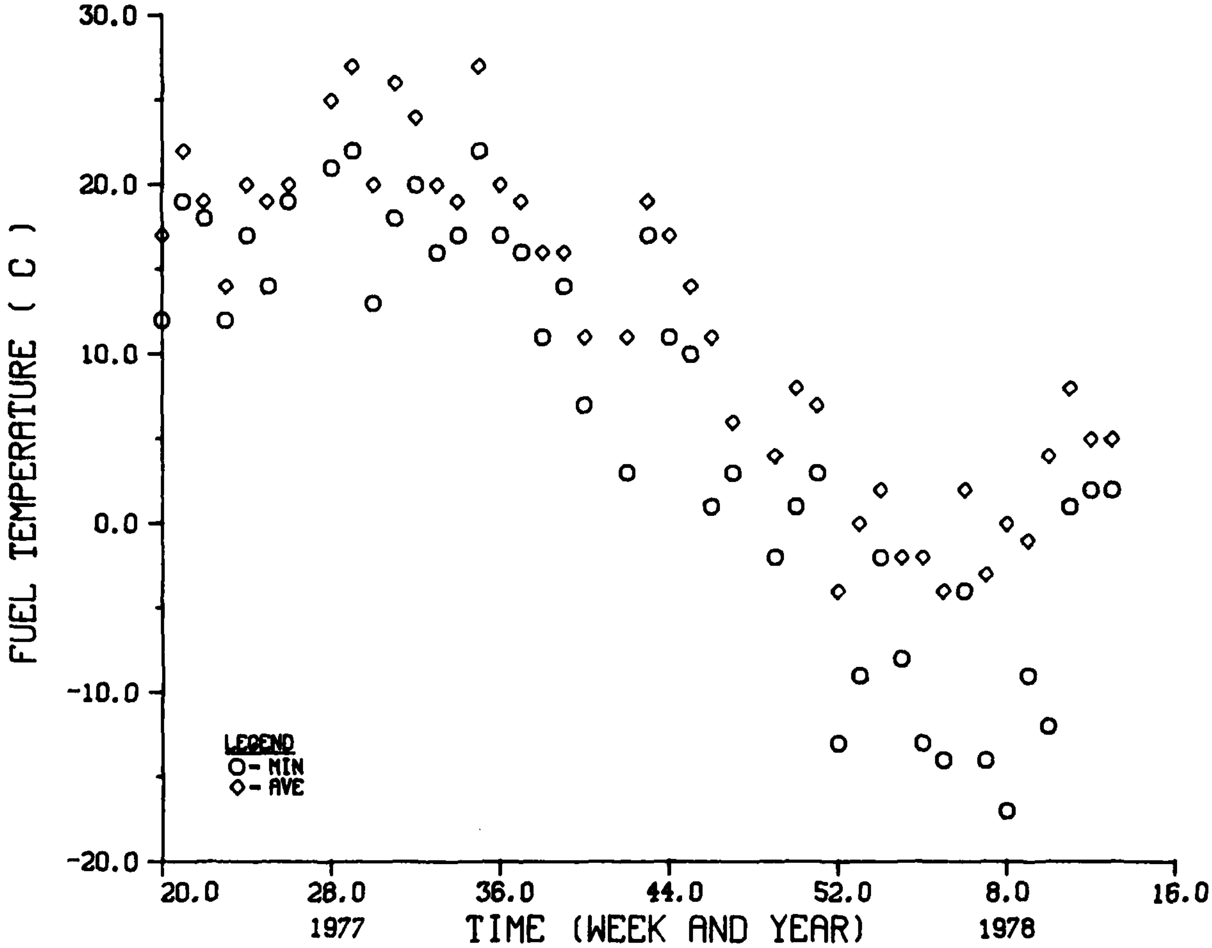

Figure 1. Fuel Temperature at Refueler - Griffiss AFB

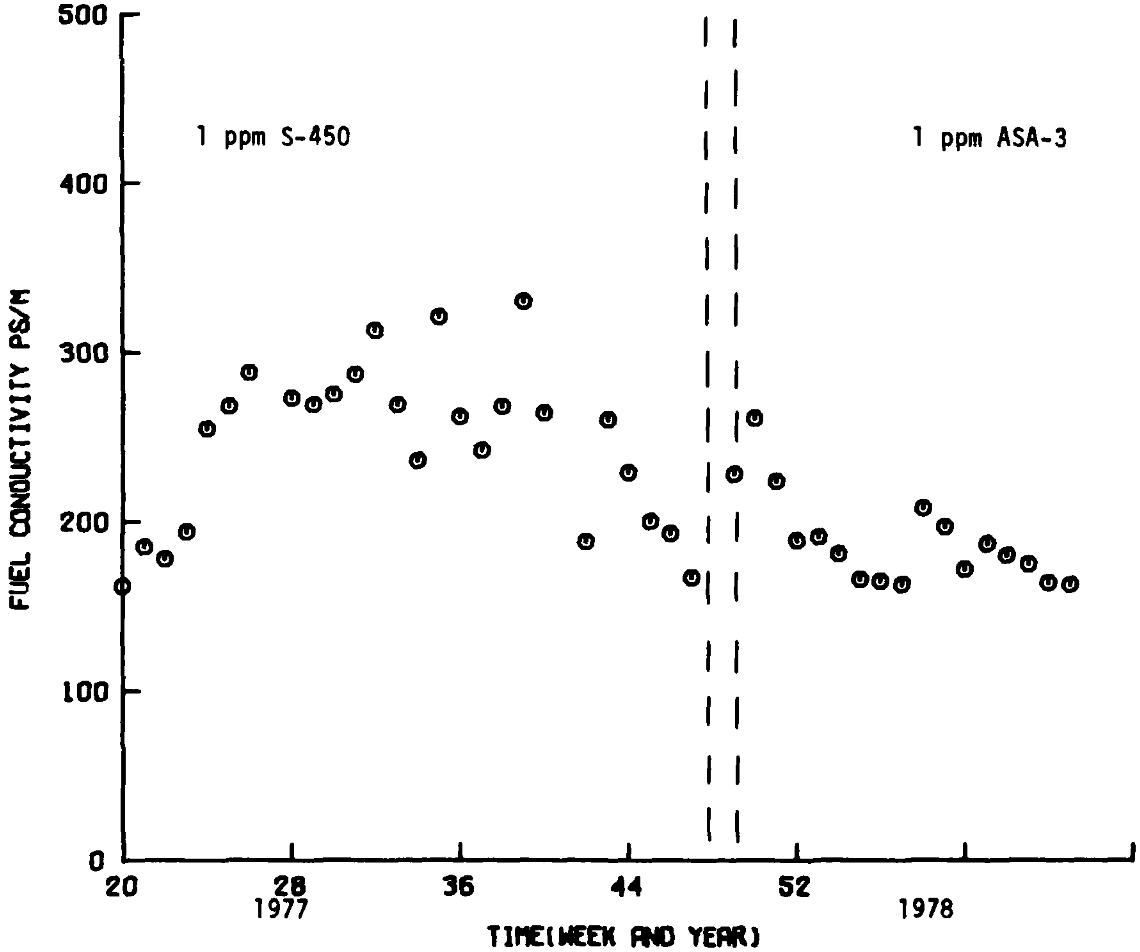

Figure 2. Average Fuel Conductivity at Refueler - Griffiss AFB

(Figure 2). The increase in fuel conductivity with the switch from 1.0 ppm Stadis 450 to 1.0 ppm ASA-3 is seen in Figure 2.

Figure 1 is also shown to illustrate the subfreezing fuel temperatures that can occur at a northern base in the winter.

d. Searsport Defense Fuel Supply Point (DFSP)

Two bulk storage tanks at Searsport DFSP were used to conduct a one year, static storage test of ASA-3 and Stadis 450 conductivity additives. Of primary concern was the loss of fuel conductivity with time. Sufficient diluted ASA-3 to give a concentration of 0.75 ppm was injected into Tank Number 2, an 80,000 bbl tank, through the fill line, and the fuel was circulated for one hour. The same procedure and additive concentration were used to inject Stadis 450 into Tank 4, a 125,000 bbl cone roof tank. Although quantities differed somewhat, the sources of JP-4 in each tank were the same. The tanks were supplied from three refineries and the fuel contained a mixture of Nalco 5402, DCI-4A, and Hitec E-515 corrosion inhibitor additives.

Uniform conductivity levels throughout the tanks were obtained in two weeks, but only after circulating the product for an additional two hours.

Complete specification tests were run on the fuel in each tank prior to and after addition of the two additives. These tests, along with conductivity measurements, were conducted monthly for the duration of the one-year test. The only significant change between the inhibited and uninhibited fuel was the water separometer index property. Both standard WSIM and Minisonic (MSS) values were obtained. For Tank 2, before the addition of ASA-3, the WSIM was 61 and the MSS was 87. After ASA-3 was added, the monthly samples averaged 72 for WSIM and 82 for MSS. The reason for the anomalous increase in the WSIM after adding ASA-3 is not known. Tank 4, before addition of Stadis 450, had a WSIM of 73 and a MSS of 92. After Stadis 450 addition, the monthly samples averaged 75 for WSIM and 90 for MSS.

JP-4 in each of the two test tanks failed the JFTOT thermal oxidation stability test both before and after addition of the additives. There was no difference in the degree of failure as a result of the additives. All other properties of the fuel met specification requirements prior to and after additive injection.

Changes in fuel conductivity values as a result of time and temperature are presented in Table 7. The last column of Table 7 gives the calculated fuel conductivity at 9°C so that the conductivity measurements made throughout the test could be directly compared to the 16 May 1977 data. After the second mixing operation on 16 May 1977, Tank 2 with ASA-3 had an average conductivity of 184 pS/m. By August, this had increased to about 203 pS/m and subsequently varied between 175 and 213 pS/m through March 1978. For Tank 4, with Stadis 450, a drop from 105 pS/m in May 1977 to 88 pS/m in August was noted. Subsequently, fuel conductivity in Tank 4 varied between 75 and 90 pS/m through March 1978.

In summary, no excessive loss of either ASA-3 or Stadis 450 was encountered during the one-year static test, and fuel properties were not significantly affected. The data indicated that ASA-3 was slightly better than Stadis 450 with respect to maintaining conductivity and also more responsive than Stadis 450 at equal doping concentrations. The test illustrated the problem of obtaining proper mixing of the additive in a large bulk tank when the additive is injected near the tank bottom.

