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Evaluation of Impacts of JP-8+100 on Army Aviation and Ground Vehicles: Phase I Impact Study

INTERIM REPORT
TFLRF No. 353

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As the Army has converted to the "Single Fuel on the Battlefield Doctrine" and extensively uses JP-8 in all diesel-powered ground material systems, there are concerns about the acceptability of JP-8+100 for Army systems as the Air Force uses JP-8+100 in the future. the potential effects of JP-8+100 fuel on Army ground and aviation equipment were investigated to determine the scope of any expected problems and possible benefits from its use.

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As the Army has converted to the "Single Fuel on the Battlefield Doctrine" and extensively uses JP-8 in all diesel-powered ground material systems, there are concerns about the acceptability of JP-8+100 for Army systems as the Air Force uses JP-8+100 in the future.

The potential effects of JP-8+100 fuel on Army ground and aviation equipment were investigated to determine the scope of any expected problems and possible benefits from its use.

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The work was funded and administered by the U.S. Army Tank-Automotive RD&E Center, Petroleum and Water Business Area, Warren, Michigan. Mr. Luis Villahermosa (AMSTA TR-D/210) served as the TARDEC contracting officer's representative and project technical monitor.

EXECUTIVE SUMMARY

Problem: As the Army has converted to the "Single Fuel on the Battlefield" doctrine and extensively uses JP-8 in all diesel-powered ground material systems, there are concerns about the acceptability of JP-8+100 for Army systems as the Air Force uses JP-8+100 in the future.

Objective: The objective was to investigate the potential effects of JP-8+100 fuel on Army ground and aviation equipment and to determine the scope of any expected problems and possible benefits from its use.

Importance of Project: The potential effects of JP-8+100 fuel on Army ground and aviation equipment could have a major impact on operations and readiness.

Technical Approach: The Army JP-8+100 Evaluation Program involves a two-phase effort. Phase 1 consists of the impact study; phase 2 consists of acceptance testing.

Under Phase 1, the following four tasks were defined and initiated:

Task 1 – Identify scenarios where the Army may be exposed to JP-8+100.
Task 2 – Investigate/confirm elastomer and seal compatibility.
Task 3 – Determine preliminary cost-benefit analysis for Army use of JP-8+100.
Task 4 – Determine short-term impact for selected Army aviation and ground vehicles and equipment.

Accomplishments: Based on the results of this project, it is recommended that the Army maintain its "no-use" policy for JP-8+100. Although JP-8+100 is not detrimental to the performance, reliability, and safety of Army aircraft, there is no firewall to guard against contamination of Army ground equipment. Furthermore, there currently is no reliable field test to detect and quantify the presence of the +100 additive package.

If an accidental refueling occurs, it should be documented and the Army Petroleum Center contacted immediately for guidance.

It is suggested that aircraft that are accidentally refueled be allowed to operate without restrictions in order to burn off the fuel in flight, thus avoiding issues of defueling. The aircraft should be considered free of JP-8+100 after three refuelings with JP-8. If defueling is necessary, it should be either into another aircraft or the fuel should be treated as hazardous waste.

It is suggested that if ground equipment is exposed to JP-8+100, it should be defueled immediately and the filter/coalescer be replaced. The fuel should be disposed as hazardous waste.

Army Special Forces were briefed on the risk of exposure to JP-8+100 when operating with the Air Force, and guidance was provided to how to minimize risk to a mission.

A field demonstration of the effects of JP-8+100 on aviation equipment is recommended.

Military Impact: The use of JP-8+100 may be detrimental to ground equipment, and may have potential benefits for aviation equipment.

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I. INTRODUCTION AND BACKGROUND

As the U. S. Army has converted to the “Single Fuel on the Battlefield” doctrine and extensively uses JP-8 in all diesel-powered ground material systems, there are concerns about the acceptability of JP-8+100 for Army systems as the Air Force uses JP-8+100 in the future.

The Air Force has been developing new JP-8 formulations to improve thermal stability to allow higher fuel operating temperatures for advanced fighter aircraft. The first additive package developed from this program, the *+100 additive*, increases thermal stability of JP-8 by 100°F and heat capacity by 50%, and consists of 25 ppm antioxidant, 70 ppm dispersant/detergent, 3 ppm metal deactivator, and 158 ppm solvent oil (Figure 1). Air Force results have shown that it cleans internal engine parts, which can result in reduction in the frequency of engine maintenance and has potential cost savings for some engine types (Figure 2). Because the dispersant/detergent component permanently disables water separators in fueling systems, the Air Force and the Navy are jointly working on developing a "drop in" replacement for filter/separators (F/S), which would be necessary to introduce JP-8+100 into current fuel distribution/hydrant systems.

The use of JP-8+100 is currently limited to fighter, training, and other aircraft fueled by R9 and R11 refueler trucks modified with Velcon Aquacon cartridges that replace the existing F/S. The conversion of all fighter and trainer aircraft was to be completed by the end of FY 1999. However, no Air Force decision has yet been made concerning the expansion of JP-8+100 to larger aircraft, although testing of C-130s and C-141s has been underway. While JP-8’s military specification MIL-DTL-83133E includes provision for the *+100 additive*, the current Air Force policy is to inject the *+100 additive* into the fuel just prior to refueler trucks at participating locations (Figure 3). Extensive testing continues at many locations in the United States and one in the United Kingdom, with over 2,022 fighter, training and cargo aircraft and helicopters successfully using the new JP-8+100 as shown in Figure 4.

What is JP-8+100 ?

- 25 ppm Antioxidant
  - Inhibits Gum Formation
- 70 ppm Dispersant/Detergent
  - Minimizes Particle Size
  - Cleans Engine Components
- 3 ppm Metal Deactivator
  - Minimizes Impact of Trace Metals
- 158 ppm Solvent
  - Improves Handling Low Temperature Characteristics

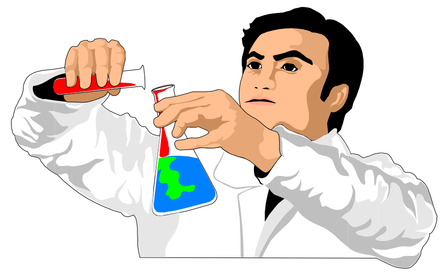
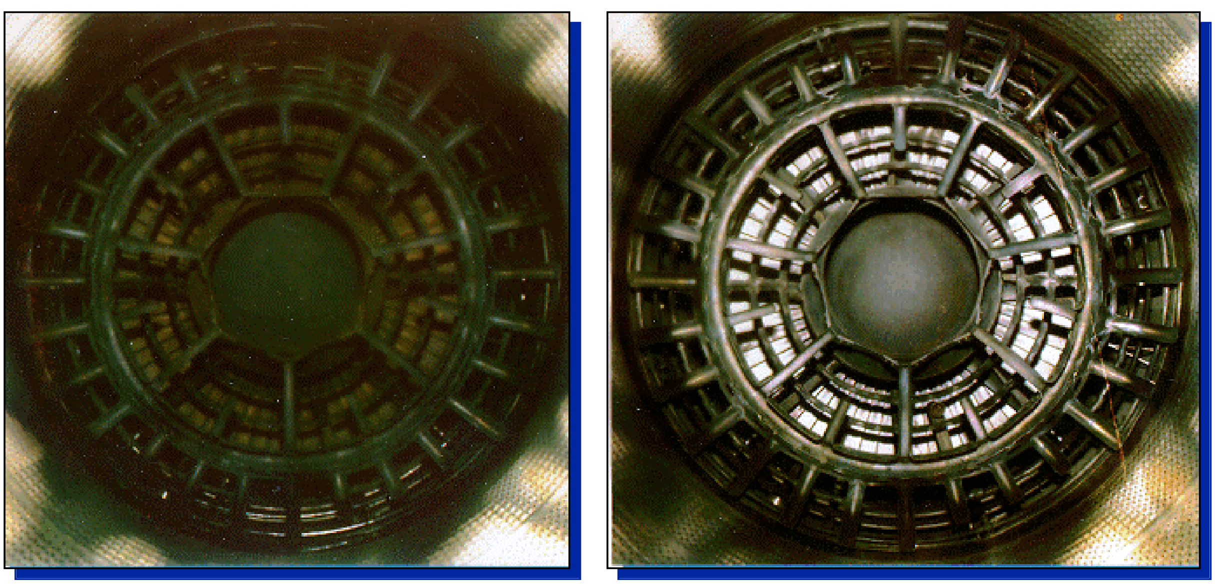


Figure 1. JP-8+*100 Additive* Package



200+ Hours on JP-8

200+ Hours on JP-8 then
56 Hours on JP-8+100

Figure 2. JP-8+100 Field Results

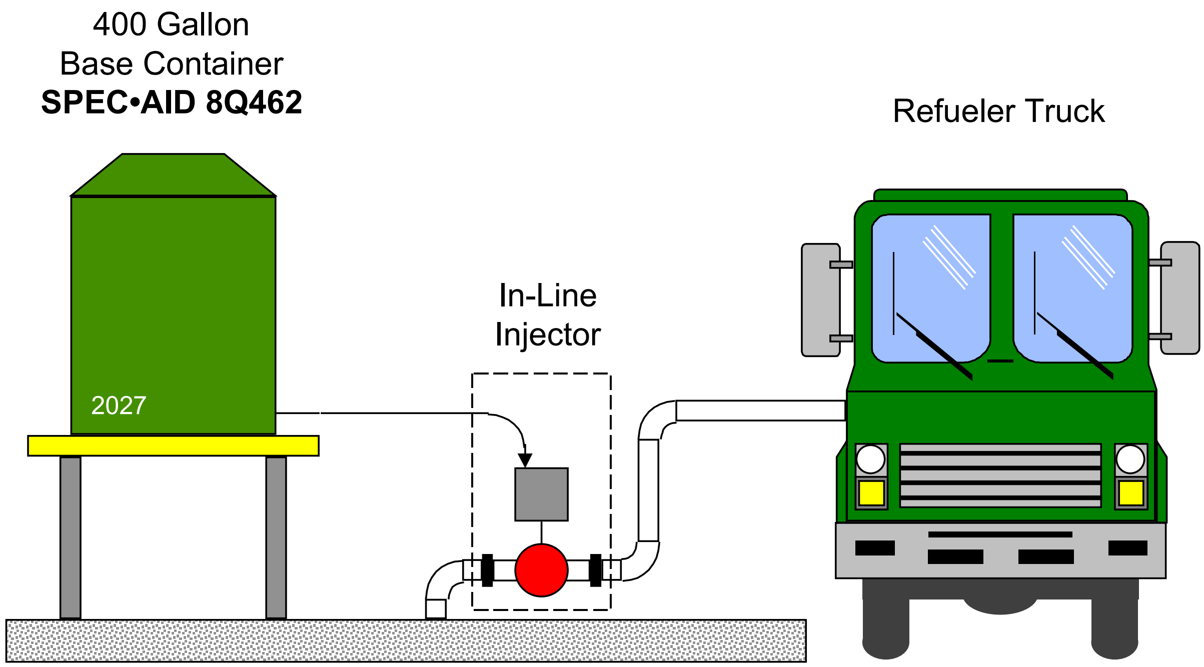


Figure 3. JP-8+100 Injection System

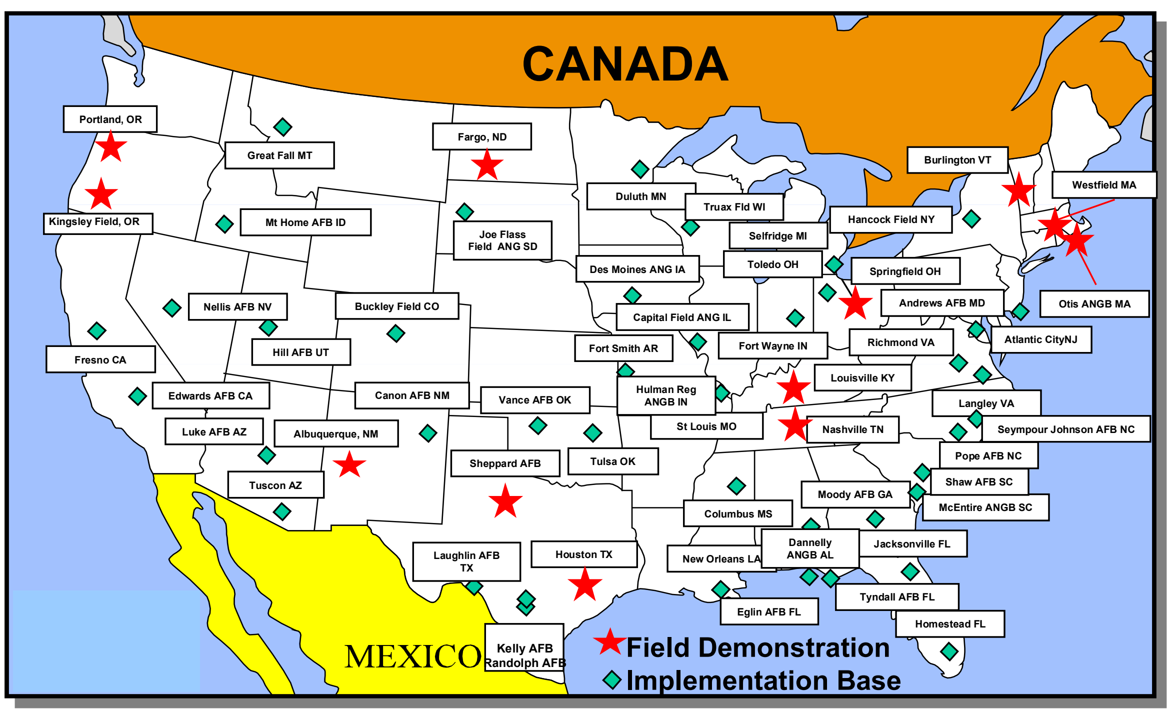


Figure 4. JP-8+100 Field Locations End of 1999

A. Army Concerns

With the known dispersant/detergent quality of JP-8+100 fuel, the differing fuel systems that exist between the Army and the Air Force have raised concerns for the Army about using this formulation for its ground equipment vehicles. For example, fuel tanks that previously contained diesel fuel are more prone to contain oxidized fuel deposits, debris, condensed water, etc., as compared to the relatively cleaner fuel tanks of aircraft and ground equipment exposed to JP-8. Other concerns are:

1. Potential filterability problems
2. Water reaction and generation of emulsions
3. Removal of existing deposited materials
4. Increase in small particulates being introduced into the injectors and combustion chamber
5. Difficulty in differentiating between JP-8 and JP-8+100 in the field
6. Compatibility of elastomer materials
7. Increased potential for microbiological growth

In addition, the *+100 additive* permanently disables water separators in vehicle fuel filters, which remain disabled after the additive is no longer present. Failure to remove water can result in corrosion and seizures of fuel injectors, and greatly encourages the proliferation of microbiological growth. The *+100 additive* can remove dirt and scale downstream to plug fuel filters. Initial use might result in a large concentration of small debris passing through fuel filters. However, Air Force evaluations in diesel-powered equipment, limited to flight line support equipment, have shown only minor initial filter plugging problems.

B. Potential Benefits

There are, however, many potential benefits associated with using JP-8+100 for Army aircraft and ground vehicles and equipment that could parallel benefits documented by the Air Force. For example, aviation and ground equipment might achieve the following benefits from using JP-8+100:

1. Reduced maintenance of helicopters currently having engine deposition problems,
2. Reduced injector nozzle fouling and nozzle clean-up labor costs for the ABRAMS tank,
3. Increased fuel system component life of Army diesel-powered equipment,
4. Potential for improved performance with reduced engine size and weight, and
5. Increased ability to use the fuel as a “heat sink” in future aircraft designs.

However, the costs to replace the large number of filter/separators in the Army’s fuel supply and distribution system might overwhelm any benefits from using the JP-8+100 unless replacements would occur through normal attrition.

II. APPROACH

The Army JP-8+100 Evaluation Program involves a two-phase effort. Phase 1 consists of the impact study; phase 2 consists of acceptance testing.

Objectives for Phase 1 are as follows:

1. Identify unique problems to be resolved.
2. Identify potential benefits of JP-8+100 for the Army.
3. Provide preliminary cost-benefit analyses.
4. Develop a test and evaluation plan for Army acceptance of JP-8+100, and
5. Provide recommendations for proceeding to Phase 2.

Under Phase 1, the following four tasks were defined and initiated:

Task 1 – Identify scenarios where Army may be exposed to JP-8+100

Task 2 – Investigate/confirm elastomer and seal compatibility

Task 3 – Determine preliminary cost-benefit analysis for Army use of JP-8+100

Task 4 – Determine short-term impact for selected Army aviation and ground vehicles and equipment.

III. TASK 1: IDENTIFY SCENARIOS WHERE THE ARMY MAY BE EXPOSED TO JP-8+100

The Air Force has been developing a new JP-8+100 fuel designed to improve the thermal stability and heat capacity, which allows higher fuel operating temperatures for their advanced fighter aircraft. The first additive package resulting from this developmental program, the "*+100 additive* package," increases the thermal stability of JP-8 by 100°F and increases the heat capacity by 50%. Its use has demonstrated maintenance benefits beyond its thermal enhancement as it reduces coking and deposits within some engines. However, one of the components in the "*+100 additive* package" is a dispersant/detergent, which disables water separators in fueling systems as well as in on-board vehicles and equipment allowing the passage of water and possibly fine particulate into fuel tanks.

The following were investigated during Task 1: how the Army obtains Air Force fuel; conditions under which such fuel transfers occur; and who within the Army uses the fuel. The approach taken was to identify those situations, locations, or operational scenarios in which Army units currently receive JP-8 directly or indirectly from the Air Force. The identification of these occurrences would provide a means to more accurately assess the probability of Army units *inadvertently* being given or *unknowingly* using the new JP-8+100. This information was accomplished by interviewing Army personnel familiar with the supply, distribution, and utilization of fuels, and gaining access to the comprehensive database maintained by the Air Force at Kelly Air Force Base (KAFB), which tracks all retail transfers of fuel from the Air Force to Army users. This tasking was later expanded to encompass units of the Special Operations Forces (SOF).

A. Approach

Task I included three sub-tasks: 1) Shared Fuel Supply Systems, 2) Fuel Transfer Methods, and 3) Fuel Supply and Consumption. The effort undertaken for this survey focused on Shared Fuel Supply Systems and Fuel Transfer Methods and was directed to only Army (and later the SOF) individuals.

The approach initially taken was to contact those individuals within the Army (and later the SOF) responsible for fuel supply and distribution and solicit the needed information. Prior to any verbal communications, an introductory email was sent as a heads-up. This merely stated the intent of this solicitation and identified the questions for which answers were being sought. These were the following:

1. **For Shared Fuel Supply Systems (SFSS)**
   - Do you know of any locations where Army/SOF and Air Force have SFSS?
   - At these locations, which service has the responsibility for the product?
   - Under what operational scenarios or doctrine policies are Army/SOF and Air Force required to have SFSS?
   - Under these scenarios, who is responsible for the product?

2. **For Fuel Transfer Methods (FTM)**
   - Are there informal procedures practiced in the field where JP-8 is transferred to Army/SOF users?
   - Is there any Army/SOF operational doctrine where Air Force "owned" JP-8 is required to be transferred directly or indirectly to Army/SOF units?

In soliciting this information for the Active Army, the Quartermaster School (QM School) at Ft. Lee, VA and the Combined Arms Support Command (CASCOM) were contacted with the QM School including input from the 49th Quartermaster Group. For the Army National Guard and Reserve components, the Army Petroleum Center at New Cumberland, PA was contacted.

For soliciting the information related to activities of the Special Operations Command (SOCOM), three separate "components" or elements of SOCOM were contacted:

- Army Component at Ft. Bragg, NC:
  - 528th Special Operations Support Battalion
  - 160th Aviation Regiment of the Army Special Operations Command (USASOC)
- Aviation Component at Hurlburt Field, FL:
  - Logistics Group of the Air Force Special Operations Command (AFSOC)
- Naval Component at Coronado, CA,
  Naval Special Operations Command (NAVSPECWARCOM):
  - Logistics Group
  - Combat Service Support

All individuals contacted by telephone or email for obtaining any necessary follow-up clarification are listed in Table 1.

Table 1. Individuals Contacted

Name	Phone Number	Agency
Ashbrook, Lonnie	(717) 770-7258	Army Petroleum Center New Cumberland PA
Barros, Jim	(804) 734-2820	Petroleum and Water Dptmt Quartermaster School Ft. Lee VA
Boenker, Matt	(256) 313- 4959	Aviation and Missile Command Redstone Arsenal AL
Cooper, B., CPT	(502) 956-3726	160th Aviation Regiment Army Special Operations Command Ft. Bragg NC
Dunning, W., LCDR	(619) 437-0880	Logistics Group Navy Special Operations Command Coronado CA
Fenton, D., MSGT	(850) 884-2440	Logistics Group Air Force Special Operations Command Herbert Air Field FL

Table 1. Individuals Contacted		
Name	**Phone Number**	**Agency**
Foley, P., Senior Chief	(619) 437-3338	Logistics Group Navy Special Operations Command Coronado CA
Gum, W., MAJ	(502) 798-1642	160th Aviation Regiment Army Special Operations Command Ft. Bragg NC
Henry, J., SFC	(910) 432-9886	528th Special Operations Support Btn. Army Special Operations Command Ft. Bragg NC
Jenks, W., LTC	(804) 734-7249	Quartermaster School and Ctr Ft. Lee VA
Kephart, S., MAJ	(703) 695-4761	Air Staff Headquarters Air Force, Pentagon, Washington DC
Kimbrough, Kay	(210) 925-1869	Trajen Contractor Kelly Air Force Base TX
Kojm, L., CDR	(813) 828-8166	Special Operations Command Headquarters MacDill Air Force Base FL
Looney, S., MAJ	(502) 798-1711	160th Aviation Regiment Army Special Operations Command Ft. Bragg NC
Lupori, Jim	(717) 770-6857	Army Petroleum Center New Cumberland PA
McKernan, T, MAJ	(804) 734-2820	Petroleum and Water Department Quartermaster School Ft. Lee VA
Newsome, T, MAJ	(804) 734-0609	Directorate of Combat Development Combined Arms Support Command Ft. Lee VA
Perdue, William	(804) 734-0572	Directorate of Combat Dvpmt Combined Arms Support Command Ft. Lee VA
Potvin, Sandra	(717) 770 6857	Army Petroleum Center New Cumberland PA
Reedy, D., CDR	(619) 437-3132	Logistics Group Navy Special Operations Command Coronado CA
Spackman, L., LTC	(703) 695-3819	Joint Chiefs of Staff Logistics/J4, Pentagon Washington DC
Spriggs, John	(717) 770-7203	Army Petroleum Center New Cumberland PA
Wilson, Jim	(256) 313-4934	Aviation and Missile Command Redstone Arsenal AL
Yoder, M., MAJ	(804) 734-1245	Petroleum and Water Department Quartermaster School Ft. Lee VA

B. Findings

The findings listed below reflect those involving Active Army operations, Army Guard/Army Reserve operations, and those involving the three components of the Special Operations Command (i.e., Army, Air Force, and Navy). For clarification purposes, each entry is referenced as to the source that provided that particular piece of information. The list of references is provided at the end of this section (III Task I, Section F) of the report.

1. Active Army

The information pertaining to Active Army units evolved from the briefing and follow-on discussions with the Quartermaster School's Petroleum and Water Department who in turn had incorporated their input with that provided by the 49th Quartermaster Group at Ft. Lee VA and the Directorate of Combat Development-Quartermaster of the Combined Arms Support Command also at Ft. Lee in effect giving an "Army consensus response." This information was augmented by input subsequently provided by the Army Petroleum Center at New Cumberland PA.

In the briefing that was given on 5 Nov 1998 in response to those questions identified above, the Petroleum and Water Department (PWD) initially described the path fuel currently follows from its initial point into the theater to its being issued in the forward area. The doctrinal Field Manuals (FM) covering this are FM 10-67 (Petroleum Supply in Theaters of Operation) and FM 10-67-1 (Concepts and Equipment of Petroleum Operation). These along with other Army FMs are available from the Army Digital Library, which can be accessed at its web site http://www.adtdl.army.mil.

This progression of fuel historically has followed a "linear battlefield doctrine," which has typically reflected a one-way movement from the port to the forward area. However, the Army's new Force XXI doctrine calls for a "non-linear battlefield doctrine," which implies that fuel movements can go in essentially any direction depending upon a variety of factors such as battlefield needs, fuel availability, location of fuel tankers and distribution equipment, etc. The point in explaining this new "non-linear battlefield doctrine" was to emphasize the greater potential and *probability* for units in the field to become exposed in the future to inadvertent or unauthorized use of the JP-8+100.

Those locations or situations where JP-8 is or can be transferred from the Air Force to the Army are as follows:

- From a Common Service Fuel Facility such as those maintained by the Air Force in Honduras, United Kingdom, Greece, locations in CONUS, etc. [1, 14, 15, 16, 17, 18]
- During Joint Operations when the Air Force is the predominant service at the airfield. [2]
- From an Air Force R-14 Fuel Distribution System. [1]
- From Air Force "bladder bird" aircraft or through "wet wing defueling" operations during a contingency or an initial insertion of forces operation. [1]
- From Pope Air Force Base (AFB) NC or McCord AFB WA, the two AFBs from which Army units deploy. [2,3]
- When Army aircraft are deployed and required to refuel at AFBs enroute to their destination. [2]

A follow-up inquiry to identify the Common Service Fuel Facility locations within CONUS that were mentioned above resulted in the generation of quantitative data that reflected a ***significant number*** of specific fuel transactions involving Air Force installations "selling" JP-8 to Army users. As these transactions occurred not only at Air Force Bases, but also at Air Force Air Guard and Air Reserve locations as well as at commercial airports including some SOF installations, the resultant findings are discussed later in this report.

2. Army Guard/Army Reserve

The information pertaining to Army Guard and Army Reserve units was provided by the Army Petroleum Center. Those locations or situations where JP-8 is or can be transferred from the Air Force to the Army National Guard or Army Reserve are as follows:

- During transient refueling when Army National Guard (or Army Reserve) helicopters in route to Army bases must refuel at AFBs. [1]
- For Army National Guard units located on Air National Guard Bases who received their fuel support directly from the Air Force. The four specific locations cited were USPFO ID, Orchard Training Center; USPFO AR, Camp Robinson (i.e., Inter-service with Little Rock AFB); USPFO SD, Rapid City (i.e., Inter-service with Ellsworth AFB); and USPFO WI, Madison, AASF#2. [2, 4, 5]

3. Special Operations Command (SOCOM)

The information pertaining to the Special Operations Forces (SOF) was obtained from the three elements of SOCOM; the Army (USASOC), the Navy (NACSPECWARCOM), and the Air Force (AFSOC). Specific information however, for many of the operations/situations was not given due to the classified nature of their activities. Those locations or situations where JP-8 is or can be transferred from the Air Force to SOF units are identified in the below paragraphs.

For SOCOM units in general:

- During insertion actions involving wet-wing defueling or fueling via the C130 bladder bird. [6]
- From those locations where SOF units are deployed as they tap into base support operations. [7, 10]

For USASOC (Ft. Bragg NC):

- During operations (Classified) where they interact directly with the Air Force who provide the fuel. [8]
- During Joint Service training exercises. [9]
- During wet-wing operations, hot/cold aircraft refueling operations, and ground refueling operations. [9] Note: Wet-wing operations was identified as a doctrine procedure described in FM 10-69 (Petroleum Supply Point Equipment Operations), which has since been replaced with FM 10-67-1.

- Whenever SOF aircraft are refueled during in-flight refueling from Air Force aerial tankers. [2, 10]

For AFSOC (Hurlburt Air Field FL):

- During many situations and operational procedures of a classified nature where AFSOC receive fuel directly for Air Force including both bulk transfers as well as air-to-air refueling. [11]

For NAVSPECWARCOM (Coronado CA):

- Fuel support depends upon whatever theater the operations are to occur. If the Air Force is responsible for a given theater of operations, Seals Ashore units would automatically be given JP-8. [12]
- Of the two elements of NAVSPECWARCOM (i.e., the Seals Ashore and the Watercraft/Boats), only the Seals Ashore would be able to use JP-8 as it is not authorized for use in their Watercraft/Boats.

In questioning individuals within the SOCOM elements, no one, except the individual from AFSOC, had any knowledge of the Air Force's JP-8+100 initiative. The one individual from AFSOC's Hurlburt Air Field did acknowledge that their location had been suggested as a test site to evaluate the new fuel; however, AFSOC preferred to await the decisions of both the Navy and Army as to whether JP-8+100 would be eventually adopted as a tri-service fuel.

C. Transfers of Air Force Fuel

In response to the generic identification of "Common Service Fuel Facilities" (i.e., those locations where Air Force owned fuel is transferred to Army users) mentioned during a November 1998 briefing by the Army's QM School, a summary was prepared based on fuel transaction data collected by KAFB that encompassed all fuel transactions (i.e., transfers or issues of fuel) occurring during Fiscal Year 1998. The availability of this data resulted from assistance provided by the QM School who facilitated the exchange of information that is maintained by the Air Force at KAFB, Tx. [14, 15, 16] Initially, the forwarded data consisted of Excel files that listed a total of 14,343 separate transactions where Air Force locations had issued (i.e., sold) JP-8 fuel to Army units or equipment. This first transmission of data consisted of essentially all Transaction Issue/Defuel (TID) *Code B* actions that represent *fuel being transferred into aircraft*.