TABLE 7

SEARSPORT FUEL CONDUCTIVITY

DATE	TANK NR.	COND. ADD.*	MEASUREMENT LOCATION	COND. (pS/m)	TEMP. (°C)	ESTIMATED pS/m AT 9°C
27 April 77	2	ASA-3	Top of Fuel	50	6	
	2	ASA-3	Middle of Fuel	150	6	
	2	ASA-3	Bottom of Fuel	500	6	
29 April 77	2	ASA-3	Top of Fuel	100	5.5	
	2	ASA-3	Middle of Fuel	100	5.5	
	2	ASA-3	Bottom of Fuel	500	5.5	
	4	S-450	Top of Fuel	110	5.5	
	4	S-450	Middle of Fuel	110	5.5	
	4	S-450	One Ft above tank bottom	450-500	5.5	
10 May 77 - Recirculated Fuel in Each Tank for 2 Hours.						
16 May 77	2	ASA-3	Top of Fuel	200	9	
	2	ASA-3	Middle of Fuel	175	9	
	2	ASA-3	Bottom of Fuel	180	9	
	2	ASA-3	One Ft above bottom	180	9	
	4	S-450	Top of Fuel and throughout tank	105	9	
Aug 77	2	ASA-3	Tank Ave.	240	14	203
	4	S-450	Tank Ave.	104	14	88
Sept 77	2	ASA-3	Tank Ave.	246	14	208
	4	S-450	Tank Ave.	100	14	85
Oct 77	2	ASA-3	Tank Ave.	197	12	179
	4	S-450	Tank Ave.	92	12	84
Nov 77	2	ASA-3	Tank Ave.	193	6	213
	4	S-450	Tank Ave.	80	6	88
Dec 77 & Jan 78	2	ASA-3	Tank Ave.	140	2	175
	4	S-450	Tank Ave.	60	2	75
Feb 78	2	ASA-3	Tank Ave.	120	-5	188
	4	S-450	Tank Ave.	57	-5	90
Mar 78	2	ASA-3	Tank Ave.	140	-2	200
	4	S-450	Tank Ave.	60	-3	88

* 0.75 ppm of the respective additive was added to the fuel on 27 April 1977. No further additions of additive were made.

e. Comparison of Stadis 450 and ASA-3

Comparison of the effectiveness of the two conductivity additives with regard to conductivity value was possible following the switch from Stadis 450 to ASA-3 at five of the service test bases in the December 1977 - January 1978 time period. Table 8 compares the average fuel conductivity at selected temperatures, the additive type and concentration used. ASA-3 was, on the average, about 85% more effective than Stadis 450 for increasing the conductivity of the JP-4. Thus, a significantly higher concentration of Stadis 450 was required with most fuels than ASA-3 to obtain the same level of conductivity. However, there was a great variation in the response of each additive, and with the Nellis AFB fuel Stadis 450 was more effective than ASA-3.

TABLE 8

COMPARISON OF STADIS 450 AND ASA-3 RESPONSIVENESS

AF BASE	STADIS 450 CONC. (PPM)	CONDUCTIVITY/TEMP.	ASA-3 CONC. (PPM)	CONDUCTIVITY/TEMP.
Griffiss	1.0	220 pS/m @ 10°C	1.0	190 pS/m @ 0°C
Davis-Monthan	1.8	130 pS/m @ 12°C	1.0	270 pS/m @ 12°C
Nellis	1.0	200 pS/m @ 10°C	1.0	180 pS/m @ 10°C
McChord	1.5	110 pS/m @ 8°C	1.0	200 pS/m @ 10°C
Carswell (Winston Ref.)	1.6	210 pS/m @ 19°C	0.4	216 pS/m @ 15°C
AVE	1.4	174 pS/m	0.9	211 pS/m

Carswell AFB was the only service test base that used both additives concurrently. About 70% of the Carswell fuel contained Stadis 450 and the remainder contained ASA-3. No compatibility problems were encountered. Also, the two additives tended to be as effective together as they were separately; i.e., there were no synergistic reactions that significantly increased or decreased the conductivity of the commingled fuels.

f. Sample Container Effects on Conductivity Results

According to Hayes (Reference 5), major reductions in conductivity over a period of a few days were observed for fuel samples stored in glass bottles and tin plated steel cans, whereas epoxy-lined cans had no apparent conductivity level-time effects. This loss in conductivity is believed to be caused by the absorption of the conductivity additive onto the glass or metal surfaces of the containers. The greater the container surface area-to-volume ratio, the greater is the effect.

Results at several of the test bases indicated that in some cases conductivity loss of samples taken in glass bottles started to occur after one half hour. The majority of coated or uncoated one gallon can samples showed no significant conductivity loss after eight hours storage. However, the few can samples that did show a decrease in eight hours made this time factor unpredictable.

Tests on samples taken in plastic, clear glass, brown glass, and coated and uncoated steel containers showed no significant variation in conductivity levels up to ten minutes. Therefore, to insure accuracy, the recommended procedure established at each test site was to measure conductivity approximately two minutes after taking the sample with no limitation on the type of sampling container. To provide some flexibility, quality control personnel at test sites were permitted to test for conductivity up to one hour after sampling provided the sample was taken in a one gallon coated or uncoated can.

Tests were made to determine the degree of correlation between conductivity measurements made at the base and the four area Aerospace Fuels Laboratories. Each base would monthly submit three one gallon cans to their respective support area laboratory. Both coated and uncoated metal one gallon cans were used for this determination. Conductivity and temperature were reported on each fuel sample. The area laboratory tested each sample by the same type EMCEE Conductivity meter as used by the base as well as by the laboratory ASTM method D 3114. Time between analyses by the base and area laboratory varied between two and 13 days. Results of this correlation program were poor, with variances as high as 120 pS/m. These findings indicated that for accuracy, conductivity measurements must be determined on-site soon after the sample is taken.

2. EFFECTS ON FUEL PROPERTIES

a. Specification Tests

Excluding the sporadic problem at McChord AFB with high filtration time fuel, which is discussed in Section VI. 5.e., the addition of ASA-3 or Stadis 450 had no effect on any fuel property except for the expected degradation in the water separation property and naturally the increase in electrical conductivity. At most service test bases thermal oxidation stability test data were obtained both before and after the injection of the conductivity additives. These data were obtained using the Jet Fuel

Thermal Oxidation Tester (JFTOT) per ASTM D 3241, and are recorded in Appendix B. No change in JFTOT ratings was seen except for one sample from Travis AFB. This one JFTOT failure was not considered significant and may have reflected a sampling problem.

The service test program fuel specification test data did, however, reveal that much of the JP-4 fuel received by the bases did not pass the thermal oxidation stability specification limits. Searsport DFSP, Myrtle Beach AFB, Griffiss AFB, and Davis-Monthan AFB all reported at least one JFTOT failure on their JP-4 before the conductivity additive was injected. These failures are believed to be caused by trace contaminants picked up by the fuel during transport from the refinery to the terminal or base.

b. Fuel-Water Separation Measurements

Three different fuel-water separation measurement methods were used during the service test; the WSIM per ASTM D 2550, the Minisonic Separometer (MSS) per ASTM D 3602, and an early development model of the new Micro Separometer (Microsep). All instruments are supplied by EMCEE Electronics, Inc. The Microsep is a cheaper, lighter, and smaller version of the MSS. These three instruments were used to detect the presence of surfactants in fuel that may degrade the ability of filter separator elements to coalesce and remove undissolved water in fuel.

Previous studies by the American Society of Testing and Materials, Committee D-2, Technical Division J, Section X, and the Air Force have shown that for JP-4 the MSS and the Microsep instruments gave higher ratings than the WSIM (for all three instruments a rating of 100 is the best obtainable and a zero rating the worst.)

Figure 3 is a plot of the decrease in WSIM ratings of service test base fuels caused by the addition of Stadis 450 and ASA-3. These data are from the tables in Appendix B. There is a great deal of data scatter in Figure 3. Part of this scatter may be caused by the variations in the amounts of additives present, as the concentrations of Stadis 450 and ASA-3 used were those necessary to obtain a fuel conductivity of about 200 pS/m and ranged from 1.0 to 1.8 ppm for Stadis 450 and from 0.25 to 1.5 ppm for ASA-3.

One observation from Figure 3 is that the decrease in WSIM rating of a fuel caused by the presence of a conductivity additive is inversely related to the initial WSIM rating. For example, a fuel with an initial WSIM rating of 95 will have a WSIM of about 93 to 77 after either ASA-3 or Stadis 450 is added. However, if the initial WSIM rating is 80, the additive will drop the WSIM rating to a range of 40 to 70.

Another observation from Figure 3 is that both ASA-3 and Stadis 450 gave equivalent decreases in WSIM ratings. This was unexpected as laboratory tests indicated that Stadis 450 would not lower WSIM ratings as much as would ASA-3. However, the need to usually use higher concentrations of Stadis 450 to obtain the desired fuel conductivity, as compared to ASA-3, accounts for the equivalent effect on WSIM ratings.

In Figure 4, the MSS ratings are plotted versus the WSIM ratings for the same fuels. These data are also found in the tables of Appendix B. The amount of scatter is seen to increase with decreasing WSIM and MSS ratings. As noted by previous investigators, the MSS gave significantly higher ratings than the WSIM for JP-4 fuels. The Figure 4 data are in relatively good agreement with the MSS-WSIM relationship established by an ASTM working panel. The conversion formula for JP-4 containing corrosion inhibitors is MSS = 0.27 WSIM + 73 (shown as dashed line on Figure 4).