Since this assessment was to include all fuel transfers from Air Force to Army, the point-of-contact at KAFB (Ms. Kay Kimbrough) subsequently forwarded another complete Excel file [17, 18] that included all TID *Code B* transfers, all TID *Code N* transfers reflecting *fuel being transferred into "non-fly" equipment*, all TID *Code E* transfers reflecting *fuel being transferred into bulk storage or containers*, and all TID *Code I* transfers that cover *in-flight refueling transfers*. The complete file encompassed Fiscal Year 1998 resulting in 17,967 transfers as compared to the previous 14,343 transfers.

The listing involved transactions that occurred at Air Force, Air National Guard, Air Force Reserve installations, and commercial airports. Of the 247 individual locations listed on the Air Force DODAAC listing, only 63 did not show any fuel transfers as having occurred, leaving 184 or 74.5% of the installations as being involved in these fuel transfers actions.

1. Fuel Transfers by Type

The distribution of the different types of fuel transfers (i.e., by individual TID Code) grouped by their total number are shown in Table 2.

Table 2. Fuel Transfers by Type

TID Code	Type	Number of Transfers	Percentage of Total
Code B	Fuel into aircraft	14,274	79.5%
Code E	Fuel into bulk	3,020	16.8%
Code I	In-flight refueling	194	1.1%
Code N	Fuel into non-fly	479	2.7%

Figure 5 illustrates the number of fuel transfers by type.

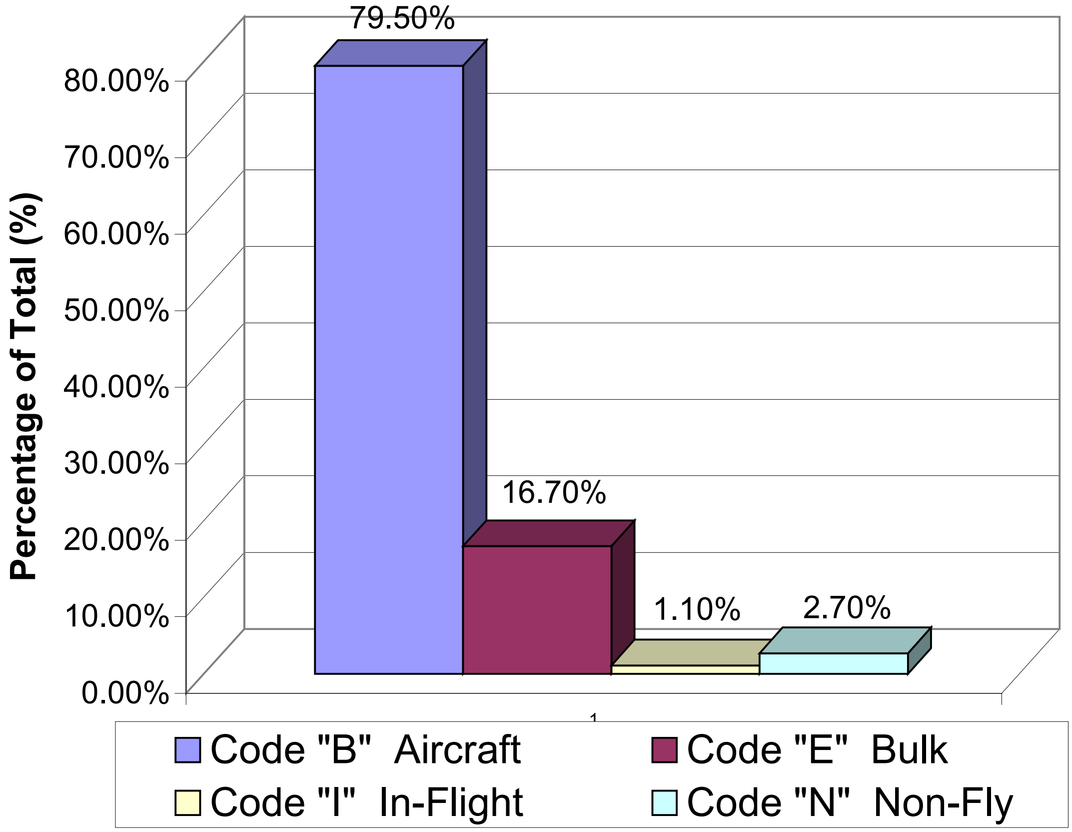


Figure 5. Number of Fuel Transfers by Type

However, the distribution for all four types of transfers by their TID Code based upon total gallons is shown in Table 3.

Table 3. Fuel Transfer by Type (Gallons)

TID Code	Type	Total Gallons Issued	Percentage of Total
Code B	Fuel into aircraft	5,367,096	35.2%
Code E	Fuel into bulk	7,343,474	48.2%
Code I	In-flight refueling	87,965	0.6%
Code N	Fuel into non-fly	2,429,058	16.0%
Total		**15,227,593**	

Figure 6 presents the fuel transfers by gallon.

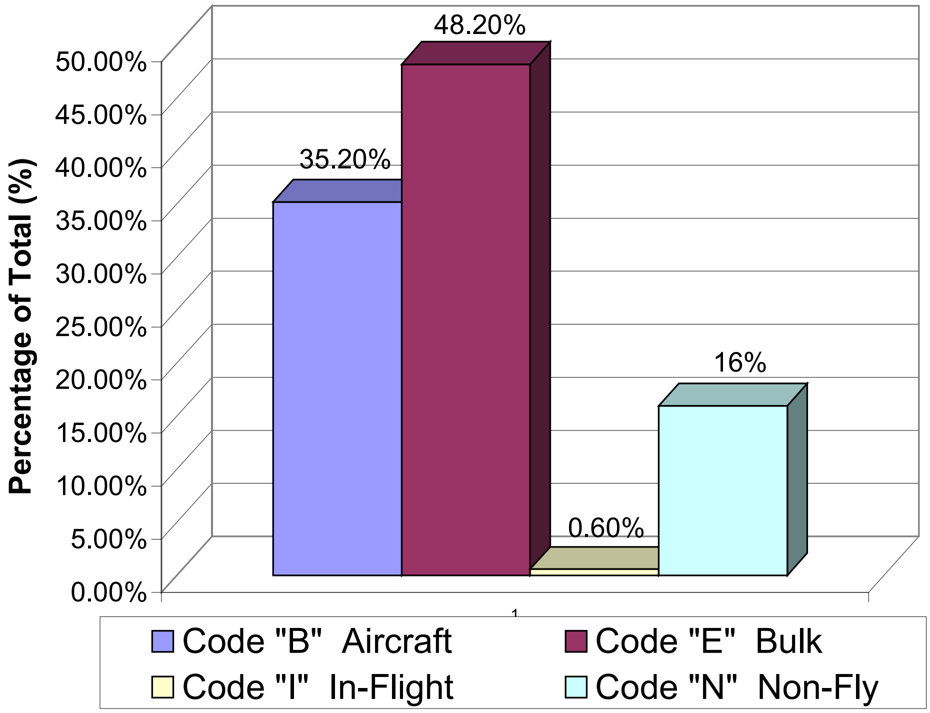


Figure 6. Fuel Transfer by Gallons

2. Fuel Transfers by Amount

An evaluation was made to determine the distribution of fuel quantities being transferred. The amounts varied from a low of 1 gallon to a high of 212,265 gallons. The distribution range gallon-wise for all four types of transfers is shown in Table 4.

Table 4. Fuel Transfers by Amounts

Amounts (Gallons)	Number of Transfers	Percent of Total Transfers
0 to 24	484	2.5%
25 to 49	1,293	7.2%
50 to 99	1,554	8.6%
100 to 499	9,261	51.7%
500 to 999	1,222	6.8%
1,000 to 1,999	1,914	10.7%
2,000 to 2,999	1,451	8.1%
3,000 to 3,999	125	0.7%
4,000 to 4,999	136	0.8%
5,000 to 5,999	58	0.3%
6,000 to 6,999	52	0.3%
7,000 to 9,999	322	1.8%
10,000 to 212,265	95	0.5%

3. Fuel Transfers by Location

A listing of all locations or installations where these transfers occurred has been generated. The number of transfers per location ranged from those having no transfers to one location having the highest number of transfers (i.e.,1,079), which was Ellington AFB , Tx. Prior to listing the individual locations, a tentative bottom line of listing only locations having at least 100 transfers had been initially agreed upon. However, this was subsequently changed to locations having at least 55 transfers as there were several locations having less than 100 transfers that reflected a significant amount of fuel having been transferred. Even though 55 was selected, random screening of the data prompted the inclusion of additional locations having less than 55 transfers but showing significant amounts of fuel being issued to Army users.

A complete listing of some 81 locations showing numbers of transfers with corresponding total gallons transferred in descending order is provided as Table 5. This listing clearly demonstrates that the higher number of transfers does not necessarily translate to the larger amounts of fuel being provided.

Table 5. Listing of Locations with Total Gallons in Descending Order

Location	Total Transfers	Total Gallons
Ellington AFB TX	1,079	903,763
Dobbins AFB GA	304	819,695
Diyarbakir AS Turkey	306	744,022
Boise Gowen FLD ID	249	565,584
Minneapolis St Paul IAP MN	108	563,201
Howard AFB CZ	744	552,012
Ramstein AB Germany	330	517,936
Truax FLD WI	72	451,141
Greater Peoria APT IL	151	412,984
McEntire AGB SC	172	398,829
Eglin AFB FL	952	365,274
Buckley AGB CO	265	362,505
Luke AFB AZ	876	357,271
Chievres AS Belgium	286	352,076
Incirlik AB Turkey	220	323,210
Lincoln ANG NE	123	319,022
Birmingham MAP AL	177	307,696
Elemendorf AFB AK	737	301,015
Pope AFB NC	627	267,104
Rickenbacher AFB OH	98	250,172
Bangor ANG ME	106	245,869
Westover AFB MA	86	235,348
Hickam AFB HI	728	231,441
McGee Tyson APT TN	87	195,765
Portland IAP OR	41	192,960

Table 5. Listing of Locations with Total Gallons in Descending Order		
Location	**Total Transfers**	**Total Gallons**
Dannelly FLD AL	81	189,590
Quonset State IAP RI	125	171,404
Westhampton Beach ANG NY	55	168,494
Andrews AFB MD	461	155,886
MacDill AFB FL	475	152,645
Fargo FLD ND	101	149,861
Forbes AGB KS	54	144,521
Homestead AFB FL	41	143,387
Nellis AFB NV	325	124,473
Kirtland AFB NM	335	120,966
Joe Foss FLD SD	68	117,903
Selfridge AGB MI	77	104,628
Ellsworth AFB SD	256	103,478
Otis AGB MA	51	103,430
Holloman AFB NM	274	100,555
Fresno Air Terminal ATM CA	44	97,844
Davis Monthan AFB AZ	166	96,694
Maxwell AFB AL	202	83,623
Shaw AFB SC	226	77,354
Kunsan AB Korea	200	73,755
Aviano AB Italy	95	72,524
Langley AFB VA	180	72,479
Hurlburt FLD FL	233	68,889
Mildenhall RAF United Kingdom	84	63,757
Peterson FLD CO	104	55,138
Osan AB Korea	228	51,879
Kadena AB Japan	157	50,626
Burlington MAP VT	81	47,118
Edwards AFB CA	110	46,193
Robins AFB GA	124	45,727
Griffiss ANG NY	106	44,156
Kelly DAO AFB TX	151	43,215
McClellan AFB CA	84	42,915
Fairford RAF United Kingdom	17	42,275
Wright-Patterson AFB OH	146	42,058
Eielson AFB AK	103	41,556
Little Rock AFB AR	78	38,830
Scott AFB IL	98	38,464
Kingsley FLD OR	27	36,359
McGuire AFB NJ	57	31,490
Tonopah Test RG NV	108	30,792
Tinker MAT IL	126	30,210
Kelly AFB TX	57	30,015
Whiteman AFB MO	77	27,890
Spangdalem AB Germany	24	27,177
Keesler AFB MS	81	26,916
Randolph AFB TX	62	25,161
Hill AFB UT	67	23,601
Patrick AFB FL	63	23,479
Barksdale AFB LA	66	23,465
Charleston AFB SC	93	22,816
AFCSSO, Langley AFB VA	56	21,868
Chicago O'Hare ANG IL	16	19,472
Mountain Home AFB ID	39	15,205
Laughlin AFB TX	11	12,935
Cannon AFB NM	32	10,529

4. Fuel Transfers by Recipients

An assessment was conducted using only the TID Code B transfers (i.e., fuel into aircraft) to identify the principal Army users (i.e., what aircraft had received the fuel). A sorting process enabled the entries to be separated, which facilitated this review. Using this process, "generic" series of aircraft were grouped and the number of transfers that particular series had received during FY 1998 allowed the percent of fuel transferred to be computed. To reduce the significant numbers of individual aircraft listed, the entries were grouped into "series." For example, OH6 and OH58 were grouped as "OH Series"; UH60, AH1 and AH64 were grouped as "UH/AH Series;" C12, C23, C26, C31, C35, C300, and C350 were grouped as "C Series Aircraft;" M11, M12, M18, M117, and M124 were grouped as "M Series Aircraft;" MH06, MH47, and MH60 were grouped as "MH Series;" UC12, UC34, UC35, and UV18 were grouped as "U Series Aircraft," etc. Using this process, the information that was generated is given below in Table 6.

Table 6. Fuel Transfer Recipients

Recipients of Fuel Transfers	Number of Transfers Received
UH/AH Series	4,754
C Series Aircraft	4,764
OH Series	712
U Series Aircraft	526
DH7 Series	510
CH47 Series	496
MH Series	270
M Series Aircraft	67
E & F Series Aircraft	33
B767 Aircraft	16
RC Series	29

Determining what types of aircraft received the transferred fuel proved to be most interesting as well as confusing. It had been anticipated that the larger users may have been the smaller aircraft. However, there was almost an equivalent percent of the fuel transfers being received by the "C Series Aircraft" or cargo transport aircraft. In reviewing the individual listings, it was somewhat confusing as many had identification numbers that appeared to be somewhat different than those currently listed. [5] More specifically, the Special Bulletin publication [19] lists under the fixed wing aircraft category the following; C12 and C23 Cargo transport, RU21 and RV1 Reconnaissance aircraft, and U21 and UV18 Utility aircraft. For the Rotary wing aircraft category, the publication lists AH64 and AH1 Attack aircraft, CH47, MH60, and MH47 Cargo aircraft, EH1 and EH60 Electronic countermeasures aircraft, OH6 and OH58 Observation aircraft, and UH1 and UH60 Utility aircraft. Because of the absence of additional information needed to further identify the receiving aircraft, the above grouping process may have introduced some errors; however, it at least gives a broad brush overview as to the major end item users for the transferred fuel.

A cursory review of the TID Code N transfers (i.e., fuel into non-fly) revealed a wide variety of recipients although many had not been identified. For those that were identified, the following represent the types of entries: TNKTRK, PATROIT, NPO, AGDBUL, ARMY, TANKER, TANKS, TRUCKS, and HEMMIT.

D. Conclusions – Task 1

From this limited survey of Army and SOF users, it is evident that many opportunities will exist in the future for the new JP-8+100 fuel to be inadvertently introduced into both Army and SOF aviation and ground vehicles and equipment. The large number of Air Force-to-Army retail fuel transfers that were documented by data provided by KAFB, Tx further amplifies the potential to inadvertently misfuel Army materiel with JP-8+100.

It was initially anticipated that the survey questions would generate responses that were more quantitative and contained more factual information. However, the respondents' lack of specificity was more than likely the result of the nature of operations in the field (e.g., differing contingencies), location of units versus supply points, changes in battlefield doctrine, and classification restrictions in the case of the SOF.

Discussions with the SOF revealed that they were unaware of the new JP-8+100 fuel undergoing field validation by the Air Force. Because of this, SOCOM HQ, USASOC, NAVSPECWARCOM, and AFSOC personnel were faxed copies of the Information Paper "Air Force Introduction of JP-8+100 and Implications for Army (and DOD) Ground Forces" to at least provide them preliminary information on the new JP-8+100.

Access to the retail fuel transaction data from KAFB resulted in a real quantification of the fuel transfer question. The number of individual retail fuel transfers, the types of fuel transfers, and the volumes of fuel being transferred reveal many future opportunities for Army users to become unknowingly exposed to JP-8+100.

E. Acknowledgments – Task 1

Acknowledgment is made of the assistance provided by all persons who provided the requested information: particularly CPT Monty Yoder (QM School) who facilitated the obtaining of data from KAFB, and; Kay Kimbough (KAFB) who generated the comprehensive listings of FY 1998 individual fuel transactions.

F. Task I: Report on Identification of Wholesale Fuel Distribution Scenarios for the U.S. Army to Potentially receive JP-8+100 in Aviation and Ground Equipment

The U.S. Army TARDEC Fuels and Lubricants Facility (TFLRF) at Southwest Research Institute (SwRI) was tasked to identify possible scenarios where JP-8+100 aviation fuel could be transferred to Army aviation and ground equipment. As part of this task, Mr. Calvin Martin worked with the Defense Energy Support Center (DESC) and reviewed fuel acquisition, storage, transportation, technical and quality assurance programs that could intentionally or unintentionally cause JP-8+100 fuel to be transferred to Army equipment. As part of this investigation, Mr. Martin contacted DESC Deputy Commander, Colonel Joe Thomas and discussed Army and Air force Shared Fuel Supply systems. Also contacted were: Mr. W. Robinson (Director of Bulk Fuels), Ms. Cathy Martin (Chief, Inventory Division), Ms. Regina Gray (Chief, Product and Technology division), and Mr. Lee Oppenheim (Chief Quality Operations Division).

At air force bases, the method for introducing the JP-8+100 additive is at the refueler, which issues fuel to aircraft. A certain amount of control can be exercised in these instances where Air Force activities refuel Army equipment. However, JP-8+100 could be issued to Army aircraft either by pilot request or as an unintentional incident by the refueling activity. These locations are described as retail fuel issues from Air Force to Army. They were investigated separately and reported in the previous section.

In pursuing other scenarios, this investigation focused on the DoD wholesale fuel system and locations where both Air force and Army aircraft receive fuel directly from DESC. This lead to an investigation of “into-plane” contracts as defined in DoD 4140.25-M “DoD Management of Bulk Petroleum Products, Natural Gas, and Coal.” See Figure 7 for definitions and other information on into-plane contracts. Into-plane contracts are used by DESC to establish refueling locations for the military services worldwide and may have varying levels of usage, such as:

- Commercial airports where refuels may be frequent or infrequent
- Commercial airports where Air National Guard units are located and use into-plane contracts as their fueling operation
- Airports in areas such as Bosnia, Italy, and the Middle Eastern Countries supporting military exercises and conflicts

INTO-PLANE CONTRACTS
(EXCERTED FROM DoD MANUAL 4140.25-M)

I. Reference: DoD Management of Bulk Petroleum Products, Natural Gas, and Coal (DoD 4104.25-M Vol. I-IV)

II. Definition: Into-Plane Contract. A supply technique whereby the U.S. Government contracts with a contractor to refuel military aircraft at commercial airports, with specified contract fuel. The fuel, lube oil and refueling facilities (storage tank, vehicle, and equipment) are supplied by the contractor with commercial product. The use of government refueling trucks, equipment, bladders, etc. is not authorized unless stipulated in the into-plane contract. Note: Commercial aircraft under a Government charter or contract may be refueled at into-plane locations.

III. Product and Servicing Specification.

a. Products. Products supplied under an into-plane contract will meet contractual specifications unless the DESC, in coordination with the Technical Quality Office of the Military Service, grants a waiver or deviation. Such waivers may be needed to supply aviation fuel without the fuel service icing inhibitor. Waiver data is indicated in the Avfuel and Avoil Into-Plane listing.

b. Servicing. MIL-STD-1548. Into-Plane Delivery of fuel and oil at Commercial Airports is incorporated in into-plane contracts. It establishes requirements for quality of products, technical requirements of equipment, quality assurance, and safety.

IV. Product Availability.

a. Aviation Fuel: Commercial Jet A (CONUS), A1 (overseas) and Jet B (Alaska and Canada).

b. Petroleum Base Jet Oil (MIL-L-6081): Grades 1005 and 1010.

c. Turbine Oil (MIL-L-7808 and MIL-L-23699): Synthetic base.

d. Engine Lubricating Oil (MIL-L-22851): Type II, Grade 1100 and Type III, Grade 1065.

V. Aviation Fuel & Oil Into-Plane Contract Listing.

This listing (prepared by DESC) summarizes contract data associated with into-plane locations such as contract number, airport, refueling agent, grade of fuel available, operating hours, waivers to product specifications (if any), operating hours , etc. The listing is intended to assist flight planners.

Figure 7. Into-Plane Contracts

These descriptions were confirmed in discussions with Col. Joe Thomas, DESC Deputy Commander, who provided insight regarding into-plane locations in Italy, Bosnia, and some Middle East locations, which were established as Air Force into-plane refueling sites and also quickly became Army refueling locations. Aviation fuel purchased at these sites is usually commercial Jet-A or Jet-A1. In a few instances the DESC is able to require airport fuel and service providers, Fixed Base Operators (FOBs), to inject military-required additives for JP-8, i.e. fuel system icing inhibitor, corrosion inhibitor and conductivity improver. However, on occasions, when the FOB will not accept the task of injecting additives and Air Force usage is critical, sustained and long-term, the service will send in Air force operators to inject additives at the FOB location.

To identify the number and locations of these FOB wholesale sites, and working through the Army Petroleum Center, the DESC was asked to query the Defense Fuel Automated Management System (DFAMS) for locations where the Air Force and Army refueled at the same into-plane locations. Information requested included the name of the location, number of issues, and quantity of fuel per issue to the Army. In addition, the total quantity issued to Army and Air Force was queried. The time period for information requested was 1997 and 1998. The list generated by the DFAMS data search (Table 7), showed location, number of Army refuels, quantity of Army refuels, number of Air Force refuels and quantity of Air Force refuels. There were 383 locations worldwide, which varied in size and quantity of product issued depending on the level of activity.