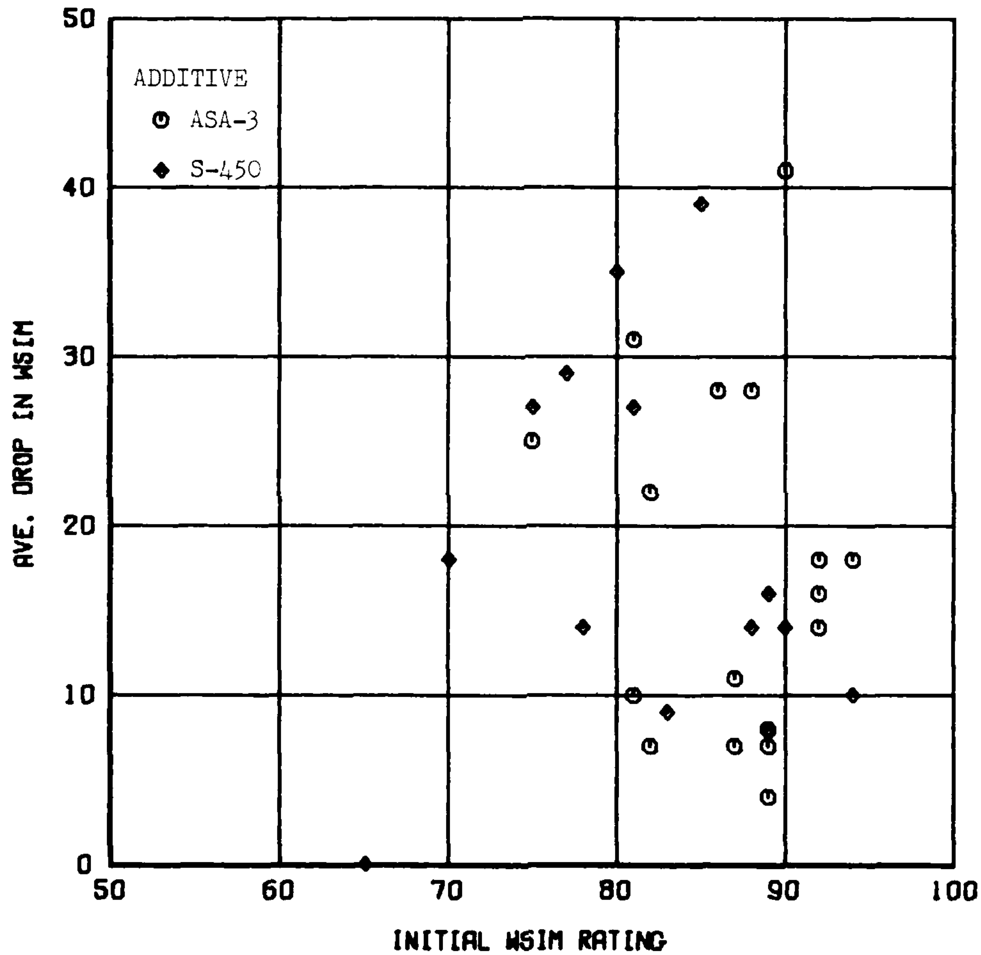

Figure 3. Decrease in WSIM Ratings

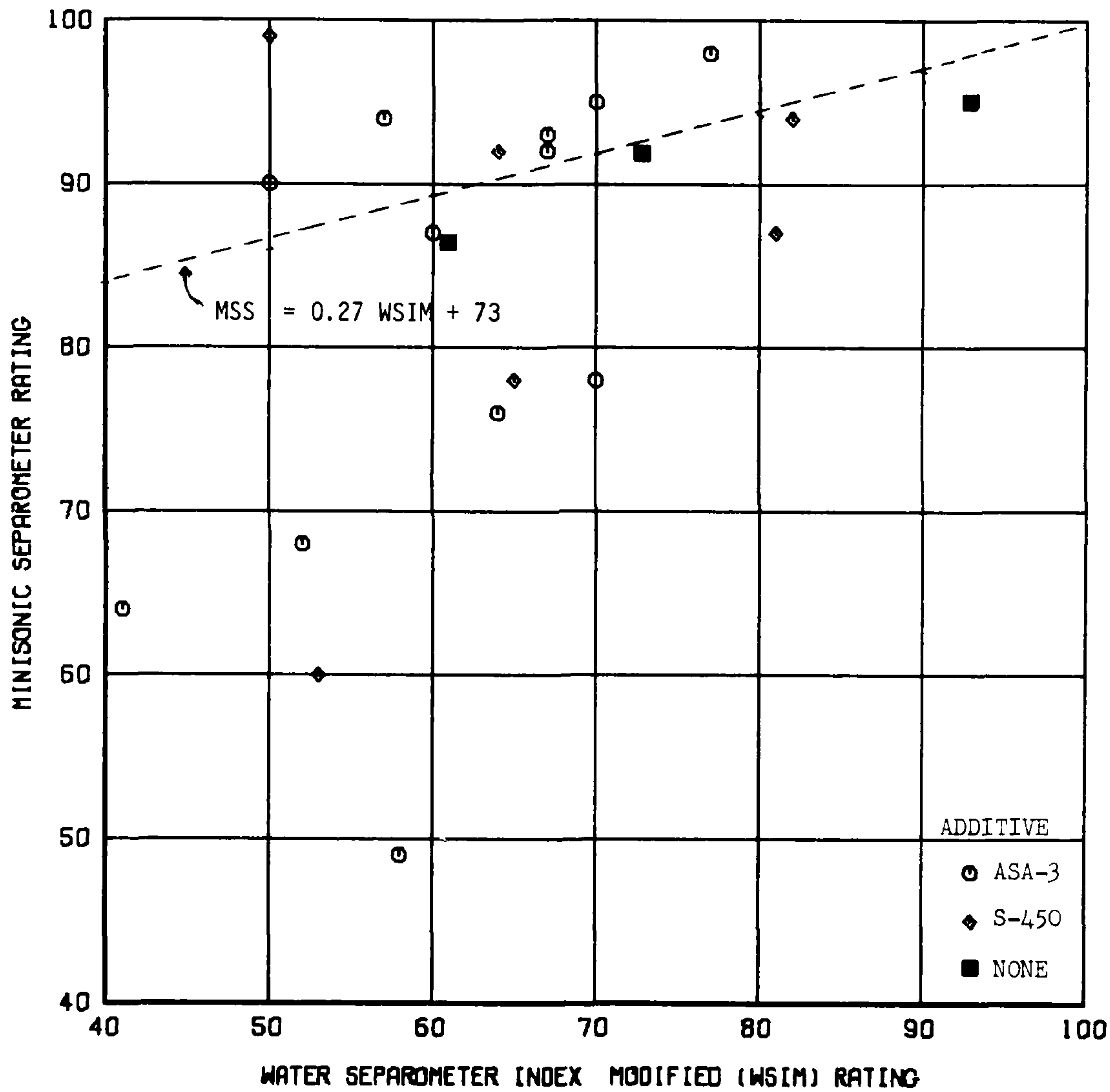

Figure 4. Comparison of Minisonic and WSIM Ratings

The Figure 4 data included fuels containing Stadis 450, fuels containing ASA-3, and fuels containing no conductivity additive. No unusual effects are apparent; i.e., neither conductivity additive gave a different MSS-WSIM relationship than did the surfactants and additives normally found in JP-4 and Jet B fuels.

The data obtained with the early development model of the EMCEE Microsep were scattered and correlated poorly, at best, with either the WSIM or the MSS. Further modifications to the Microsep have been performed by EMCEE Electronics, Inc., to improve correlation with the Minisonic Separometer. The Microsep as of January 1980 is in the process of being approved by ASTM.

3. EFFECT ON FILTER SEPARATOR PERFORMANCE

Five of the eight service test bases had been included in a filter separator test program that was conducted in 1976 by SA-ALC/SFQH. Of the test sites, only Carswell, Travis, and Mt. Home were not evaluated in the 1976 program. At Carswell and Myrtle Beach AFB's, single element tests were conducted the day before the base started using the additive. At most of the test bases, elements in selected filter separator vessels were changed at the same time the base began use of the additive. This procedure permitted the capability to measure at a later date the effect of fuel containing conductive additive on element performance.

In the 1976 program, as well as the element performance tests conducted at the service test bases after exposure to the additive, the test procedure was the same. Tests were performed on site using the single element tester manufactured by Gammon Technical Products. At least two coalescer elements from each preselected filter separator vessel were tested individually by injecting water into the fuel stream at an initial rate of 0.5%. Fuel supply was provided from a refueler by connecting the single point nozzle to the inlet of the tester. A flow rate between 20 and 25 gallons per minute was established for each coalescer under test. The effluent JP-4 was discharged into the hatch of the refueler. The ability of the element, which is mounted in the transparent plastic housing of the tester, to coalesce the highly emulsified water in the fuel stream was visually determined. While the water injection rate was increased to 3%, the appearance of the water droplets from the coalescer element at the start of the test was considered the crucial point for evaluating performance. At several test sites both tap water and water from JP-4 bulk tank bottoms were used.

Single element coalescer tests were conducted at six of the eight service test bases. Element in-service time varied from 4 to 14 months and thruput on the 300 or 600 GPM vessels ranged from 600,000 to 9,200,000 gallons. Average thruput was 3,700,000 gallons. At two bases, Mt. Home and Davis-Monthan, the fuel distribution procedure was modified to obtain maximum thruput on test vessels. This accelerated use equated to approximately 2 1/2 years of in-service time under normal conditions. Air Force element change criteria for time in-service is 3 years. All elements tested were qualified to performance specification MIL-F-8901 and were either the DOD standard element, NSN 4330-00-983-0998, or elements identified by NSN 4330-00-844-1502. Element manufacturers were Velcon Filters Inc., Keene Corp. and Banner Engineering.

Results of these tests shown in Table 9 indicated that no significant degradation of element performance was detected as a result of using the two additives, either singularly or in combination.

4. EFFECT ON AIRCRAFT

No unusual and unexplainable maintenance action or problem on aircraft related to the conductivity additive was reported during the service test. Also, no additional fuel tank fires, as evidenced by burned or scorched fuel tank foam, were reported.

The effects of excessive fuel conductivity on aircraft fuel tank gaging systems were determined for an A-7 and an A-10 aircraft when the JP-4 at Myrtle Beach AFB was unintentionally raised above 1000 pS/m. By cooling the fuel until on-scale readings could be obtained on the EMCEE meter, the actual conductivity of the fuel in the bulk tank was estimated to be 1400 to 1500 pS/m.

Using the refueler fuel flow totalizing meter and knowing the gravity of the fuel, the amount of fuel added to the aircraft by the refueler and the quantity of fuel added as determined by the aircraft's fuel quantity gages were compared. For the A-10 aircraft 10,414 pounds of fuel were serviced as measured by the refueler, and the aircraft's gages indicated the receipt of 10,203 pounds; a difference of 211 pounds or 2.1%. This error is within the 3% accuracy limits required for the A-10's fuel quantity gaging system.

For the A-7 aircraft 7,802.5 pounds of fuel were serviced according to the refueler's meter and the aircraft received 7,349.1 pounds according

TABLE 9

FILTER SEPARATOR ELEMENT PERFORMANCE

AF Base	Element Inst Date	Start Date of Additive	Date of Test	Cond. Add. Used	F/S Location	ThruPut X 1000 Gallons	Dif. Pres (PSI)	Coalescence Performance
Griffiss	May 1977	2 May 77	25 Oct 77	S-450	Hyd PH 2	600	1.0	Satis
	March 1975				Hyd PH 3	900	2.5	Satis
Myrtle Beach	May 1977	14 June 77	31 Oct 77	ASA-3	Fillstand 1	1,000	5.0	Satis
	June 1977				Fillstand 3	1,800	5.0	Satis
Carswell	July 1977	20 June 77	23 Feb 78	S-450	Hyd PH	1,880	20	Satis
	June 1977			&	Fillstand	9,200	12	Satis
	Aug 1975			ASA-3	R-5 Ref.	4,900	7	Satis
Travis	July 1977	18 July 77	20 Mar 78	ASA-3	Hyd PH C	3,700	17	Satis
	Oct 1976				Hyd PH D	1,300	6	Satis
	March 1976				Hyd PH E	2,200	16	Marginal*
	Nov 1976				Rec Line B	7,500	5	Satis
Mt Home	Oct 1977	19 Oct 77	23 Mar 78	ASA-3	PH 1317	6,000	4	Satis**
	May 1975				PH 265	Unknown	1.5	Satis***
	Sept 1975				R-9 Ref.	750	6	Satis
Davis-Monthan	Nov 1977	25 July 77	14 Sept 78	S-450	Hyd PH J-3	7,000	6	Satis
	Nov 1977				Hyd PH J-3	7,000	8	Satis

* Element defects not caused by additive.
** Coalesced water droplets smaller than usual.
*** Separator Cannister was covered with carbon indicating an internal low order fire. This probably occurred during filling of vessel after element change in May 1975.
NOTE: Bases using STADIS 450 were converted to ASA-3 in Dec 77 and Jan 78.

to the aircraft's fuel gaging system; a difference of 453.4 pounds or 5.8%. This difference is excessive and indicates that the capacitance gages in the A-7 were adversely affected by the 1500 pS/m fuel.