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL				
LOCATION	**NO. ARMY**	**ARMY GALLONS**	**NO. USAF**	**USAF GALLONS**
DTTA CARTHAGE IAP/TUNIS	2	1527	7	12840
EBBR BRUSSELS NATIONAL/BR	33	7290	72	207736
EDBB TEMPLEHOF APT, BERLI	10	2602	2	3968
EDBT TEGEL (2212)	7	4407	18	63152
EDDF FRANFURK MAIL IAP (2)	19	11745	1054	9720553
EDDM MUNCHEN IAP/MUNICH	66	12271	18	66589
EDDS STUTTGART IAP/ECHTER	849	160867	898	1196767
EFHK VANTAA IAP/HELSINKI	2	793	8	37773
EIDW DUBLIN IAP/DUBLIN	32	15070	13	35690
ESSA ARLANDA IAP/STOCKHOL	1	351	3	7062
FDAG BARSTOW-DAGGETT APT/	2196	362250	44	37585
FERI ERIE IAP	46	11304	2	4346
FFFT CAPITAL CITY AIRPORT	583	150674	1	319
FHEF MANASSAS REG APT	8	2275	10	7162
FLWS LEWISTON-NEX PERCE A	23	5271	3	570
FMHR MATHER FIELD __________	131	21110	13	20415
FRKD KNOX CO. APT/ROCKLAN	6	867	1	378
FSDM BROWN FIELD MAPT/SAN	14	2593	8	6495
FSEF SEBRING REG. APT	28	12611	4	1279
FSGJ ST. AUGUSTINE APT	640	134691	11	12341
FVNY VAN NUYS APT/VAN NUY	25	6069	31	41852
FWDR WINDER-BARROW APT	982	119658	1	284
FYWH WINDHOEK IAP/LAUGHAW	1	12199	7	57445
GMME SALE APT/RABAT	2	766	20	26613
GOOY DAKAR/YOFF	3	1020	109	1325336
HECA CAIRO IAP/CAIRO	7	3006	174	191080
HTDA DAR ES SALAAM (8001)	2	48772	18	121415
TOTAL	**5718**	**1112059**	**2550**	**13207045**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	NO. ARMY	ARMY GALLONS	NO. USAF	USAF GALLONS
KABI ABILENE RAG APT (443)	166	40625	710	192544
KABQ ALBUQUERQUE IAP	161	59303	87	28816
KABY SOUTHWEST GEORGIA RA	172	28498	16	5903
KACT WACO REG APT (4416)	133	44001	180	43288
KADM ARDMORE MUN APT	103	21689	267	64432
KAEX ALEXANDRIA IAP, ALEX	403	70835	345	722458
KAFW ALLIANCE APT, FT. WO	30	13261	703	398187
KAGR MACDILL AFB AUX FIEL	6	1392	3	2271
KAGS BUSH FIELD, AUGUSTA	385	102027	157	222891
KAHN ATHENS-BEN EPPS APT	139	41076	6	3430
KAKO AKRON-WASHINGTON CO	6	877	1	227
KALN ST. LOUIS REG APT	1	105	1	710
KAMA AMARILLO INT APT (44)	194	100371	1271	445076
KANB ANNISTON METRO APT	326	48234	9	8866
KAPA CENTENNIAL APPT, DEN	11	2699	7	3175
KARA ACADIANA REG APT, 19	58	11935	444	164872
KAST ASTORIA REGIONAL APT	92	15648	1	433
KAUS ROBERT MULLER MAPT	740	143531	151	41343
KAVL ASHEVILLE REG APT/AS	198	43251	165	160290
KAVP WILKES-BARRE SCRANTO	149	32332	25	52340
KBED LAURENCE G HANSCOM F	162	36467	385	658936
KBFI BOEING FLD, KING CO	52	13490	56	149522
KBFL MEADOWS FIELD/BAKERS	104	18760	13	4623
KBFM MOBILE DOWNTOWN APT	51	4771	1	200
KBGR BANGOR IAP ___________	226	65358	123	807671
KBHM BIRMINGHAM IAP	149	38091	95	32691
KBIF BIGGS ARMY AIRFIELD,	919	186627	265	291333
KBIH BISHOP APT	71	14925	3	868
KBIL LOGAN IAP/BILLINGS	62	17594	34	37866
TOTAL	**5269**	**1217773**	**5524**	**4545262**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	**NO. ARMY**	**ARMY GALLONS**	**NO. USAF**	**USAF GALLONS**
KBIS BISMARK MUN APT	5	1333	1	184
KBJC JEFFCO APT, DENVER	2	615	1	475
KBKT BLACKSTONE MAPT/AAF	126	42762	1	1623
KBNA NASHVILLE IAP (4305)	71	13822	409	1744243
KBOI BOSIE AIR TERMINAL ___	273	67911	49	76722
KBRO BROWNSVILLE IAP (44)	45	25748	36	9283
KBTR BATON ROUGE METRO AP	132	27366	9	7638
KBUF GREATER BUFFALO IAP	79	20256	107	69896
KBWD BROWNWOOD MUN APT (4	111	29524	1	209
KCAE COLUMBIA METRO APT	432	126236	37	36795
KCFW CHENNAULT IND. AIRPA	29	3656	271	97352
KCHA LOVELL FLD, CHATTANO	294	81266	14	16825
KCHO CHARLOTTESVILLE-ALBE	130	18291	29	4559
KCKB BENEDUM APT, CLARKSB	1202	260032	5	1295
KCLL EASTERWOOD FLD, COLL	180	27535	750	193108
KCMH PORT COLUMBUS IAP	5	986	1	330
KCNW TSTC-WACO/WACO	6	2685	145	560738
KCOS CTY OF COLORADO SPRG	73	25568	141	148875
KCPS ST. LOUIS DOWNTOWN-P	12	2072	5	24084
KCRP CORPUS CHRISTI IAP	54	20144	36	14594
KCRW YEAGER APT, CHARLEST	180	24061	27	8767
KCSM CLINTON-SHERMAN APT	14	6520	23	7786
KCWF CHENNAULT IND. APT	25	4181	170	74206
KCXY CAPITAL CITY AIRPORT	120	24247	5	4781
KCYS CHEYENNE MUN APT (51	47	9374	17	21997
KDAB DAYTONA REG APT	52	15772	38	40873
KDAL DALLAS LOVE FIELD (4	33	9762	35	61491
KDHN DOTHAN AIRPORT	1138	100160	14	12359
KDLH DULUTH IAP	1	165	4	1611
TOTAL	**4871**	**992050**	**2381**	**3242699**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	**NO. ARMY**	**ARMY GALLONS**	**NO. USAF**	**USAF GALLONS**
KDWH DAVID WAYNE HOOKS ME	360	80117	163	41190
KEFD ELLINGTON FLD (4448)	168	43792	734	679085
KELM ELMIRA/CORNING REG A	5	1254	11	18318
KELP EL PASO IAP/EL PASO	414	117992	317	390450
KESF ESLER REG APT/PINEBE	954	89799	17	14267
KEUG MAHLON SWEET FLD, EU	28	8052	10	93617
KFAT FRESNO AIR TERMINAL	169	27985	4	1693
KFDK FREDRICK MAPT, (2103	69	8470	31	4749
KFLL FT. LAUDERDALE-HOLLO	69	20634	39	57033
KFOE FORBES FIELD, TOPEKA	34	7444	7	2399
KFRG REPUBLIC APT	3	1021	6	6347
KFSD JOE FOSS FIELD, SIOU	24	6343	2	891
KFSM FT. SMITH MUN APT	385	139613	680	293802
KFTY FULTON CO APT BROWN	424	87547	50	23011
KGEG SPOKANE IAP	239	62572	236	169774
KGGG GREGG COUNTY APT, LO	55	18368	42	12278
KGJT WALKER FLD, GRAND JU	27	5963	60	26161
KGLH MID DELTA RAPT/GREEN	61	9981	43	16790
KGLS SCHOLES FLD, GALVEST	38	9463	15	5700
KGON GROTON-NEW LONDON AP	375	76925	13	8694
KGPT GULFPORT-BILOXI REGI	184	35486	49	67616
KGRB AUSTIN STRAUBEL IAP	5	944	1	537
KGTF GREAT FALLS IAP/GREA	50	17544	139	299577
KGVW RICHARD-GEBAUR APT	42	11650	58	23876
KGWO GREENWOOD-LEFLORE AP	46	10884	10	3037
KHAR CAPITAL CITY APT, HA	72	13594	4	772
KHEZ NATCHEZ-ADAMS CO APT	63	19522	1	369
KHGR WASHINGTON CO RAPT H	139	34342	11	3779
KHIO PORTLAND-HILLSBORO A	75	13117	52	36892
TOTAL	**4577**	**980418**	**2805**	**2302704**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	**NO. ARMY**	**ARMY GALLONS**	**NO. USAF**	**USAF GALLONS**
KHKS HAWKINS FLD, JACKSON	969	156068	2	588
KHLN HELENA REG APT	46	11833	4	1451
KHRL RIO GRANDE VAL IAP H	8	1286	11	32410
KHSV HUNTSVILLE IAP CT JO	321	73603	283	73257
KHTS TRI-ST/WALTER LONG	116	22151	5	9964
KHUF TERRE HAUTE IAP, HUL	3	712	2	922
KHUT HUTCHINSON MUN APT	53	13469	277	69721
KIAD DULLES IAP, WASH DC	63	17540	83	172083
KIAH GEORGE BUSH IAP/HOUS	15	3979	10	8903
KICT WISHITA MID-CONTINEN	21	9490	26	8870
KIDA FANNING FLD, IDAHO F	48	18736	9	3239
KIGM KINGMAN APT	105	22832	7	4632
KIKK	50	9791	1	199
KILE KILLEEN MUN APT (443	91	21905	3	746
KIND INDIANAPOLIS IAP	107	36705	2	3016
KIPL IMPERIAL CO. APT	48	17966	3	4189
KISO KINSTON REG JETPORT	48	8013	2	2302
KIWA CHANDLER/WILLIAMS GA	44	20032	340	141830
KJAN JACKSON IAP	2	550	75	22363
KJAX JACKSONVILLE IAP	89	27095	49	40484
KJST CAMBRIA CO. APT/JOHN	801	169445	3	3691
KJUN JUNEAU IAP	110	34882	34	25914
KLAL LAKELAND REGIONAL AP	696	130015	15	7095
KLAN CAPITAL CITY APT, LA	55	13532	2	611
KLAS MCCARREN IAP, LAS VE	150	40079	107	210971
KLAW LAWTON MUN APT	54	24616	191	104444
KLAX LOS ANGELES IAP	6	19393	104	384225
KLBB LUBBOCK IAP (4420)	33	11270	336	107478
KLBE WESTMORELAND CO APT	235	51328	6	7762
TOTAL	**4387**	**988316**	**1992**	**1453360**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	**NO. ARMY**	**ARMY GALLONS**	**NO. USAF**	**USAF GALLONS**
KLBL LIBERAL MUN APT (17	4	1141	1	162
KLCH LAKE CHARLES REG APT	18	2420	8	1631
KLFT LAFAYETTE REG APT, 1	60	7337	17	23768
KLGB DAUGHERTY FLD/LONG B	87	25703	78	594634
KLIT ADAMS FLD, LITTLE RO	373	106127	205	70781
KLMT KLAMATH FALLS IAP KI	31	8609	18	7203
KLMU MONROE REG APT, 1910	127	40450	398	113693
KLRD LAREDO IAP (4429)	22	3925	408	102393
KLSE LA CROSS MUN APT (50	8	2796	1	200
KLWT LEWISTOWN MAPT/LEWIS	15	3138	135	21222
KMAF MIDLAND IAP/MIDLAND	117	52715	632	214072
KMCN MIDDLE GEORGIA REG A	187	46473	4	6536
KMCO ORLANDO IAP	485	110683	87	170901
KMDW CHICAGO MIDWAY APT	40	7796	7	3167
KMEI KEY FLD MERIDIAN	478	222861	260	68830
KMEM MEMPHIS IAP (4304)	102	24081	121	76308
KMER CASTLE APT/MERCED ______	1	121	1	15359
KMFE MILLER IAP, MCALLEN	26	5308	11	3640
KMFR ROGUE VALLEY IAP	20	7874	2	1078
KMGM DANNELLY FIELD, MONT	360	65297	35	12311
KMGW MORGANTOWN MUN (4904	179	33522	19	13010
KMHK MANHATTAN MUN APT (1	25	6430	17	23856
KMHT MANCHESTER APT/GRENI	45	6599	10	14963
KMIA MIAMI IAP	66	28906	182	293990
KMKG MUSKEGON CO APT,	10	1481	6	4105
KMKL MCKELLAR-SIPES RAPT/	405	66333	2	2502
KMKO DAVIS FLD, MUSKOGEE	155	33809	42	39486
KMLI QUAD CITY APT, MOLIN	35	10047	12	12292
KMOB MOBILE REGIONAL APT	344	44993	38	13206
TOTAL	**3825**	**976975**	**2757**	**1925299**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	NO. ARMY	ARMY GALLONS	NO. USAF	USAF GALLONS
KMOT MINOT IAP	3	325	13	33473
KMQY SMYRNA APT (4306)	1088	166757	123	37646
KMRY MONTEREY PININSULA	112	45471	121	111385
KMSN DANE CO REG TRAUX FL	23	4496	36	7886
KMSO MISSOULA IAP/MISSOUL	39	9643	18	10560
KMSP MINNEAPOLIS-ST PAUL	6	2344	8	7790
KMSY NEW ORLEANS IAP, 190	10	3656	33	56257
KMWH GRANT CO. APT/MOSES	59	8514	12	60903
KMYR MYRTLE BEACH IAP (41	145	217769	26	14037
KNEW LAKEFRONT APT, NEW O	994	138763	50	34312
KNQA MILLINGTON MAPT (431	9	2872	23	25642
KOAJ ALBER J ELLIS APT JA	10	2852	14	5651
KOGD OGDEN-HICKLEY APT (4	13	5540	7	8875
KOKC WILL ROGERS WORLD OK	156	58004	491	342517
KOMA EPPLEY AIRFLD, OMAHA	8	2995	3	952
KONP NEWPORT MUNI APT	12	866	2	6420
KOPF OPA LOCKA APT/MIAMI	23	7756	39	37836
KORL ORLANDO EXECUTIVE AP	38	11634	3	1131
KOTH NORTH BEND MUN APT	17	1359	4	6679
KOWB OWENSBORO-DAVIESS CO	88	15310	1	361
KPAE PAINE FIELD, SMIHOMI	79	29568	6	15636
KPAH BARLEY REG PADUCAH	20	3945	1	489
KPBI PALM BEACH IAP	160	60284	26	68682
KPDK DE KALB-PEACHTREE AP	45	10670	4	1772
KPDT EASTERN REG APT	16	7967	2	659
KPEQ PECOS MUN APT (4456)	101	43528	7	3356
KPHX PHOENIX-SKY HARBOR I	205	63385	61	225198
KPIB HATTIESBURG-LAUREL R	435	82643	5	3574
KPIE ST PETERSBURG CLEARW	39	7794	4	1080
TOTAL	**3953**	**1016710**	**1143**	**1130759**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	**NO. ARMY**	**ARMY GALLONS**	**NO. USAF**	**USAF GALLONS**
KPKB WILSON FLD, GILL ROB	316	73772	15	7372
KPNS PENSACOLA REG APT	129	22986	16	4252
KPRC ERNEST A LOVE FLD, P	75	18363	11	5585
KPSC TRI-CITIES APT, PASC	30	4459	3	3288
KPSK NEW RIVER VALLEY APT	26	7533	1	196
KPTB PETERSBURG MUN APT	120	21994	3	967
KPUB PUEBLO MEM APT	29	5698	40	17582
KPWK PAL-WAUKEE APT	31	7529	3	1043
KPWM PORTLAND INT. JETPOR	91	12189	9	3226
KPWT BREMERTON NAT APT (4	115	23482	10	14038
KQBK GLYNCO JETPORT, BRUN	28	5040	6	1268
KRDM ROBERTS FIELD/REDMON	64	11857	13	3843
KRNO RENO IAP	102	23435	214	552614
KROA ROANOKE RAPT, WOODRU	89	21166	11	4423
KROW ROSWELL IND AIR CTR_	42	13709	377	354438
KSAF SANTA FE CO MUNI	660	106258	115	56315
KSAT SAN ANTONIO IAP (441	270	59694	68	57040
KSAV SAVANNAH IAP	165	55415	128	101998
KSBA SANTA BARBARA MAPT	55	9200	7	2304
KSCK STOCKTON METRO APT	225	53317	21	31810
KSDF STANDIFORD FLD, LOUI	53	13489	671	2360838
KSEZ SEDONA APT	127	21935	2	449
KSHV SHREVEPORT REG APT	86	13024	96	232968
KSJC SAN JOSE IAP/SAN JOS	28	29471	5	5283
KSJT MATHIS FIELD, SAN AN	183	64546	446	123943
KSLC SALT LAKE CITY IAP	88	24482	79	170594
KSLN SALINA MUN APT (1702	54	12404	35	27493
KSMX SANTA MARIA PUBLIC A	35	5277	15	5564
KSRQ SARASOTA-BRADENTON A	17	4848	2	630
TOTAL	**3333**	**746572**	**2422**	**4151364**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	**NO. ARMY**	**ARMY GALLONS**	**NO. USAF**	**USAF GALLONS**
KSTL LAMBERT-ST LOUIS IAP	14	3342	14	9619
KSWF STEWART APT, NEWBURG	510	81320	16	20934
KSYR SYRACUSE HANCOCK IAP	180	34160	38	43069
KTCL TUSCALOOSA MUN APT	90	14071	66	16124
KTLH TALLAHASSEE REG APT	259	43776	110	41080
KTPA TAMPA IAP	20	5187	34	40097
KTUL TULSA IAP	899	201487	1042	2527878
KTUP TUPELOO MUN-CD LEMM	643	65224	3	1637
KTVR VICKSBURG-TALLULAH R	17	3122	1	120
KTXK WEBB FLD, TEXARKANA	77	26672	35	10027
KTYS MCGHEE TYSON MUN APT	108	33221	161	61124
KUGN WAUKEGAN REG APT	13	2663	1	228
KTKM YAKIMA AIR TERM (480	453	118145	41	60339
K0R9 HAMMOND MUN APT	88	18303	1	150
LATI RINAS IAP/TIRANA	1	357	2	910
LCLK LARNACA IAP/LARNACA	66	13530	11	28683
LDSP SPLIT (1097)	18	4173	7	7773
LDZA ZAGREB (1092)	309	71728	240	214236
LEMD BARAJAS APT	2	726	8	14647
LFPB LE BOURGET IAP/PARIS	8	3307	25	74753
LGAT ATHENS IAP/ATHENS____	5	1890	22	39583
LGKR IOANNIS KAPODISTRIAS	83	28901	5	2075
LGTS MAKEDONIA IAP/THESSA	1	1646	1	173
LHBP FERIHEGY APT, (9861)	42	11432	146	69095
LIBR CASALE IAP/BRINDISI	28	17227	504	1928607
LIEO COSTA SMERALDA IAP/O	2	803	60	62629
LIPY FALCONARA IAP/ANCONA	7	2016	1	482
LIPZ TESSERA IAP/VENICE	10	2580	1	132
LIRA CIAMPINO IAP/ROME	15	9053	38	85914
TOTAL	**3968**	**820062**	**2634**	**5362118**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	NO. ARMY	ARMY GALLONS	NO. USAF	USAF GALLONS
LIRN CAPODICHINO IAP/NAPL	126	39815	508	981621
LIRP PISA IAP/PISA	17	7839	121	470491
LKPR RUZYNE/PRAGUE (9831)	2	450	20	45046
LLBG BEN BURION APT, TEL	6	2288	131	1112938
LOWW SCHWECHAT IAP/VIENNA	1	169	11	33516
LSGG COINTRIN IAP/GENEVA	2	258	11	62594
LTAB ANKARA/ESENBOGA (650	15	4054	59	104731
LTBA ATATURK IAP/ISTANBUL	2	509	5	20059
LTBJ ADNAN MENDERES IAP/I	1	411	128	194949
LYSK SKIPJI AIRPORT (4375	206	195171	132	283669
MGGT LA AURORA, GUATEMAL	13	3687	15	87675
MHLC GOLOSON IAP (2604)	27	9276	59	57604
MTPP PORT-AU-PRINCE IAP	1	372	14	57535
MWCR OWENS ROBERTS IAP	2	568	3	3949
MZBZ S.W. GOLDSON IAP/BEL	110	40949	48	112775
NSTU PAGO PAGO IAP/TUTUIL	2	5968	173	2073084
OBBI BAHRAIN INT APT I/	20	4831	366	2187578
OEDR DHAHRAN INT AB	77	16787	107	51731
OEJD JEDDAH INT APR (5502	1	3149	93	187020
OERK KING KHALID IAP/RIYA	13	5545	89	38400
OERY RIYADH MIL APT	2	15198	78	77962
OTBD DOHA IAP/DOHA_________	7	4047	146	984895
PAKT KETCHIKAN IAP	47	15852	58	64428
PHKO KEAHOLE APT	112	24095	12	60668
PHOG KAHULUI APT, MAUI IS	362	58371	5	12100
PHTO HILO IAP/HAWAII ISLA	464	121194	16	72196
PTPN PONAPE ISLAND	1	1654	2	3495
SBGL RIO DE JANEIRO IAP	2	640	15	87809
SEGU SIMO BOLIVAR IAP GU	7	6983	61	104548
TOTAL	**1648**	**590130**	**2486**	**9635066**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	**NO. ARMY**	**ARMY GALLONS**	**NO. USAF**	**USAF GALLONS**
SLCB JORGE WILSTERMAN, CO	1	390	26	44614
TIST ST. THOMAS	1	238	38	113958
TISX H.E. ROHLSEN APT/ST.	183	45487	291	1616114
VTBU U-TAPHAO, THAILAND	52	18295	277	2781267
YSSY SYDNEY IAP/SIDNEY______	1	640	1	451
0118 FLORALA MAPT	3462	390804	142	90003
0119 ANDALUSIA-OPP APT	4418	308370	32	18796
0602 PEUBLO MEM APT	168	26515	93	92619
0603 JEFFCO APT, DENVER	9	2007	4	1476
0604 CTY OF COLORADO SPRG	264	85386	200	273022
0608 WALKER FLD, GRAND JU	84	24976	182	71748
0610 LAKE CO. APT LEADVIL	111	19281	1	90
0613 DURANGO-LA PLATA CO.	22	6511	56	37592
0615 EAGLE CO REG APT, GY	966	114752	4	8221
0616 CENTENNIAL APT, DENV	22	4375	14	4463
0801 V.C. BIRD INTL APT	1	319	92	1007698
0802 GRANTLEY ADAMS INT A	14	5777	29	106579
0806 BERMUDA NAS/IAP (TXK	2	1044	17	65928
1040 EAGLE NEST HELIPORT	21	4825	1	163
1202 ELDORADO INT BOGOTA	22	2883	190	340983
1206 ERNESTO CORTISSOZ AP	5	2691	1	1334
1402 QUAD CITY APT, MOLIN	118	34436	94	48950
1404 U OF ILL, WILLARD FL	9	2126	2	8597
1407 CHICAGO MIDWAY APT	48	13700	47	36239
1408 GREATER ROCKFORD	14	3258	3	765
1409 ST LOUIS DOWNTOWN-PA	50	28619	16	41204
1410 ST LOUIS REG APT	31	6817	2	1687
1412 MT. VERNON-OUTLAND A	11	2003	2	385
1413 AURORA MUN APT	6	1423	1	500
TOTAL	**10116**	**1157948**	**1858**	**6815446**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	**NO. ARMY**	**ARMY GALLONS**	**NO. USAF**	**USAF GALLONS**
1420 WAUKEGAN REG APT	61	16391	10	3988
1501 DE LAS AMERICA INT	137	34590	5	1362
1504 INDIANAPOLIS INT APT	483	129116	40	102709
1505 HULMAN FLD, TERRA HA	14	1989	7	3538
1510 GARY MUN APT	15	3065	2	5170
1601 MARISCAL SUCRE, QUIT	5	810	111	186219
1602 SIMON BOLIVAR INT. G	8	2160	209	278787
1702 SALINA MUN APT	251	49040	134	96447
1705 FORBES FLD, TOPEKA	183	58250	44	127067
1707 WICHITA MID-CONTINEN	101	34900	31	9533
1708 MANHATTAN MUN APT	137	35319	64	84939
1803 BLUE GRASS FLD, LEXI	203	49356	9	11454
2301 W K KELLOGG REG APT	11	2638	4	6343
2305 KALAMAZOO/BATTLECREEK	18	2980	1	253
2306 CHERRY CAPITAL APT	33	4943	7	2708
2308 KENT CO INT APT, GRA	1	156	12	17065
2314 CAPITAL CITY AIRPORT	209	47473	15	6136
2401 DULUTH INT APT	8	1294	32	19797
2402 MINNEAPOLIS-ST PAUL	15	4630	61	97618
2501 LA AURORA, GUATEMALA	24	6003	16	44153
2503 KEY FLD MERIDIAN	322	140301	161	40378
2513 TRENT LOTT APT/PASCA	17	3568	5	1006
2601 LAMBERT-ST LOUIS INT	65	19786	178	185063
2610 RICHARDS-GEBAUR APT	107	30451	259	100435
2702 GALLATIN FLD, BOZEMA	23	3998	5	2109
2706 HELENA REG APT/HELE	177	43934	15	43151
2801 CENTRAL NEBR REG APT	63	14942	11	6022
2802 LINCOLN MUN APT	106	34690	121	58430
2804 EPPLEY AIRFLD, OMAHA	14	4588	17	11973
TOTAL	**2811**	**781361**	**1586**	**1553853**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	NO. ARMY	ARMY GALLONS	NO. USAF	USAF GALLONS
3004 PEASE ANGB	22	7505	82	242885
3402 PIEDMONT TRIAD INT A	211	50829	87	368136
3403 RALEIGH-DURHAM APT	152	35533	44	30251
3409 NEW HANOVER INT APT	166	45112	15	11555
3501 NORMAN MANLEY INT AP	116	15318	30	71102
3502 SNAGSTER INTL	68	16402	14	26239
3504 MINOT INTL APT	35	3442	30	121567
3601 AKRON-CANTON REG APT	41	9199	12	4556
3604 TOLEDO EXPRESS APT	94	14614	4	1591
3605 CLEVELAND-HOPKINS IN	13	1687	65	63417
3606 CINCINNATI MUN APT	102	15017	4	3380
3607 BURKE LAKE FRONT APT	12	3108	11	5348
3610 PORT COLUMBUS INT AP	30	6616	5	1622
3614 RICKENBACKER ANGB, C	182	39323	10	4485
3913 GEN C A SPAATZ FLG-R	60	10455	23	7096
4001 T F GREEN ST APT, WA	92	11743	54	102542
4101 GREENVILLE-SPARTANBU	250	67493	20	17147
4103 CHARLESTON AFB/INT A	101	24013	21	10062
4104 FLORENCE REG APT	338	73094	1	1538
4106 GRAND STRAND APT, MY	276	59026	21	7283
4201 JOE FOSS FLD, SIOUX	77	19232	33	18083
4408 MEACHAM FLD, FT WORT	44	30925	2	505
4703 RICHMOND IAP/BYRD FL	168	48221	45	52784
4706 WILLIAMSBURG IAP	174	52695	33	15321
4708 PRESTON GLENN FLD, L	68	13910	10	6868
5001 SILVIO PETTIROSI INT	47	8853	52	260932
5002 DANE CO. REG. TRUAX	167	42334	194	68044
5007 LA CROSS MUN APT	66	16494	21	30754
5010 GEN MITCHELL IAP (K	26	6132	20	19682
TOTAL	**3198**	**748325**	**963**	**1574775**

Table 7. INTOPLANE LOCATIONS WHERE ARMY AND AIR FORCE HAVE RECEIVED FUEL (continued)				
LOCATION	**NO. ARMY**	**ARMY GALLONS**	**NO. USAF**	**USAF GALLONS**
5101 NATRONA INT APT, CAS	52	11212	8	3278
5102 CHEYENNE MUN APT	181	46267	61	86298
5203 MANILLA IAP (RPMM)	1	2280	27	124360
6203 JOHAN A PENGEL (SMJP	3	4750	2	5188
6902 EL SALVADOR INT APT	48	10715	25	128802
7801 BANKOK INT APT	10	59249	166	372405
8701 PORT-AU-PRINCE INT A	23	6375	86	337601
9581 OWEN ROBERTS INT	9	3083	33	99463
TOTAL	**327**	**143931**	**408**	**1157395**
GRAND TOTAL	**58001**	**12272630**	**31209**	**58057145**
		212 GAL/EVENT		1860 GAL/EVENT

Although current Air Force policy does not require JP-8+100 by into-plane contracts, it is possible that such a policy will be generated. This requirement would be driven by the expanding use of JP-8+100 in Air Force aircraft systems. Given one of the ways into-plane contracts are used in supporting military exercises and areas of conflict, JP-8+100 will eventually be required for weapon systems deployed for use, even if the Air Force has to send personnel to inject the additive. Since Air Force and Army units will most likely be refueled from the same into-plane sites, it is likely that the Army will receive JP-8+100 either intentionally or inadvertently.

G JP-8+100 Fueling Impact

During Operation Eastern Rampage (26 September – 10 October 1999) an incident of JP-8+100 misfueling was recorded. The incident occurred at Standford Field, a commercial airport where common service (military and commercial aircraft) occurs. Air Force and Army fuel tankers received JP-8+100. These tankers then fueled Air Force and Army helicopters. It is not known if the JP-8+100 was used to fuel Army ground equipment. The Army Petroleum Center is investigating the incident. This incident illustrated that despite the procedures in place, JP-8+100 can reach Army equipment.

H. Summary of Risk

Army aviation assets appear to be the most at risk of inadvertently receiving JP-8+100 as nearly 80% of the retail level fuel transfer events from the USAF to the Army go to aircraft. Based on fuel volume transferred, approximately 35% goes to aircraft, while 48% goes to bulk. From an operational standpoint, in-transit refuelings and joint operations involving SOFs have the highest risk of receiving JP-8+100.

IV. TASK 2: ELASTOMER COMPATIBILITY

A. Aviation Materials

The approach taken to evaluate issues of materials compatibility between JP-8+100 and fuel systems of Army aircraft was to make maximum use of Air Force experience and testing and then determine if that covered all Army materials. The evaluation of the Air Force experience and testing was in two parts:

- The extensive materials compatibility testing conducted by the Air Force
- Air Force testing of engines and aircraft in the Army inventory

The Air Force considers that its materials compatibility study with JP-8+100 is the most extensive fuels compatibility study ever undertaken. They identified literally every element of the aircraft that fuel could (or does) accidentally come into contact with and conducted compatibility tests appropriate for that material. This included not only all of the elements of the various fuel systems in all of the aircraft in their inventory, but also any element that the fuel might be spilled upon such as paints and inks used on wing and fuselage surfaces.

Table 8 summarizes the categories of materials that were tested, including the number of materials tested within each category and a general listing of the materials tested within each category. Over 200 different material applications were tested. The details of the tests and the results are far too extensive to repeat here. It is sufficient to say that there were no instances where the *+100 additive* caused a failure of a compatibility test. Complete details of the materials, the tests conducted on each, and the results can be found on the website of the Air Force Fuels Branch (This is a secure web site, and permission to access the site must be obtained.)

Table 8. Synopsis of Air Force Materials Compatibility Tests for JP-8+100		
MATERIAL CATEGORY	**# TESTED**	**EXAMPLES**
Adhesives	9	Primers, Epoxies, Nitrile, Vinyl, Polyamide, Phenolic
Fuel Bladder Materials	14	Nitrile, Polyurethane, Various clothes
Fuel-Tank Interior Coatings	6	Nitrile, Polyurethane, Epoxy
Fuel Tank Sealants	12	Dichromate, Manganese, Polysulfide, Lead oxide, Fluorosilicone, Polyurethane, Polythiolether
Composites	5	Epoxy graphite, Graphite bismaliemide
Filter Materials	?	Phenolic, Latex, Acrylic, Glass, Various metals
Foams	6	Polyurethane
O-Rings & Gaskets	25	Buna-N, Fluorosilicone, Viton, Kalrez, Cork, Urethane, Teflon
Refueling Hoses	5	Nitrile, Epichlorohydrin
Electrical Insulation	9	Teflon, Nylon, Pylethylene, Vinyl, Plastic, Varnish
Welding Materials	14	2319, Ni alloys, Cu, Ti, Al, Stainless steels, Brazing solder
Airframe Coatings	9	Dry lubricants, Ink stamps, Pump bearings, etc
Thread Locking Compounds	3	Mil-S-22473 (Locktite, Red, Brown)
Airframe, Tank, & Plumbing Mat'ls	40	SS's, Ferous, Ni, and Cr steels, Ti, Cu/Ni,Cu/Al, Mg, Pb, Neodymium, Monel, & Brass
Fuel Lines & Fittings	25	Ti, Ni, Al, SS's, Ferrous, Ni, & Cr steels
Fuel-Control Floats	8	Nitrile, Polyurethane, & Cork
Potting Compounds	5	Epoxy, Polysulfide, Silicone, & Urethane
Total (approximate)	200	

The Air Force has the H-60 helicopter in its inventory and has made sure that all materials were included in the evaluation.

Likewise, the Air Force has overseen two non-military field demonstrations involving aircraft and engines common to the Army. The Aviation/Marine Squad of the Tampa, Florida, Police Department (TPD) and the Aviation Unit of the Hillsborough County Florida Sheriff's Office (HSCO) have experienced maintenance problems with Allison T63-A-720 engines that they felt could be reduced by the use of JP-8+100 and asked the Air Force to supervise an evaluation. These engines are used by the TPD and HCSO in OH-6 and OH-58 helicopters. A review of the materials on the fuel systems of these aircraft and engines were conducted before flight testing and found to be included in the Air Force materials evaluation program.

The only two other engines in the Army inventory are the T53 and T55 series engines, originally developed by Lycoming and now manufactured by Allied Signal. The list of materials evaluated by the Air Force was supplied to the engine project offices at Allied Signal who reviewed the list and passed it along to their vendors, most importantly for the fuel control systems. Allied Signal responded that they and their vendors were satisfied that all materials had been covered and that there would be no issues to prevent a flight test.

As a final point to address airframe fuel systems, all fuel bladders, fuel lines, transfer pumps, and valves are made by the same few companies whether used in Air Force or Army aircraft, and they have to pass the same fuel compatibility tests to be certified. Thus, it is very unlikely there would be any materials that are unique to the fuel systems of Army helicopters.

Thus, it is concluded that there are no materials compatibility issues with JP-8+100 for Army aircraft.

B. Ground Vehicle Materials

The approach was to determine if the materials compatibility testing of JP-8+100 by the U.S. Air Force included all the fuel system materials in representative Army ground vehicles. The following represent Army ground equipment families included in the study:

- FMTV, M1083, Caterpillar 3116 engine
- 900 Series Truck, Cummins NHC 2500 engine
- M1 Abrams Tank, AGT-1500 engine
- Bradley Vehicle, M2, Cummins VTA903T engine
- M113 APC, DDC 6V53T engine
- HMMWV, GM 6.2L engine

Three methods of identifying materials of Army vehicle fuel systems were developed. First, the engine or fuel system component manufacturer of each vehicle was contacted to obtain materials information. Second, lists of elastomeric and other fuel system components of selected vehicles were compiled and compared to the USAF list. Finally, the summarized list of USAF materials that had been tested was sent to the PM offices of the selected equipment families for review and comparison with the materials used in their equipment.

1. Engine and Fuel System Manufacturers

The engine and fuel system manufacturers of the selected ground vehicles were contacted and asked to supply information on elastomeric and other materials used in the fuel system of their respective vehicle. The first step in this process was to identify contacts with the manufacturers. TFLRF contacted military customer support personnel at these corporations. If a contact at the manufacturer was not known, the PM office of the respective vehicle was contacted, and the name and contact information of a representative at the engine manufacturer was obtained. If the PM could not provide useful information, the technical customer support telephone line was used. The military contacts or customer support personnel were asked to supply a reference to a technical representative or an engineer with knowledge of elastomeric components of the respective engine or fuel system. This engineer or technician then supplied TFLRF with a comprehensive list of elastomers and other materials used in the engine and/or fuel system component that they manufacture.

Based on discussions with ground equipment manufacturers, the most common fuel system elastomers are nitrile (BUNA-N) or fluorocarbon (Viton), both of which have been successfully tested by the USAF for compatibility with JP-8+100.

2. Fuel System Diagrams

Complete fuel system diagrams for most military vehicles are located in standard Army parts manuals. The diagrams are generally located in section two of the -20P or -24P manuals. These diagrams include detailed schematics and comprehensive parts lists of the entire fuel system. The fuel system section generally includes information on the fuel tank, lines, injectors and other components. These diagrams were obtained and scanned for elastomeric components. The part number of a component was noted if it 1) was believed to be composed of elastomeric material, and 2) appeared to be exposed to fuel under typical operation.

After a master list of elastomeric components was formed for the representative vehicles, the FED LOG software program was used to find the NSN, more detailed description, and the specific type of elastomer material of each part. The elastomer type was compared with the list of products tested by the Air Force. The parts were then divided into three categories: parts that have been tested by the Air Force, parts that have not been tested by the Air Force, and parts that could not be classified as tested or not tested.