5. PROBLEM AREAS

a. High Conductivity Fuel at Myrtle Beach AFB

At the initiation of the service test at Myrtle Beach AFB, SC, in June 1977, the on-base fuel in one bulk storage tank and the off-base contractor's tank were injected with 0.5 ppm ASA-3. Within three days, the two tanks had fuel conductivity readings in excess of 1000 pS/m. Fuel from the remaining on-base undoped bulk storage tank was blended with the high conductivity fuels, and additional undoped fuel was brought into the terminal until the excessive fuel conductivity problem was corrected.

The majority of fuel being supplied to Myrtle Beach AFB at the initiation of the service test was produced by the Southwest Refinery at Corpus Christi, TX, containing the corrosion inhibitor DCI-4A. However, this fuel was added to a Charleston, SC terminal tank that contained a heel of JP-4 from Hess Petroleum, St. Croix, Virgin Islands, and the Hess Fuel contained Hitec E-515 corrosion inhibitor. The Charleston terminal supplies JP-4 to Myrtle Beach AFB.

Subsequently, the additive concentration of the fuel delivered to Myrtle Beach AFB ranged from 0.6 to 0.9 ppm of ASA-3 to maintain adequate fuel conductivity. However, during mid March 1978, the fuel conductivity again rose to over 1000 pS/m.

The reasons for the two occurrences of high fuel conductivity at Myrtle Beach AFB are not known. One fuel corrosion inhibitor, Hitec E-515, is known to synergistically react with ASA-3 to increase the response of ASA-3. Also, as seen in Section VI.1.e., the amount of additive required to increase the fuel conductivity to some given level varies from one fuel to another.

b. Low Conductivity Fuel at Mt. Home AFB

Fuel delivered to Mt. Home AFB cor[illegible], from Salt Lake City, UT by multiproduct pipeline to the Holly Corporation terminal. There JP-4 is clay filtered and then fuel system icing inhibitor (FSII) and corrosion inhibitor Unicor J are injected prior to the fuel entering the Holly terminal storage tanks. The fuel is then delivered through a 13 mile dedicated pipeline to Mt. Home AFB.

At the start of the service test, ASA-3 was added to the terminal storage tanks prior to fuel receipt. Later in the service test for experimental purposes, ASA-3 was premixed with the corrosion inhibitor Unicor J and the mixture injected into the line leading to the terminal tanks.

From November 1977 to March 1978, fuel conductivity at the Holly terminal tanks averaged 197 pS/m at 50^{o}F. In the same time period refuelers at the base had an average fuel conductivity of 220 pS/m at 51^{o}F. During this time, the additive concentration was maintained at 1.5 ppm of ASA-3. Subsequently, the additive concentration has been increased to as high as 1.8 ppm ASA-3, yet fuel conductivities at the refueler occasionally fell below 100 pS/m.

The reasons for the poor response of ASA-3 at Mt. Home AFB are not known. The near simultaneous injection of the FSII and the Unicor J-ASA-3 mix may be a factor. The possibility of the fuel having a high nitrogen content which decreases the response of ASA-3 could also contribute. Studies are being conducted to determine the cause of this problem. The problem is not with the Mt. Home AFB fuel system, as there is no decrease in fuel conductivity between the terminal and refuelers.

c. Additive Response Time

Dukek, et al (Reference 4) and others have reported that up to 24 hours time may be required to reach equilibrium value of conductivity after ASA-3 is mixed into a fuel. Stadis 450 is reported to reach its ultimate conductivity level at a more rapid rate but this was not confirmed in the test program. This delayed response appears to be affected by the degree of fuel-additive mixing and temperature. Fuel conductivity measurements, made by the refineries that supplied Carswell AFB, were obtained immediately after the fuel had been added to rail tank cars or tank trucks into which the additive had been placed. These measurements differed by as much as 100 pS/m as compared to the conductivity measurements obtained after the fuel had been transported to Carswell AFB but with the fuel still contained in the rail tank cars or tank trucks.

This phenomenon implies that fuel suppliers that inject the additive immediately before fuel shipment will not be able to obtain valid conductivity measurements. Thus, bases receiving the fuel under these conditions must inform the supplier or Government Quality Assurance Representative if adjustments to the additive concentration are required.

d. Conductivity Meters

Problems encountered with the EMCEE Model 1151 conductivity meters included cable-to-probe connection breaks (sometimes resulting in the loss of the probe), rapid run-down of batteries, and electronic malfunctions where the meter failed to operate or could not be calibrated. Several of the meters were returned to the manufacturer for repairs during the service test. EMCEE subsequently modified the meter and began the production of the model 1151A meter. Problems with this newer model have been minimal.

Field experience with the Ethyl Intertech meter was not nearly as extensive as with the EMCEE meters as only four of the Ethyl meters were procured. One disadvantage of the Ethyl meter was the large probe diameter as compared to the EMCEE meter probe. Results obtained with the digital readout Ethyl meters compared favorably with the EMCEE meter.

Field experience with the Maihak meter was minimal as only one meter was available. Although results were satisfactory, its high cost and large probe size did not make it practical for base use.

e. High Filtration Time Fuel at McChord AFB

McChord AFB was placed in the test program primarily to determine the effects of barge transport on fuel containing conductivity additive. The majority of JP-4 delivered to McChord during the test program was supplied by Mobil Oil in Ferndale, WA and the Defense Fuel Supply Point in Mukilteo, WA. Conductivity additive at both locations was added to barge tanks during the loading operation. Fuel was off-loaded at the Buckeye Pipeline terminal, Port of Tacoma, WA and transferred via a 16 mile single product pipeline to McChord AFB. McChord began using Stadis 450 on 29 July 1977 and changed to ASA-3 on 10 Jan 1978.

From the beginning of the test program, occasional problems with filtration time failures on receipt of product from the Buckeye terminal were reported by McChord AFB quality control personnel. The problem became more severe after January 1978 when ASA-3 began to be used. Various investigations and tests were performed by the contractors, DCAS Quality Assurance Representatives and Defense Fuel Supply Center personnel. Slightly less than one-half of the JP-4 barge shipments to the Buckeye Pipeline terminal exceeded the 15 minute specification limit for filtration time during the service test period. While all JP-4 shipped from each source met the filtration time property before addition of the conductivity additives, it must be pointed out that many of the batches were close to the maximum 15 minute limit. In addition, McChord AFB had a history of filtration time problems dating back to 1971. However, it was apparent the addition of Stadis 450 and more significantly ASA-3 resulted in more frequent failures of this property. The impact was a significant increase in the number of element changes in filter separator vessels at McChord AFB due to exceeding the differential pressure criterium.

Mobil Oil believed that at least part of the problem was due to incompatibility of both corrosion inhibitors and conductivity additives with JP-4 derived from Alaskan crude. The work done at Mobil Oil without the addition of conductivity additive indicated significant differences in filtration time and also WSIM results when the type of corrosion inhibitor used was varied. Differences in filtration time results were also experienced when JP-4 was stored in coated and uncoated tanks and also if mixing paddles were used in the finished blend tank. Contrary to what would be expected, JP-4 produced higher filtration time in the coated tank than in the uncoated tank.

McChord AFB was the only service test site which experienced a problem with filtration time. The average filtration time result on receipt samples at the seven other test bases was five minutes.

f. Filter Separator Internal Fires

During the winter of 1977-78, two filter separator fires occurred at USAF bases; one at Westover AFB, MA, and the other at McChord AFB, WA, a service test base. Fuel samples taken at the two bases revealed there was no conductivity additive in the Westover AFB fuel, as anticipated, and that the McChord AFB fuel had a conductivity of 240 pS/m, also as anticipated. The McChord JP-4 had a mixture of ASA-3 and Stadis 450 since this occurred at the time the base was being switched from Stadis 450 to ASA-3. These incidents, as well as most all other similar low order fires, occurred when the vessel was being filled after element change or maintenance.

The incident at McChord AFB, as well as several filter separator fires that have occurred in Canada and elsewhere with fuels containing ASA-3 conductivity additive, confirm that the use of fuel conductivity additive will not prevent internal fuel filter separator fires.

Fuel conductivity additives are not successful in preventing filter separator fires because of the element construction materials and design of filter separator vessels. Coalescer elements are known to be excellent static charge generators and retain the charge longer since they are constructed of poor conductive materials (i.e., paper and glass fiber with plastic end caps). The elements are not electrically bonded to the filter separator vessel. Thus, when the vessel is being filled after element change, the fuel and elements become highly charged as fuel passes through the coalescer elements. These electrostatic charges can result in incendive sparks that may ignite the fuel-air mixture within the vessel.

Once filled, the filter separator vessel normally remains full of fuel, which eliminates the static spark initiated fire problem. Thus, special instructions concerning the initial filling of filter separator vessels have been disseminated to the field. The instructions require that filter separators be slowly gravity filled from an adjoining vessel. Thus, charge generation is kept to a minimum and additional time is provided for charge relaxation.

A related problem has been reported using membrane filters to measure the filtration time of JP-4 or to determine the particulate contamination level of fuel. With the normal glass filtration apparatus used in laboratories to measure filtration time and particulate contamination and the plastic field monitors used for in-line sampling, significant static charges may build-up during fuel filtration. Again as with filter separator fires, the use of conductivity additives will not prevent these static initiated fires unless special steps are taken to electrically ground components of the apparatus. Because of this hazard, the Air Force as well as ASTM requires bonding wire in filtration equipment and sampling containers. There is also a requirement to wait three minutes before separating the field membrane monitors from the in-line stainless steel holders.

6. POTENTIAL PROBLEM WITH THE F100 ENGINE

The Pratt and Whitney Aircraft Group has notified the Air Force of a potential problem involving the electrical conductivity fuel additives and the F100 engine, used in F15 and F16 aircraft. The F100 engine fuel control includes a stepper motor whose windings are exposed to the fuel. The fuel in contact with the motor windings is often at elevated temperatures of 200°F to 300°F. With JP-4 containing no conductivity additive, an electrochemical attack of the motor windings has occurred resulting in premature failure of some of the stepper motors.

The stepper motor winding failure is believed caused by the release of chloride ions from the winding insulation, which, with the electrical potential that exists between motor windings, can corrode the windings and cause motor failure. This problem has been reported only on stepper motors whose windings have a particular insulating varnish curing procedure and an epoxy overcoat over the insulating varnish. Steps have been taken to correct this situation, but many motors employing this particular winding insulation system have already been produced and are in the USAF inventory.

There is a concern that the use of electrical conductivity fuel additives will result in an increased rate of attack on the motor windings, aggravating the existing problem. Tests have been initiated to determine the effect of the fuel conductivity additive, ASA-3, on the stepper motors.*

The conductivity additive ASA-3 has been used for many years with aircraft that include fuel boost pumps that have electrical windings exposed to the fuel. No problems have been reported. Also, F15 aircraft employing the F100 engine have been stationed at Nellis Air Force Base throughout the service test of the fuel conductivity additives, and no unusual fuel system problem has been reported.

*NOTE: Preliminary test results indicate that with 90% confidence, the current production stepper motor life will not be affected by the use of ASA-3 fuel conductivity.

SECTION VII

RECOMMENDATIONS

1. Adoption of fuel conductivity additive in JP-4 and JP-8 turbine fuels was recommended by SA-ALC and Aero Propulsion Laboratory to the Air Force Ad Hoc Committee on Static Electricity on 10 May 1978*.

2. The location of additive injection should be governed by the supply mode to each base. Where a base received fuel directly from a refinery by tank truck, tank car, barge, or single product pipeline, the additive should be injected during product loading. This location permits retention of the Water Separometer Index specification requirement for JP-4 and JP-8 prior to injection of the additive. Where bases receive product from terminals, the additive should be injected on receipt into the terminal. Based upon industry experience of excessive fuel conductivity loss, the additive should not generally be added to fuel transported in ocean tankers or multiproduct pipelines.

3. Work is needed to determine the maximum fuel conductivity that can be tolerated with existing USAF aircraft without adversely affecting fuel tank quantity capacitance gages. The maximum level of conductivity may differ significantly for different aircraft. (Note: This has been completed for four aircraft; the F-15, F-16, A-7, and KC-135. Results indicated there is negligible effect on the quantity system at the maximum use limit of 700 pS/m. Data will be published in a technical report.)

*NOTE: As of 7 May 1979, Headquarters U.S. Air Force directed the use of a fuel conductivity additive in all JP-4 and JP-8. This directive was based upon the results of the service test and related research and development programs on electrostatic hazards in aicraft conducted under the auspices of the Air Force Ad Hoc Committee on Static Electricity. Specifications MIL-T-5624 for JP-4 and MIL-T-83133 for JP-8 were revised on 18 May 1979 to require the mandatory use of a fuel conductivity additive at a concentration sufficient to give a conductivity level between 200 and 600 pS/m. A target implementation date of mid-1980 was established.

4. Increased monitoring of ground fuel filter separators is recommended for three years after adoption of conductivity additives to insure there are no long term effects that were not discovered during the service test. On-site single element coalescence tests should be made at a representative number of bases to make this determination.

5. A survey of JP-4 and JP-8 serviced to USAF aircraft should be undertaken to determine the degree and extent of thermal oxidation stability degradation between the supplier and base.

APPENDIX A

TABLES OF FUEL TEMPERATURE AND CONDUCTIVITY MEASUREMENTS AT SERVICE TEST BASES

TABLE A-1 FUEL TEMPERATURE AND CONDUCTIVITY MEASUREMENTS FOR CARSWELL AFB

DATE	FUEL CONDUCTIVITY, PS/M					FUEL TEMPERATURE, CELSIUS				
WEEK-YEAR	AVG. AT RECEIPT	AVG. AT BASE STG.	MAX. AT REFUELERS	MIN. AT REFUELERS	AVG. AT REFUELERS	AVG. AT BASE STG	MIN. AT REFUELERS	AVG. AT REFUELERS	NUMBER OF RECEIPTS	ADDITIVE TYPE
25-7	193.0	190.0	270.0	60.0	177.0	28.3	24.4	31.1	45	U
26-7	127.0	104.0	200.0	90.0	136.0	29.4	26.9	31.1	99	U
27-7	187.0	168.0	240.0	110.0	161.0	30.0	28.9	31.7	129	U
28-7	125.0	140.0	230.0	80.0	145.0	26.9	28.3	31.1	55	U
29-7	168.0	181.0	240.0	80.0	153.0	31.7	28.3	28.3	21	U
30-7	347.0	204.0	380.0	100.0	191.0	29.4	26.7	31.1	14	U
31-7	367.0	338.0	420.0	160.0	251.0	31.1	27.8	30.5	12	U
32-7	310.0	228.0	360.0	160.0	258.0	30.6	21.1	28.3	14	U
33-7	288.0	258.0	340.0	120.0	248.0	28.9	25.6	29.4	13	U
34-7	291.0	270.0	350.0	100.0	276.0	30.0	24.4	28.3	14	U
35-7	296.0	278.0	320.0	80.0	189.0	27.8	24.4	27.2	21	U
36-7	423.0	184.0	320.0	50.0	214.0	27.2	25.6	27.2	18	U
37-7	288.0	261.0	320.0	120.0	223.0	26.7	24.4	26.7	20	U
38-7	205.0	213.0	400.0	100.0	225.0	26.1	22.2	27.8	21	U
39-7	387.0	264.0	400.0	150.0	270.0	23.9	23.3	28.3	15	U
40-7	176.0	184.0	265.0	130.0	211.0	22.2	20.0	22.8	12	U
41-7	215.0	203.0	250.0	100.0	188.0	20.0	20.0	24.4	11	U
42-7	194.0	189.0	240.0	120.0	188.0	23.3	21.7	24.4	17	U
43-7	184.0	199.0	300.0	95.0	236.0	21.7	20.0	24.4	15	U
44-7	191.0	176.0	330.0	160.0	244.0	19.4	15.6	22.2	25	U
45-7	301.0	276.0	390.0	200.0	289.0	19.4	16.0	16.7	18	U
46-7	243.0	235.0	460.0	150.0	275.0	21.7	18.3	22.2	21	U
47-7	193.0	254.0	340.0	130.0	233.0	20.0	17.8	20.5	15	U
48-7	225.0	257.0	310.0	165.0	230.0	17.2	13.0	15.6	11	U
49-7	221.0	273.0	320.0	110.0	203.0	13.4	11.1	18.3	19	U
50-7	276.0	268.0	390.0	90.0	210.0	18.3	7.8	16.9	18	A
51-7	186.0	248.0	285.0	120.0	202.0	17.8	8.9	16.7	19	A
52-7	216.0	254.0	240.0	105.0	161.0	15.0	10.0	13.9	8	A
1-8	253.0	268.0	390.0	50.0	209.0	16.1	10.0	16.7	9	A
2-8	215.0	242.0	310.0	100.0	195.0	13.3	5.6	12.8	12	A
3-8	188.0	231.0	320.0	120.0	238.0	12.2	4.4	12.8	11	A
4-8	210.0	213.0	270.0	125.0	189.0	12.8	3.3	12.2	10	A
5-8	239.0	177.0	230.0	130.0	178.0	12.2	5.6	12.8	15	A
6-8	298.0	254.0	340.0	170.0	222.0	7.2	8.9	11.1	16	A
7-8	243.0	228.0	500.0	90.0	211.0	11.7	8.9	10.6	14	A
8-8	244.0	196.0	380.0	100.0	209.0	11.1	6.7	12.2	14	A
9-8	292.0	258.0	440.0	140.0	271.0	11.7	10.0	15.0	12	A
10-8	279.0	287.0	440.0	90.0	267.0	12.8	10.0	15.6	21	A
11-8	311.0	347.0	400.0	150.0	327.0	15.0	11.1	17.2	15	A
12-8	265.0	312.0	500.0	140.0	332.0	19.4	14.4	22.2	12	A
13-8	230.0	218.0	500.0	80.0	163.0	17.8	12.2	18.9	11	A

TABLE A-2 FUEL TEMPERATURE AND CONDUCTIVITY MEASUREMENTS
DAVIS-MONTHAN AFB

DATE	FUEL CONDUCTIVITY, PS/M					FUEL TEMPERATURE, CELSIUS				
WEEK-YEAR	AVG. AT RECEIPT	AVG. AT BASE STG.	MAX. AT REFUELERS	MIN. AT REFUELERS	AVG. AT REFUELERS	AVG. AT BASE STG	MIN. AT REFUELERS	AVG. AT REFUELERS	NUMBER OF RECEIPTS	ADDITIVE TYPE
32-7		200.0	290.0	90.0	162.0	30.5	22.2	27.2	0	S
33-7	150.0	170.0	180.0	90.0	137.0	27.2	22.8	26.1	2	S
34-7		140.0	300.0	90.0	143.0	26.9	23.3	27.2	0	S
35-7	150.0	170.0	200.0	80.0	140.0	27.2	25.6	27.2	1	S
36-7		160.0	220.0	100.0	154.0	35.6	22.2	30.0	0	S
39-7		115.0	160.0	100.0	121.0	23.9	22.2	25.0	0	S
40-7	210.0	150.0	180.0	120.0	147.0	25.6	22.2	23.9	2	S
41-7		120.0	160.0	100.0	125.0	23.9	20.0	23.3	0	S
42-7	240.0	120.0	160.0	100.0	117.0	21.1	18.3	21.1	2	S
43-7	223.0	190.0	200.0	120.0	167.0	20.0	16.7	20.0	4	S
44-7		150.0	180.0	100.0	144.0	21.1	13.3	19.4	0	S
45-7	200.0		200.0	100.0	160.0		10.0	20.0	1	S
46-7	200.0		180.0	140.0	152.0		12.8	16.7	1	S
47-7			200.0	100.0	128.0		12.2	15.6	0	S
48-7		110.0	120.0	100.0	110.0	17.2	14.4	16.1	1	S
49-7	160.0	140.0	160.0	100.0	119.0	16.1	11.7	14.4	1	S
50-7	193.0	160.0	200.0	100.0	131.0	17.2	14.4	16.1	3	S
51-7	260.0	177.0	180.0	100.0	163.0	15.0	12.2	13.9	1	S
52-7		120.0	200.0	100.0	145.0	12.8	5.6	10.5	0	S
1-8		180.0	170.0	100.0	129.0	10.6	6.7	9.4	0	A
2-8	250.0		400.0	100.0	264.0		9.4	12.2	2	A
3-8	240.0	260.0	380.0	160.0	284.0	15.5	8.9	12.2	1	A
4-8	310.0	280.0	380.0	110.0	309.0	8.3	6.1	8.9	1	A
5-8		300.0	400.0	220.0	292.0	12.2	11.1	13.3	0	A
6-8	220.0	280.0	320.0	220.0	258.0	10.6	8.3	11.7	1	A
7-8		350.0	340.0	180.0	239.0	12.8	6.7	10.0	0	A
8-8	315.0		500.0	200.0	283.0		8.9	15.6	2	A
9-8	310.0	310.0	410.0	220.0	316.0	14.4	14.4	16.1	2	A
10-8		320.0	410.0	120.0	264.0	17.8	12.2	15.5	0	A
11-8	170.0	340.0	440.0	230.0	282.0	22.2	10.0	14.4	1	A
12-8		280.0	480.0	260.0	315.0	17.3	17.8	20.5	0	A
13-8	420.0		440.0	120.0	303.0		15.0	19.4	1	A