3. Solicitation of Project Managers

The Project Manager offices of the selected vehicles were contacted and asked to assist TFLRF in the review of elastomeric and other fuel system components of their vehicle. Known contacts and the www.tacom.army.mil internet site were used to locate telephone numbers and e-mail addresses of various members of the PM teams. The first objective was to contact the Technical Director or Assistant Project Manager of each PM office. If this individual could not be reached, an engineer was contacted. Once the Assistant PM or engineer was contacted, they were provided with background information on the project and asked for assistance. The PM offices were asked to review the list of elastomers and other materials tested by the Air Force and compare the list to the elastomer and other materials used in the fuel system of their respective vehicle. They were also asked to inform TFLRF of any elastomer or other materials used in their vehicle that were not tested by the Air Force. The Technical Director or Assistant Project Manager would then assign the work to an engineer in the PM office or solicit assistance from the vehicle's manufacturer. Two of the five Project Manager offices pursued provided TFLRF with feedback.

a. PM Abrams Tank

The PM Abrams Tank provided TFLRF with a detailed list of elastomeric fuel system components of the M1 Abrams Tank. Team Tank's approach was similar to that used by TFLRF in identifying elastomeric and other fuel system components. Team Tank reviewed fuel system diagrams and noted parts that 1) were believed to be composed of elastomeric material, and 2) appeared to be exposed to fuel under typical operation. Although the fuel system diagrams reviewed by TFLRF, which are located in Technical Manuals, are believed to be comprehensive, Team Tank's review may be more thorough due to their access to a variety of schematics and other information on the fuel system. As a result, Team Tank identified several more elastomeric materials in the fuel system of the M1. Furthermore, information on materials that could not be classified by

TFLRF, such as parts with no material information, was found by Team Tank. This allowed many parts that were not classified by TFLRF to be placed in the "tested" section.

Materials found in the fuel system of the M1 that have been tested by the Air Force include Locktite retaining compound, polyethylene, cork, fluorosilicone and fluoropolymer molding as well as Buna-N and Fluorocarbon. Additional materials that could not be classified as tested or not tested include a thread locking compound, cellular rubber, expanded plastic and rubber coating. Many of these items can not be classified because the specifications that govern them contain information on several materials, some of which have been tested by the Air Force and some that have not. Additional materials that have not been tested by the Air Force were also identified: Fiberfrax duraboard insulation; polyvinylidene fluoride, chloroprene, and polychloroprene.

b. PM M113 Armored Personnel Carrier

The PM Office of the M113 Armored Personnel Carrier and the vehicle manufacturer, United Defense, L.P. (UDLP) provided TFLRF with useful information on a number of fuel system components of the M113A3. First, the PM office was contacted and asked for assistance. They solicited the help of UDLP, who compiled a list of elastomeric and other parts and compared the list to those tested by the Air Force. Although UDLP's list of elastomeric and other parts was substantially smaller than TFLRFs, it provides a great deal of useful information. UDLP has access to more detailed drawings and information than TMs provide. Therefore, UDLP may have been able to identify elastomeric components that TFLRF could not. Polybutene and chlorinated polyolefin are two elastomeric materials identified by UPLP that were not tested by the Air Force and not identified by TFLRF. A caulking compound governed by TT-C-1796 and composed of oil base material, siliconized-acrylic latex, butyl rubber or 100% silicone can not be classified as tested because all of the possible compositions have not been tested.

Table 9 shows the materials identified that require compatibility testing with JP-8+100.

Table 9. Materials Requiring Compatibility Testing	
Material	**Vehicle Series**
Asbestos gasket material	HMMWV, M1, M113
Chloroprene/Neoprene/Polychloroprene	Bradley, M1, M113
Polycaprolactam rubber	M113
Isobutylene-Isoprene rubber	M1
Polyvinylidene Fluoride	M1
Fiberfrax Duraboard Insulation	M1
Chlorinated Polyolefin	M113
Polybutene	M113

It was confirmed with a representative at the University of Dayton that these materials were not tested in the USAF/University of Dayton JP-8+100 materials compatibility program.

Overall, most of the fuel wetted materials of representative Army ground vehicles were tested by the Air Force and found to be acceptable. A relatively small number of materials shown in Table 9 have not been tested. It is recommended that the materials in Table 9 be tested for compatibility with JP-8+100 following the procedures used by the Air Force. Acceptable compatibility performance of these materials would complete the materials compatibility tests required for JP-8+100 approval for Army ground vehicles.

V. TASK III: COST-BENEFIT ANALYSIS

A. Aviation Results

The experience of the U.S. Air Force has shown that the use of JP-8+100 not only increases the life of fuel nozzles but has demonstrated the unexpected benefit of reducing carbon deposits throughout the combustion chamber, most notably on:

- the exterior face around the exit orifice of the fuel nozzle,
- the swirl cups surrounding the fuel nozzle,
- liner walls
- gas producer nozzle guide vanes
- turbine blades, and
- exhaust surfaces

The first two of these, combined with fuel nozzle fouling, can lead to serious loss of hot section life through hot streaks impinging on combustor liner walls and first-stage nozzle guide vanes, and by accelerating high-cycle thermal fatigue of the turbine blades.

Deposits that form around the exit orifice of a fuel nozzle can seriously distort the fuel spray and lead to hot streaks. Figures 8 and 9 are photographs of two swirl cups and fuel nozzles from different T55 combustors that were submitted to Corpus Christi Army Depot (CCAD) for maintenance. Figure 8 shows a “flower” of hard carbon adjacent to the fuel nozzle; deposits such as this were typical of most of the swirl cups on all of the combustors viewed at that time at CCAD. If these grow large enough, they can block the fuel spray in local areas. Clean spots are evident on the swirl cup where chunks have broken off, perhaps causing erosion of guide vanes and turbine blades as they passed through the turbine. Figure 9 is the more extreme case where the deposit has grown and actually extends out over the exit of the fuel nozzle partially blocking the fuel spray. This certainly would cause a distorted fuel spray that could impinge on the combustor wall causing burn-through; if the hot streak extends further downstream, it could impinge on nozzle guide vanes and cause them to burn off. Figure 10 is a photograph of a spot on the liner of a T55 combustor that has blistered and is about to burn through; the dome and swirl cup is visible on the left side of the picture. If, as the Air Force has found, JP-8+100 will reduce combustion chamber deposits in Army aircraft turbine engines, the life of combustion chambers and nozzle guide vanes could be extended, thus reducing maintenance costs.

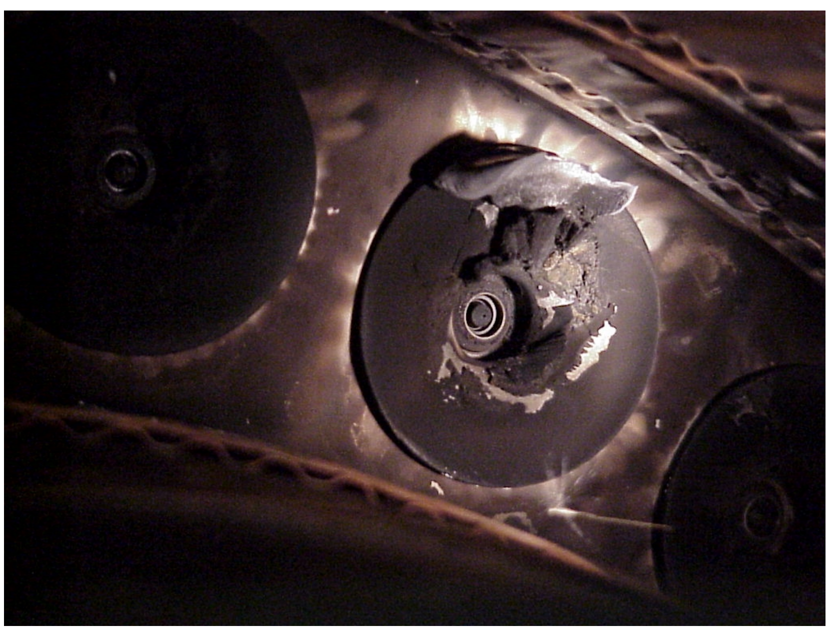


Figure 8. Coked Fuel Deposits on Swirl Cup of T55 Combustor

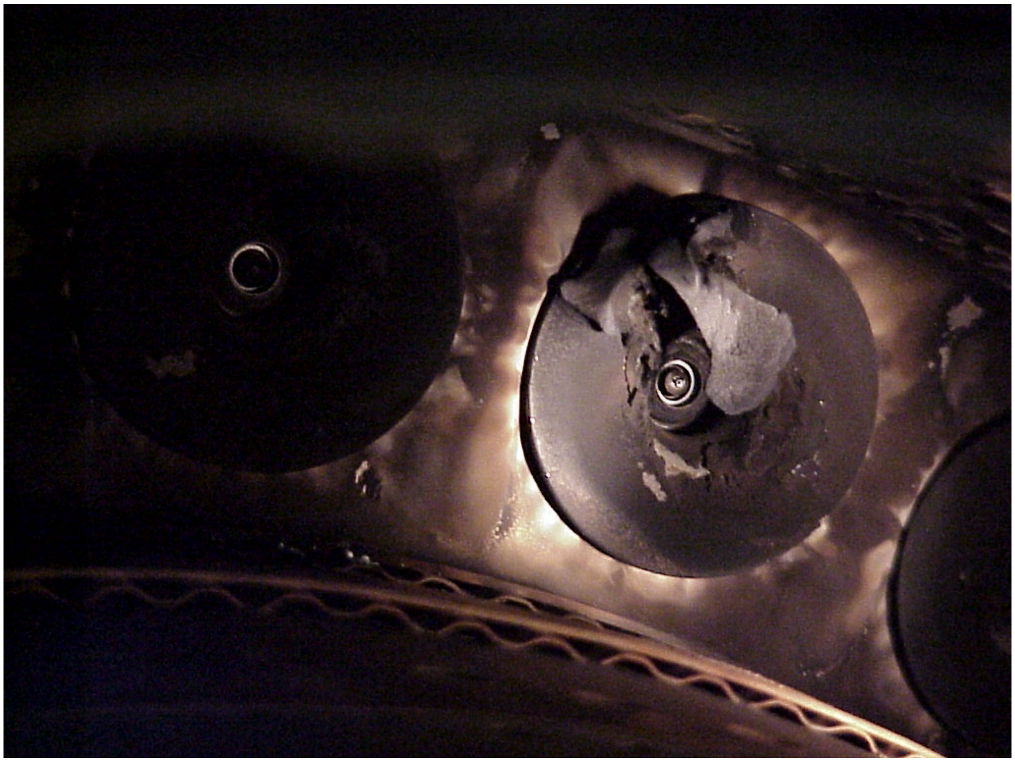


Figure 9. Coked Fuel Deposit on Swirl Cup of a T55 Combustor

Figure 10. T-55 Liner distress Due to a Hot Streak

High-cycle thermal fatigue of the turbine blades is caused by alternating stresses as the blades move through exhaust gases of varying temperature. Engine companies go to great lengths in combustor design to ensure uniform exhaust temperature profiles to prevent this. Three of the Army's four aviation turbine engines, i.e., T53, T55, and T700, have annular combustors with multiple fuel nozzles distributed around the dome of the annulus. The nozzles in a given engine will generally not have the same thermal environment and will potentially experience different fouling rates according to their temperatures. Since the pressure drops across the fuel nozzles are the same, the variance in fouling will lead to disparities in the fuel flow rates among the nozzles and non-uniformities in the temperature distribution around the exhaust plane. Thus, JP-8+100 can be potentially effective at increasing the life of turbine blades where high-cycle thermal fatigue is the life-limiting factor.

Excessive soot formation can also lead to the clogging of cooling passages in guide vanes and turbine blades causing them to overheat and fail prematurely. Again, JP-8+100 could have a positive effect on maintenance costs.

While the above discussion identifies several failure modes in the hot section that could be reduced by JP-8+100, it is not possible to conduct a complete cost-benefit analysis. This is because the Army does not maintain a maintenance database through which one can identify fuel nozzle fouling or combustion chamber deposits as a root cause of failure. It is only possible to determine the amount of money that the Army spends on unscheduled maintenance of these items and judge whether that potential savings is 1) a significant number, and 2) larger than the cost of implementation.

According to the previous discussion, the four maintenance items that would be impacted by JP-8+100 are the following:

- fuel nozzle
- combustion chamber liner
- 1st-stage gas producer guide vanes
- 1st-stage turbine rotor assembly

There is no scheduled maintenance for these parts; therefore, all replacement/repair is unscheduled maintenance, i.e., Average Monthly Demand (AMD) is all unscheduled. Unscheduled maintenance rates can be determined from the charts of these items and the item costs. Table 10 summarizes the replacement rates for unscheduled maintenance of the above four items and their replacement cost for the various engines and models in the Army inventory. The sum of these results shows that there is a potential reduction in hot-section maintenance costs of approximately 32 million dollars per year. This does not include maintenance actions where the part was simply repaired such as welding up a crack in a combustor liner. The cost of labor was not included because standard labor requirements to remove and replace maintenance items are not available for all items on all engines, and cost of labor is not uniform. Where the cost of labor could be determined it was only about one percent of the item cost and therefore not significant within the uncertainties of this analysis.

The pie charts of Figure 11 summarize the relative importance of these costs. Most of the unscheduled replacement costs of the four items in this analysis are associated with the T700 gas generator rotor/stator assemblies that account for almost 80 percent of the total.