TABLE A-3 FUEL TEMPERATURE AND CONDUCTIVITY MEASUREMENTS
FOR GRIFFISS AFB

DATE	FUEL CONDUCTIVITY, PS/M					FUEL TEMPERATURE, CELSIUS				
WEEK-YEAR	AVG. AT RECEIPT	AVG. AT BASE STG.	MAX. AT REFUELERS	MIN. AT REFUELERS	AVG. AT REFUELERS	AVG. AT BASE STG	MIN. AT REFUELERS	AVG. AT REFUELERS	NUMBER OF RECEIPTS	ADDITIVE TYPE
20-7	270.0	170.0	220.0	20.0	162.0	16.7	11.7	17.2	6	S
21-7	290.0	199.0	240.0	150.0	185.0	17.2	18.9	22.2	3	S
22-7	280.0	192.0	200.0	60.0	178.0	15.[illegible]	17.8	19.4	2	S
23-7	300.0	225.0	220.0	140.0	194.0	16.1	12.2	14.4	4	S
24-7	315.0	284.0	320.0	130.0	255.0	18.3	16.7	20.0	4	S
25-7	305.0	297.0	340.0	220.0	266.0	18.3	14.4	18.9	4	S
26-7	327.0	292.0	410.0	240.0	266.0	19.4	18.9	20.0	3	S
28-7	324.0	301.0	360.0	180.0	273.0	24.4	21.1	25.0	5	S
29-7	330.0	340.0	360.0	80.0	269.0	27.2	22.2	26.7	4	S
30-7	327.0	297.0	360.0	160.0	275.0	23.3	13.3	20.0	3	S
31-7	345.0	328.0	380.0	100.0	287.0	25.0	17.8	25.5	4	S
32-7	250.0	288.0	380.0	260.0	313.0	25.0	20.0	24.4	4	S
33-7	280.0	275.0	380.0	80.0	259.0	22.8	15.6	20.0	2	S
34-7	287.0	288.0	320.0	95.0	235.0	21.7	16.7	18.9	3	S
35-7	240.0	336.0	390.0	160.0	321.0	27.8	22.2	27.2	2	S
36-7	220.0	280.0	340.0	120.0	252.0	23.9	16.7	20.0	2	S
37-7	293.0	249.0	340.0	140.0	242.0	20.6	15.6	19.4	3	S
38-7	356.0	342.0	360.0	200.0	268.0	20.0	11.1	15.5	5	S
39-7	207.0	360.0	360.0	240.0	330.0	20.[illegible]	14.4	16.1	3	S
40-7	260.0		300.0	220.0	264.0		6.7	10.5	3	S
41-7	235.0	244.0				15.0			4	S
42-7	250.0	222.0	280.0	120.0	188.0	14.4	3.3	10.5	4	S
43-7	165.0	250.0	400.0	180.0	260.0	18.9	16.7	19.4	4	S
44-7	210.0	225.0	260.0	180.0	229.0	18.3	11.1	17.2	2	S
45-7	200.0	224.0	220.0	160.0	200.0	16.7	10.0	13.9	3	S
46-7	185.0	211.0	260.0	120.0	193.0	15.0	1.1	11.1	4	S
47-7	200.0	200.0	220.0	100.0	157.0	14.4	3.3	5.5	3	S
49-7	160.0	349.0	440.0	180.0	228.0	8.9	-2.2	3.9	2	U
50-7	192.0	308.0	300.0	180.0	261.0	7.8	1.1	7.5	5	A
51-7	215.0	260.0	280.0	110.0	224.0	11.1	3.3	6.7	4	A
52-7	140.0	235.0	260.0	140.0	189.0	11.1	-13.3	-3.9	2	A
1-8	170.0	253.0	260.0	160.0	191.0	12.8	-8.9	0.0	2	A
2-8	207.0	211.0	290.0	120.0	181.0	5.[illegible]	-2.2	2.2	3	A
3-8	247.0	226.0	180.0	160.0	166.0	9.4	-7.8	-1.7	3	A
4-8	255.0	224.0	200.0	140.0	165.0	11.7	-13.3	-1.7	4	A
5-8	164.0	236.0	260.0	120.0	163.0	8.9	-13.9	-4.4	5	A
6-8	195.0	222.0	260.0	160.0	208.0	10.6	-4.4	1.7	4	A
7-8	185.0	205.0	380.0	160.0	197.0	8.9	-13.9	-2.8	4	A
8-8	267.0	205.0	260.0	140.0	172.0	9.4	-16.7	0.0	3	A
9-8	180.0	218.0	300.0	140.0	187.0	11.1	-9.4	-1.1	3	A
10-8	320.0	204.0	340.0	120.0	180.0	6.9	-12.2	3.9	3	A
11-8	136.0	212.0	360.0	140.0	175.0	11.1	1.1	7.8	4	A
12-8	175.0	216.0	240.0	140.0	164.0	13.9	1.7	5.0	4	A
13-8	210.0	187.0	240.0	120.0	153.0	12.2	2.2	5.0	4	A

TABLE A-4 FUEL TEMPERATURE AND CONDUCTIVITY MEASUREMENTS
FOR MCCHORD AFB

DATE	FUEL CONDUCTIVITY, PS/M					FUEL TEMPERATURE, CELSIUS				
WEEK-YEAR	AVG. AT RECEIPT	AVG. AT BASE STG.	MAX. AT REFUELERS	MIN. AT REFUELERS	AVG. AT REFUELERS	AVG. AT BASE STG	MIN. AT REFUELERS	AVG. AT REFUELERS	NUMBER OF RECEIPTS	ADDITIVE TYPE
32-7		198.0	330.0	240.0	299.0	21.1	22.2	22.2	0	S
33-7	185.0	207.0	280.0	150.0	195.0	20.0	18.9	20.0	2	S
34-7	180.0	158.0	250.0	124.0	161.0	18.3	17.2	18.3	1	S
35-7	210.0	174.0	195.0	110.0	158.0	20.0	13.9	18.3	1	S
36-7		167.0	210.0	190.0	200.0	17.2	16.1	18.3	0	S
37-7	158.0	246.0	250.0	190.0	210.0	20.0	12.8	16.7	2	S
38-7	150.0	160.0	290.0	130.0	153.0	17.8	13.3	17.2	1	S
39-7	130.0	156.0	190.0	100.0	124.0	15.6	12.2	14.4	1	S
40-7		170.0	210.0	190.0	165.0	15.0	12.2	15.0	0	S
41-7		193.0	205.0	140.0	187.0	15.6	12.2	15.0	0	S
42-7		105.0	195.0	110.0	165.0	12.5	10.0	11.7	0	S
43-7		193.0	200.0	145.0	175.0	12.8	10.0	12.2	0	S
44-7		151.0	200.0	100.0	175.0	11.7	9.4	10.6	0	S
45-7	140.0	195.0	200.0	130.0	170.0	10.[illegible]	8.9	11.1	1	S
46-7		135.0	190.0	110.0	145.0	12.2	8.9	10.0	0	S
47-7	170.0	128.0	200.0	100.0	144.0	8.3	0.0	7.2	1	S
48-7		141.0	160.0	110.0	145.0	11.1	9.4	10.0	0	S
49-7		95.0	130.0	90.0	107.0	11.1	3.9	10.6	0	S
50-7	180.0	137.0	150.0	100.0	122.0	11.7	8.9	11.1	1	S
51-7			170.0	95.0	129.0		4.0	9.0	0	S
52-7	100.0	102.0	185.0	80.0	110.0	6.1	0.0	5.6	1	S
1-8		120.0	115.0	80.0	101.0	9.4	2.2	7.2	0	A
2-8		180.0	255.0	100.0	152.0	11.7	7.8	10.6	0	A
3-8			290.0	100.0	216.0		7.8	10.6	0	A
4-8			325.0	200.0	282.0		-1.1	4.4	0	A
5-8			305.0	130.0	199.0		3.9	8.3	0	A
6-8			350.0	110.0	234.0		3.9	10.6	0	A
7-8			220.0	140.0	181.0		8.9	9.4	0	A
8-8		190.0	260.0	160.0	184.0	8.9	5.6	8.9	0	A
9-8		190.0	250.0	110.0	149.0	6.7	3.9	7.8	0	A
10-8		200.0	280.0	120.0	160.0	11.1	7.8	10.6	0	A
11-8		180.0	180.0	100.0	119.0	10.0	6.7	8.3	0	A
12-8		240.0	300.0	105.0	166.0	13.9	10.0	13.3	0	A
13-8		190.0	290.0	110.0	174.0	12.2	12.2	13.9	0	A

TABLE A-5 FUEL TEMPERATURE AND CONDUCTIVITY MEASUREMENTS
FOR MYRTLE BEACH AFB

DATE	FUEL CONDUCTIVITY, PS/M					FUEL TEMPERATURE, CELSIUS				
WEEK-YEAR	AVG. AT RECEIPT	AVG. AT BASE STG.	MAX. AT REFUELERS	MIN. AT REFUELERS	AVG. AT REFUELERS	AVG. AT BASE STG	MIN. AT REFUELERS	AVG. AT REFUELERS	NUMBER OF RECEIPTS	ADDITIVE TYPE
25-7	557.0	542.0	480.0	260.0	295.0	26.1	24.4	25.6	2	A
26-7	260.0	722.0	460.0	190.0	335.0	27.2	26.1	28.3	1	A
27-7	250.0	615.0	600.0	220.0	365.0	27.2	26.7	28.3	1	A
28-7	380.0	500.0	300.0	190.0	230.0	29.4	29.4	30.0	1	A
29-7	110.0	660.0	240.0	100.0	195.0	29.4	27.2	28.3	2	A
30-7	360.0	555.0	720.0	160.0	270.0	28.3	23.3	25.6	1	A
31-7	160.0	495.0	480.0	160.0	364.0	26.1	26.1	27.8	1	A
32-7	160.0	525.0	480.0	130.0	185.0	27.3	29.4	30.0	1	A
33-7		530.0	240.0	160.0	200.0	27.3	27.2	27.8	0	A
34-7	20.0	465.0	340.0	100.0	215.0	27.3	26.7	27.8	2	A
35-7	31.0	770.0	180.0	100.0	165.0	28.3	26.7	27.8	3	A
36-7	[illegible]	640.0	240.0	100.0	165.0	27.2	26.7	27.2	1	A
37-7	60.0	570.0	110.0	80.0	94.0	27.2	23.9	26.1	2	A
38-7	125.0	610.0	280.0	160.0	205.0	27.3	27.2	27.2	2	A
39-7	100.0	580.0	220.0	160.0	190.0	27.2	23.9	26.7	1	A
40-7	36.0	420.0	160.0	120.0	155.0	22.3	16.1	17.8	4	A
41-7	360.0	260.0	160.0	110.0	145.0	22.2	12.8	18.3	1	A
42-7	290.0	210.0	160.0	90.0	120.0	17.3	12.2	15.0	1	A
43-7	240.0	230.0	180.0	110.0	155.0	20.0	18.3	20.0	1	A
44-7	160.0	280.0	440.0	160.0	303.0	17.2	16.7	20.5	1	A
45-7	280.0	380.0	380.0	180.0	272.0	22.2	18.9	20.5	2	A
46-7	150.0	270.0	200.0	120.0	136.0	15.0	11.1	15.0	2	A
47-7	480.0	250.0	140.0	110.0	129.0	21.1	15.6	18.3	2	A
48-7	200.0	233.0	180.0	120.0	152.0	17.2	15.6	16.1	1	A
49-7	400.0	210.0	180.0	120.0	144.0	16.7	11.1	12.2	1	A
50-7	90.0	240.0	320.0	160.0	240.0	11.7	6.1	9.4	2	A
51-7	1000.0	440.0	440.0	210.0	384.0	16.7	6.7	7.8	2	A
52-7	300.0	385.0	320.0	200.0	249.0	10.0	1.7	2.8	1	A
1-8	280.0	580.0	340.0	300.0	314.0	6.1	3.9	5.0	1	A
2-8	280.0	510.0	300.0	210.0	274.0	4.4	4.4	6.1	2	A
3-8	230.0	350.0	300.0	260.0	280.0	14.4	6.1	10.6	2	A
4-8	300.0	360.0	380.0	280.0	331.0	13.3	7.2	11.7	1	A
5-8	55.0	390.0	240.0	180.0	218.0	7.2	2.8	3.9	2	A
6-8	320.0	410.0	380.0	200.0	284.0	11.7	1.7	4.4	1	A
7-8	320.0	407.0	360.0	300.0	320.0	15.5	7.2	9.4	1	A
8-8	315.0	380.0	500.0	240.0	325.0	15.5	2.8	7.8	2	A
9-8	330.0	360.0	999.0	240.0	363.0	9.4	6.1	8.9	2	A
10-8	410.0	390.0	380.0	320.0	342.0	12.2	10.0	11.1	2	A
11-8	999.0	990.0	999.0	620.0	951.0	17.2	13.9	17.8	2	A
12-8	210.0	793.0	999.0	680.0	986.0	17.8	16.7	17.2	1	A
13-8	260.0	690.0	999.0	320.0	755.0	17.8	16.7	16.7	1	A

TABLE A-6 FUEL TEMPERATURE AND CONDUCTIVITY MEASUREMENTS FOR NELLIS AFB

DATE	FUEL CONDUCTIVITY, PS/M					FUEL TEMPERATURE, CELSIUS				
WEEK-YEAR	AVG. AT RECEIPT	AVG. AT BASE STG.	MAX. AT REFUELERS	MIN. AT REFUELERS	AVG. AT REFUELERS	AVG. AT BASE STG	MIN. AT REFUELERS	AVG. AT REFUELERS	NUMBER OF RECEIPTS	ADDITIVE • TYPE
31-7	273.0	239.0	300.0	180.0	228.0				6	A
32-7	208.0	144.0	220.0	100.0	160.0				6	A
33-7	290.0	243.0	385.0	220.0	250.0				5	A
34-7	358.0	380.0	390.0	320.0	361.0	29.4		28.9	8	A
35-7	271.0	201.0	340.0	200.0	284.0	30.0		29.4	5	A
36-7	270.0	267.0	320.0	220.0	274.0	28.3	31.7	32.2	3	A
37-7	244.0	264.0	260.0	220.0	233.0	28.3	23.9	26.1	5	A
38-7	219.0	220.0	260.0	180.0	225.0	25.0	21.1	24.4	7	A
39-7	217.0	198.0	260.0	160.0	207.0	25.6	21.7	24.4	5	A
40-7	192.0	201.0	260.0	200.0	222.0	24.4	22.2	25.0	5	A
41-7	211.0	206.0	210.0	180.0	197.0	23.9	18.9	21.1	4	A
42-7	244.0	222.0	260.0	210.0	234.0	23.9	21.1	22.8	4	A
43-7	215.0	224.0	240.0	180.0	210.0	21.7	16.7	18.9	4	A
44-7	227.0	215.0	220.0	120.0	198.0	21.1	14.4	16.1	5	A
45-7	226.0	218.0	240.0	170.0	206.0	18.3	11.1	15.6	5	A
46-7	220.0	238.0	260.0	190.0	222.0	16.9	13.3	15.0	5	A
47-7	204.0	208.0	230.0	180.0	211.0	13.9	8.3	10.5	4	A
48-7	215.0	214.0	240.0	180.0	211.0	18.3	11.7	13.3	4	A
49-7	205.0	200.0	220.0	160.0	199.0	15.0	7.2	12.8	5	A
50-7	183.0	195.0	210.0	190.0	198.0	15.0	7.8	9.4	5	A
51-7	195.0	195.0	210.0	180.0	196.0	12.8	8.9	10.0	4	A
52-7	200.0	195.0	220.0	170.0	187.0	12.2	10.0	11.1	2	A
1-8	196.0	177.0	340.0	140.0	199.0	9.4	6.7	8.3	3	A
2-8	190.0	178.0	200.0	110.0	176.0	11.7	6.7	9.4	5	A
3-8	207.0	202.0	190.0	160.0	184.0	12.8	8.3	10.5	5	A
4-8	215.0	218.0	240.0	110.0	198.0	11.1	5.0	7.2	4	A
6-8	246.0	248.0	200.0	120.0	165.0	15.6	10.0	11.1	5	A
7-8	259.0	206.0	200.0	130.0	161.0	13.3	4.4	8.3	4	A
8-8	232.0	230.0	220.0	110.0	153.0	13.3	8.9	11.7	3	A
9-8	253.0	232.0	280.0	140.0	190.0	13.3	11.1	13.3	4	A
10-8	318.0	296.0	290.0	120.0	156.0	16.9	11.1	12.8	6	A
11-8	300.0	275.0	170.0	140.0	150.0	21.1	11.1	11.7	4	A
13-8	363.0	294.0	200.0	140.0	171.0	20.6	10.0	16.7	5	A

TABLE A-7 FUEL TEMPERATURE AND CONDUCTIVITY MEASUREMENTS FOR TRAVIS AFB

DATE	FUEL CONDUCTIVITY, PS/M					FUEL TEMPERATURE, CELSIUS				
WEEK-YEAR	AVG. AT RECEIPT	AVG. AT BASE STG.	MAX. AT REFUELERS	MIN. AT REFUELERS	AVG. AT REFUELERS	AVG. AT BASE STG	MIN. AT REFUELERS	AVG. AT REFUELERS	NUMBER OF RECEIPTS	ADDITIVE TYPE
30-7	265.0	186.0	160.0	130.0	140.0	20.5	20.0	20.5	6	A
32-7	260.0	159.0	185.0	140.0	167.0	21.7	20.0	21.7	6	A
33-7	246.0	178.0	180.0	105.0	143.0	20.6	20.0	20.0	8	A
34-7	211.0	180.0	160.0	150.0	156.0	16.9	20.0	20.0	3	A
35-7	230.0	167.0	165.0	150.0	161.0		20.0	20.5	3	A
36-7	295.0	174.0	180.0	170.0	178.0		20.0	21.1	2	A
37-7	250.0	223.0	195.0	150.0	168.0		20.0	20.5	3	A
38-7	240.0	188.0	180.0	160.0	173.0		20.0	20.6	4	A
39-7	320.0	206.0	200.0	170.0	186.0		20.0	20.6	4	A
40-7	490.0	222.0	200.0	180.0	186.0		20.0	20.6	1	A
41-7	390.0	217.0	210.0	190.0	198.0		20.0	21.1	4	A
42-7	410.0	235.0	200.0	180.0	194.0		18.3	19.4	3	A
43-7	405.0	316.0	300.0	250.0	291.0		18.9	20.0	4	A
44-7	395.0	284.0	250.0	230.0	234.0		18.3	18.9	2	A
45-7	326.0	[illegible]	200.0	180.0	195.0		18.3	18.9	3	A
46-7	323.0	262.0	210.0	190.0	202.0		17.6	18.9	4	A
47-7	297.0	269.0	210.0	180.0	197.0		16.7	17.8	3	A
48-7	303.0	273.0	220.0	200.0	207.0		16.7	17.5	3	A
49-7	280.0	222.0	210.0	190.0	200.0				3	A
50-7	272.0	247.0	230.0	180.0	205.0				4	A
51-7	267.0	244.0	230.0	180.0	202.0				3	A
52-7	285.0	250.0	240.0	155.0	209.0				2	A
1-8	265.0	246.0	280.0	240.0	258.0				2	A
2-8	232.0	227.0	230.0	190.0	212.0				4	A
3-8	217.0	181.0	290.0	180.0	215.0				3	A
4-8	213.0	216.0	230.0	190.0	199.0				3	A
5-8	247.0	219.0	210.0	180.0	202.0				4	A
6-8	235.0	223.0	200.0	160.0	176.0				2	A
7-8	283.0	234.0	210.0	170.0	189.0				3	A
8-8	315.0	231.0	200.0	170.0	188.0				2	A
9-8	293.0	256.0	220.0	200.0	211.0				3	A
10-8	327.0	302.0	310.0	250.0	280.0				3	A
11-8	307.0	297.0	320.0	260.0	285.0				3	A
12-8	333.0	279.0	300.0	225.0	274.0				3	A
13-8	273.0	299.0	280.0	240.0	261.0				3	A

TABLE A-8 FUEL TEMPERATURE AND CONDUCTIVITY MEASUREMENTS FOR MT. HOME AFB

TIME	FUEL CONDUCTIVITY (pS/M)				FUEL TEMPERATURE (Celsius)				Number	Type	Additive
Week/Yr	Ave. at Receipt	Ave. at Base Stg	Ave. at Refueler	Min. at Refueler	Ave. at Receipt	Ave. at Base Stg	Ave. at Refueler	Min. at Refueler	of Receipts	Additive Used	Concenc. (ppm)
43-77		177	260	120	17	20	21	14	1	A	1
44-77	145	163	110	40	18	18	16	11	2	A	1
45-77	130	191	178	60	15	17	12	1	5	A	1
46-77	130	263	156	100	14	15	11	3	2	A	1.5
47-77	-	340	195	110	-	9	6	-6	0	A	1.5
48-77	-	300	281	200	-	13	10	6	0	A	1.5
49-77	240	260	216	100	18	10	9	7	1	A	1.5
50-77	220	160	200	100	8	10	9	5	1	A	1.5
51-77	220	300	131	80	7	9	3	-2	1	A	1.5
52-77	-	260	155	90	-	7	2	-1	0	A	1.5
1-78	-	-	177	90	-	-	2	-2	0	A	1.5
2-78	-	-	221	120	-	-	6	4	0	A	1.5
3-78	360	180	202	100	7	6	6	4	1	A	1.5
6-78	280	-	254	160	11	-	8	6	1	A	1.5
7-78	310	-	252	180	6	-	4	-1	1	A	1.5
8-78	230	220	255	150	13	7	4	1	1	A	1.5
9-78			269	220	-	-	8	6	0	A	1.5
10-78	290	240	231	140	8	8	8	6	1	A	1.5
12-78	100	330	258	180	15	8	14	5	1	A	1.5
13-78	185	240	297	240	22	11	16	13	2	A	1.5

APPENDIX B

FUEL PROPERTY DATA AT SERVICE TEST BASES

TABLE B-1 FUEL PROPERTY MEASUREMENTS AT CARSWELL AFB

DATE	REFINERY & ADDITIVE	BEFORE ADDITIVE INJECTION			AFTER ADDITIVE INJECTION			AVE COND. AT RECEIPT
		JFTOT		WSIM	JFTOT		WSIM	
		CODE	PRES.	RATING	CODE	PRES.	RATING	
JUL 77 - AUG 77	Winston/ASA-3 @ 0.4 ppm	1	0	75, n = 12	1	0	50, n = 12	270
	Winston/S-450 @ 1.6 ppm	1	0	75, n = 12	1	0	48, n = 12	210
	Longview/ASA-3 @ 0.5 ppm	1	0	92, n = 7	1	0	73, n = 7	N/A
SEP 77	Winston/S-450 @ 1.6 ppm	1	0	81, n = 6	1	0	54, n = 6	203
	Longview/ASA-3 @ 0.26 ppm	-	-	92, n = 4	-	-	76, n = 4	332
	Pride/ASA-3 @ 0.5 ppm	1	0	92, n = 7	1	0	78, n = 7	408
OCT 77	Winston/S-450 @ 1.6 ppm	1	0	85, n = 11	-	-	46, n = 3	188
	Pride/ASA-3 @ 0.5 ppm	1	0.5	86, n = 4	-	-	58, n = 2	178
	Longview/ASA-3 @ 0.3 ppm	1	0	94, n = 4	-	-	76, n = 4	210
NOV 77	Winston/S-450 @ 1.6 ppm	-	-	77	-	-	48	209
	Pride/ASA-3 @ 0.5 to 0.75 ppm	-	-	81	-	-	71	183
	Longview/ASA-3 @ 0.5 ppm	-	-	90	-	-	75	336
DEC 77 - Jan 78	Winston/S450 @ 1.6 ppm through 5 DEC, ASA-3 @ 0.4 ppm thereafter.	-	-	77	-	-	48	216
	Pride/ASA-3 @ 0.75 ppm	-	-	88	-	-	60	196
	Longview/ASA-3 @ 0.4 ppm	-	-	-	-	-	-	241
FEB 78 - MAR 78	Winston/ASA-3 @ 0.4 ppm	-	-	81	-	-	47	241
	Pride/ASA-3 @ 0.75 ppm	-	-	94	-	-	76	212
	Longview/ASA-3 @ 0.4 ppm	-	-	88	-	-	-	351

n = Number of Tests Averaged Together

TABLE B-2 FUEL PROPERTY MEASUREMENTS AT DAVIS-MONTHAN AFB

DATE	ADDITIVE TYPE AND CONCENT.	FUEL WITHOUT CONDUCTIVITY ADDITIVE		FUEL WITH CONDUCTIVITY ADDITIVE			
		JFTOT	WSIM	JFTOT	WSIM	MSS	MICROSEP
AUG 77	1.2 ppm S-450	Fail	94	Fail	84		
SEP 77	1.5 ppm S-450		90		76		
OCT 77	1.5 ppm S-450		89(n = 2)*		75(n = 3)*		
NOV 77	1.8 ppm S-450	Pass	88	Pass	74 82**	94**	85**
DEC 77 JAN 78	1.8 ppm S-450 1.0 to 1.2 ppm ASA-3		88		74 46**	76**	71**
FEB-MAR 78	0.6 to 1.0 ppm ASA-3		82(n = 2)*		60**	87**	

* n = Number of Runs Averaged Together.

** Correlation Sample Run by Quality Control Laboratory.

TABLE B-3 FUEL PROPERTY MEASUREMENTS AT GRIFFISS AFB

DATE	ADDITIVE TYPE CONC.	FUEL PROPERTIES BEFORE ADDITIVE INJECTION					FUEL PROPERTIES AFTER ADDITIVE INJECTION				
		JFTOT			MINISONIC	MICRO	JFTOT			MINISONIC	MICRO
		CODE	Pres	WSIM	SEPAROM.	SEPAROM.	CODE	Pres	WSIM	SEPAROM.	SEPAROM.
MAY - AUG	S-450/1.0 ppm	4	1mm	-	90	84	4	1mm	-	87	65
SEP	S-450 @ 1.0 ppm	4A	-	79			4A	-		68	61
OCT	S-450 @ 1.0 ppm	-	-	68, 62			4	-	73, 58	88, 69	59,49
NOV	S-450 @ 1.0 ppm			89			0	0	81	87	22
DEC - JAN	(1)								70	78	35
FEB - MAY	ASA-3 @ 1.0 ppm								52	68	

(1) S-450 at 1.0 ppm was used until 30 NOV 77; thereafter ASA-3 at 1.0 ppm was used. The WSIM, Minisonic SEparometer, and Micro Separometer values were not identified as to which additive was in use.

TABLE B-4 FUEL PROPERTY MEASUREMENTS AT MCCHORD AFB

DATE	ADDITIVE TYPE AND AMOUNT	FUEL PROPERTIES WITHOUT ADDITIVE				FUEL PROPERTIES WITH ADDITIVE			
		JFTOT	WSIM	MSS	MICROSEP	JFTOT	WSIM	MSS	MICROSEP
JUL - AUG 77	S-450 @ 1.5 ppm	Pass					61 Ave		
SEP 77	S-450 @ 1.5 ppm	Code 1 2 mm	72, 89			Code 1 1 mm	45		
OCT 77	S-450 @ 1.5 ppm					Pass	51*	89*	91*
NOV 77	S-450 @ 1.5 ppm		83				77, 72		
DEC 77	S-450 @ 1.5 ppm						50*	99*	98*
JAN 78	S-450 @ 1.5 ppm until 13 Jan 78. ASA-3 @ 1.0 ppm thereafter.								
FEB - MAR 78	ASA-3 @ 1.0 ppm						57*	94*	

* Correlation Samples Run by Quality Control Laboratory.

TABLE B-5 FUEL PROPERTY MEASUREMENTS AT MYRTLE BEACH AFB

DATE	ADDITIVE TYPE AND CONCENTRATION	FUEL WITHOUT CONDUCTIVITY ADDITIVE				FUEL WITH CONDUCTIVITY ADDITIVE			
		JFTOT	WSIM	MSS	MICROSEP	JFTOT	WSIM	MSS	MICROSEP
JUN 77	ASA-3	Fail*	93	95	94	Fail*		66	57
OCT 77	ASA-3 @ 0.9 ppm					Fail	52		
NOV 77	ASA-3 @ 0.7 ppm					Fail	64	76	54
DEC 77 - JAN 78	ASA-3 @ 0.6 ppm						58	49	74
FEB - MAR 78	ASA-3 @ 0.6 ppm					Fail**	41	64	

* Fuel failed JFTOT on both tube deposits and pressure drop at 260°C but passed when retested at 243°C.

** Fuel also failed the test for fuel system icing inhibitor content and for total solids.

TABLE B-6 FUEL PROPERTY MEASUREMENTS AT NELLIS AFB

DATE	ADDITIVE TYPE AND CONCENTRATION	FUEL PROPERTIES WITHOUT ADDITIVE		FUEL PROPERTIES WITH ADDITIVE			
		JFTOT	WSIM	JFTOT	WSIM	MSS	MICROSEP
AUG 77	1.5 ppm S-450		70		52		
SEP 77	1.5 ppm S-450		78(N = 8)*	Pass	64 (n = 8)*	92	90
OCT 77	1.25 ppm S-450				78 (n = 4)*		
NOV 77	1.5 ppm S-450		77.5(n = 7)*		53**	60**	64**
DEC 77 JAN 78	1.5 ppm S-450 1.0 ppm ASA-3 after 16 JAN 78						
FEB 78	1.0 ppm ASA-3		88		70**	95**	

* Averaged results with n being the number of data points averaged.

** Correlation samples run by an independent Quality Control Laboratory.

TABLE B-7 FUEL PROPERTY MEASUREMENTS AT TRAVIS AFB

DATE	ADDITIVE TYPE AND CONCENTRATION	FUEL QUALITY BEFORE ADDITIVE INJECTION				FUEL QUALITY AFTER ADDITIVE INJECTION			
		JFTOT	WSIM	MSS	MICROSEP	JFTOT	WSIM	MSS	MICROSEP
AUG 77	ASA-3, 0.4 ppm	Code 1 0.5 mm n = 4	89 n = 7	NR	NR	Code 1 0 mm n = 4	85 n = 7	NR	NR
SEP 77	ASA-3, 0.4 ppm	Pass	87	NR	NR	Pass	80	NR	NR
OCT 77	ASA-3, 0.5 ppm	Pass	89 n = 4	NR	NR	Fail	81 n = 4	NR	NR
							67*	92*	96*
NOV 77	ASA-3, 0.6 ppm	Pass	89 n = 5	NR	NR	Pass	82 n = 5	NR	NR
							77*	98*	84*
DEC 77 JAN 78	ASA-3, 0.6 to 0.7 ppm	NR	87.5 n = 4	NR	NR	NR	76.5 n = 4	NR	NR
							66*	93*	94*
FEB 78 MAR 78	ASA-3, 0.6 to 0.7 ppm	NR	82 n = 3	NR	NR	NR	75 n = 3	NR	NR
							50*	90*	

n - number of tests averaged together
* - base correlation samples
NR - not run

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