Table 10. Summary of Hot-Section Parts, Replacement Rates, and Annual Costs

ENGINE/AIRCRAFT	NSN[1]	AMD[2] #/mo	COST EACH	TOTAL COST PER YEAR
T53-L-13B/UH-1H				
Fuel Injector	2915-00-944-7295	20[3]	$ 124	$29,931
Combustion Chamber Liner	2840-00-943-2375	1.63	$ 399	$7,804
1st-Stage GP Nozzle Assy	2840-00-570-9803	2.11	$ 448	$11,343
1st-Stage Turbine Rotor Assy	2840-01-031-8758	0.59	$1,048	$7,420
T53-L-703/AH-1				
Fuel Injector	2915-00-944-7295	20[3]	$ 124	$29,931
Combustion Chamber Liner	2840-01-010-5841	0.74	$ 3,531	$31,346
1st-Stage GP Nozzle Assy	2840-01-008-5985	1.12	$10,121	$136,031
1st-Stage Turbine Rotor Assy	2840-01-010-1450	0.21	$14,560	$36,691
T53 Total				$290,479

Table 10. Summary of Hot-Section Parts, Replacement Rates, and Annual Costs				
ENGINE/AIRCRAFT	NSN[1]	AMD[2] #/mo	COST EACH	TOTAL COST PER YEAR
T55-L-712/CH-47D				
Fuel Injector	2915-01-342-0236	32	$ 388	$ 74,195
Combustion Chamber Liner	2840-01-128-6611	1	$ 26,875	$ 322,500
1st-Stage GP Nozzle Assy	2840-01-242-1759	4.67	$ 21,232	$ 1,189,841
1st-Stage Turbine Rotor Assy	2840-01-177-9015	0.88	$ 68,935	$ 727,954
T55-L-714/CH-47E				
Fuel Injector	2915-01-342-0236	(Too		
Combustion Chamber Liner	2840-01-458-9984	new,		
1st-Stage GP Nozzle Assy	2840-01-461-4685	no AMD		
1st-Stage Turbine Rotor Assy	2835-01-199-7697	available)		
T55 Total				$ 2,389,287
T63-A-720/OH-58				
Fuel Injector	2915-01-039-4730	1.77	$ 1,070	$ 22,875
Combustion Chamber Liner	2840-01-170-6514	0.06	$ 3,010	$ 2,167
1st-Stage GP Nozzle Assy	2840-01-175-0797	0.11	$ 3,446	$ 4,547
T63 Total				$ 41,762
T700-GE-701/AH-64				
Fuel Injector	2915-01-247-7136	36.92[5]	$ 167	$ 74,195
Combustion Chamber Liner	2840-01-344-5923	1.78	$ 16,266	$ 347,442
1st-Stage GP Nozzle Assy	2840-01-241-7465	6.04	$ 18,684	$ 1,354,216
1st-Stage Turbine Rotor Assy	2840-01-087-1845	11.21	$ 89,068	$11,981,427
T700-GE-700/UH-60				
Fuel Injector	2915-01-247-7136	36.92	$ 167	$ 74,195
Combustion Chamber Liner	2840-01-281-3617	0.23	$ 8,617	$ 23,783
1st-Stage GP Nozzle Assy	2840-01-419-2225	1.26	$ 26,957	$ 407,590
1st-Stage Turbine Rotor Assy	2840-01-120-7673	3.30	$ 111,920	$ 4,432,032
T700-GE-701C/AH-64D				
Fuel Injector	2915-01-304-4299	27.08	$ 307	$ 99,763
Combustion Chamber Liner	2840-01-304-4302	0.92	$ 13,807	$ 152,429
1st-Stage GP Nozzle Assy	2840-01-317-1933	1.67	$ 13,687	$ 274,287
1st-Stage Turbine Rotor Assy	2840-01-305-2444	7.66	$ 106,616	$ 9,800,143
T700 Total				$29,021,502
Grand Total				$31,743,030

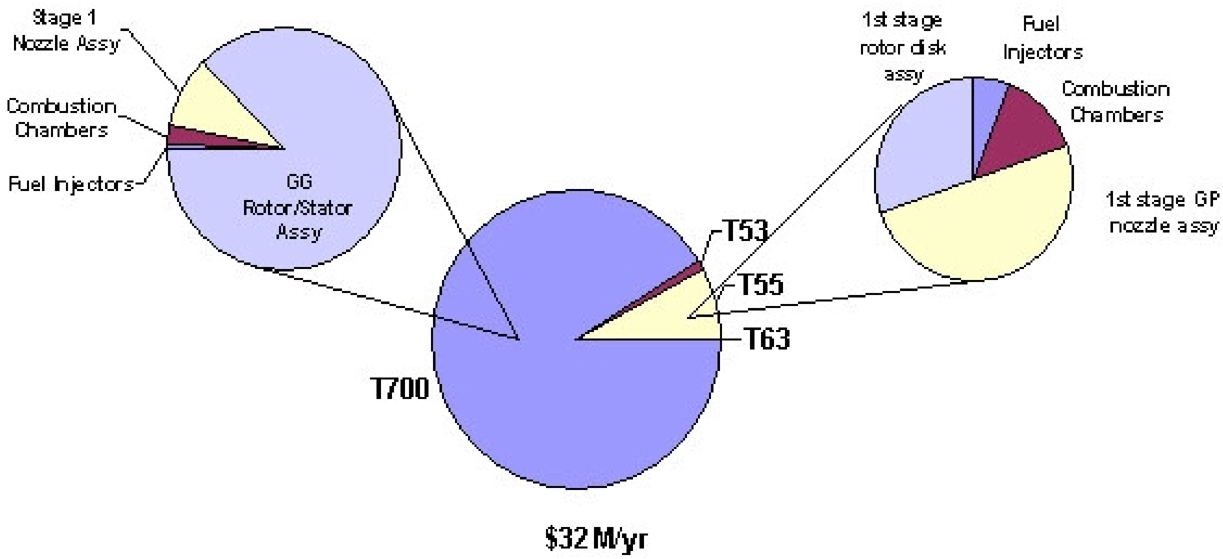


Figure 11. Distribution of Unscheduled Hot-Section Maintenance Costs of Army Helicopter Engines

Weighed against this potential reduction in maintenance costs of $32 million are the first-time costs of installing an additive injection system. Based on Air Force experience, it was estimated that the cost of setting up the additive blending equipment would be $30,000 per unit. Additional details are presented in Section B.5. Since the DESC provides the additive at no cost to the unit, there will be no increase in fuel cost.

In summary, while it is not possible to develop a definite cost benefit, the potential savings in maintenance costs of $32 million per year is quite significant and the investment is relatively small. Thus, even if only a small fraction of the potential cost savings is realized, there will still be a significant cost benefit. The only way of verifying this potential cost savings is to conduct a field demonstration with an Army air unit and keep track of unscheduled maintenance costs and aborts to compare with historical maintenance records of the unit and/or those of other units.

B. Ground Equipment

As an initial approach to calculate the cost benefit, if any, of using JP-8+100 in ground equipment, visits to selected installations were coordinated through the G-4 Staff and TACOM Logistics Assistance Officers to meet with maintenance personnel to brief them on the Air Force and Army JP-8+100 programs. The briefing first described the Air Force program to develop JP-8+100 and defined why the Army might be at risk. The second part of the briefing described the current program to determine the risk by identifying issues and concerns and our approach toward developing a cost analysis and defining a test program that would lead to an Army decision on the acceptance and/or use of JP-8+100. Discussions ensued with key maintenance personnel to ascertain whether problems existed with the use of JP-8 in the different diesel engines powering the fielded ground equipment. Discussions centered on fuel injectors and hot section turbine and diesel components insofar as carbon and soot buildup where the use of JP-8+100 could potentially be beneficial. Following the discussions, visits were made to selected maintenance facilities to inspect on-board and bulk fuel tanks and hot section components. Inspections were conducted using a high-powered light source and fiber optics borescope equipment.

1. Installations Visited

The diversity of equipment found in the following installations was the main criterion for the selection and subsequent visits to the following installations:

- Fort Hood, TX
- Fort Stewart, GA
- Fort Campbell, KY
- Anniston Army Depot

2. Inspection Parameters

Inspection parameters included on-board and external fuel tanks for fuel clarity, sediment and debris. The rationale for inspecting these components was that if sediment and debris were present in the fuel tanks, then the characteristic of particle suspension in JP-8+100 could possibly cause filter plugging. Also, if water contamination were present, the dispersant/ detergent compound in the *+100 additive* would disable water separators in fuel systems allowing the passage of water and possibly fine particulate into fuel injection systems and engines.

Hot section components in turbine and diesel engines were inspected for carbon accumulation, soot buildup and thermal damage. The presence of these parameters would indicate that the cleansing action of the *+100 additive* would be beneficial for these systems.

3. Equipment Selected for Inspection

The following combat and tactical vehicles and miscellaneous equipment were selected for inspection due to the high density in the Army inventory:

- M1A2 Abrams Main Battle Tank
- M3A2 Bradley Fighting Vehicle
- M113A2 Personnel Carrier
- HEMTT Series 10 Ton Trucks and Tankers
- M35A2 Series 2 ½ Ton Trucks
- M39A2 Series 5 Ton Trucks
- LMTV Series 2 ½ Ton Trucks
- MTV Series 5 ton Trucks
- HMMWV Series Vehicles
- M976A1 Trailer Tanker, Fuel, 5,000 Gallons
- Pod Fuel, 600 Gallon Fuel Systems
- Extended Range Fuel System (ERFS) 600 Gallon Steel Tanks
- Collapsible Fabric Drums
- Forward Area Refueling Equipment (FARE)
- M1A2 Nozzles and Combustion Chambers
- Fuel Injector Assemblies - AVDS 1790, DD8V92, 8V71T, DD6V53, NHC250, GM 6.2L

4. Findings

All on-board fuel tanks on ground equipment were found to be extremely clean and free of sediment and debris. No evidence was found that the introduction of JP-8+100 due to its cleansing effect on fuel systems would be expected to cause problems with filter plugging. The HEMTT fuel tankers, M976A1 Trailer Fuel Tankers, and the 600-gallon Fuel Pod Systems were also found to be extremely clean. The only evidence of debris and water contamination was found in the 600 gallon ERFS used with the forward area refueling system on the CH47 Chinook helicopter. However, the steel tanks are bottom drained prior to use for refueling; thereby, eliminating the possibility of fuel contamination.

In addition to discussions with installation maintenance personnel concerning turbine and diesel hot section carbon and soot buildup, visits were made to depot repair facilities at Anniston Army Depot, AL, Directorate of Logistics Maintenance Division, and the 4th Infantry Division general and depot repair facility at Ft. Hood, Tx. It is at these locations that an accurate assessment could be made concerning the condition of hot section components sent in for repair from installations throughout CONUS. Engineering staff for the different power plants in combat and tactical vehicles at Anniston Army Depot and Fort Hood, collectively opinioned that hot section components that are received at the depot and maintenance facilities do not show evidence of carbon and soot buildup. Approximately 2 percent of the damaged combustion chambers are due to carbon deposits, which result in irregular nozzle spray patterns on the AGT1500 turbine engine. The most prevalent cause of damage is due to hot starts and hydro-mechanical unit over fueling conditions. These anomalies not only cause combustion chamber damage, but also damage scroll assemblies, curl rings, and 1st stage nozzle assemblies. Figures 12-14 show damages caused from an explosion in the combustion chamber resulting from a hot start attempt. Figures 15 and 16 show a typical serviceable curl ring assembly and a hot start damaged curl ring assembly. Figure 17 shows a hot start damaged 1st stage nozzle assembly. A large number of AGT1500 fuel nozzles were inspected for evidence of soot and carbon build-up, which might distort the fuel spray pattern and cause combustion chamber burn-through. There appears to be no indication that these factors are a problem. Personnel at the facilities stated that nozzle fouling problem in the AGT 1500 engine was solved with the introduction of the two-stage nozzle. Figures 18 and 19 show a typical serviceable nozzle and one damaged by a hot start. Numerous diesel engine injectors were inspected at the Anniston and Ft. Hood facilities. Figure 20 shows the typical condition of the injectors inspected for the AVDS1790 engine, which powers the medium recovery and bridge launching tracked vehicles. Figure 21 shows a series of three Detroit Diesel self-metering injectors found in the two-cycle engines that power various tracked and wheeled vehicles and a variety of ground support equipment. Figure 22 is a close-up of the spray tip on the self-metering injector. Finally, Figure 23 shows a series of three injectors for the Cummins engine that also powers several tracked and wheeled vehicles and a myriad of ground support equipment in the Army inventory.

Figure 12. AGT 1500 Engine Combustion Chamber

Figure 13. AGT 1500 Engine Combustion Chamber

Figure 14. AGT 1500 Engine Combustion Chamber

Figure 15. Typical Serviceable AGT 1500 Engine Curl Ring Assembly

Figure 16. Hot Start Damaged AGT1500 Engine Curl Ring Assembly

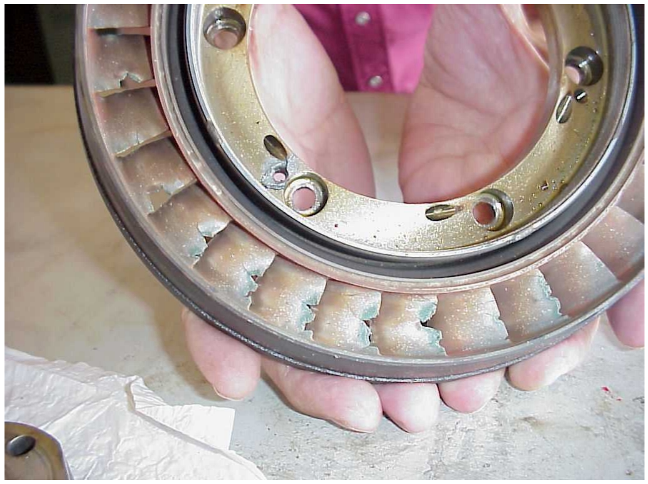


Figure 17. Hot Start Damaged First Stage Nozzle Assembly

Figure 18. Typical Serviceable AGT1500 Engine Nozzle Assembly

Figure 19. Hot Start Damaged AGT1500 Engine Nozzle Assembly

Figure 20. Typical Serviceable AVDS1790 Engine Injector

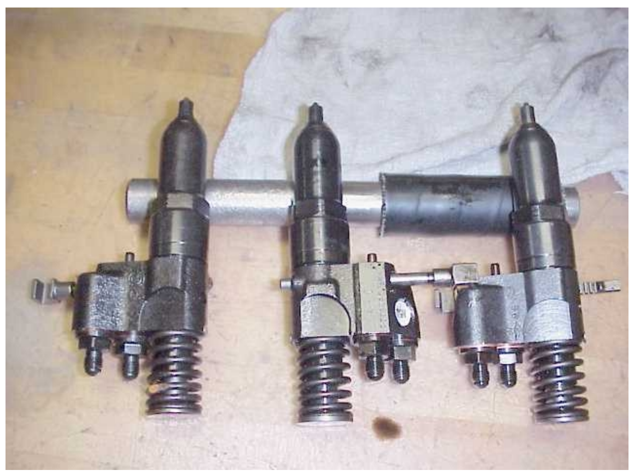


Figure 21. Typical Serviceable Detroit Diesel Engine Injectors

Figure 22. Close-up of Detroit Diesel Engine Injector

Figure 23. Typical Serviceable Cummins Engine Injectors

From the inspections conducted, it was concluded that 1) vehicle on-board fuel tanks, tankers, pods, and other fueling equipment showed that the introduction of JP-8+100 would not be expected to result in filter plugging, and 2) no evidence was found where JP-8+100 would be beneficial if used in ground vehicles and ground support equipment.

5. JP-8+100 Implementation Costs

Early into the program it was concluded that the hot section component cleansing benefits associated with the use of JP-8+100 in several engines powering Air Force aircraft were not identified in ground vehicles. However, since the potential existed that the use of the *+100 additive* in rotary and fixed winged aircraft in the Army inventory may in fact reduce maintenance costs, implementation costs were calculated to determine the impact to the Army should a decision be reached to adopt JP-8+100. Also considered was the possibility of ground equipment exposure to JP-8+100 during joint exercises.

a. Setup and Hardware Costs

The cost of setting up the apparatus to inject the *+100 additive* to JP-8 fuel was estimated at $30,000 per installation. The following items were considered in the setup total:

1. Fuel Injector Stand
2. Hose Cart and Hydrant Service Unit
3. Containment and Platform Stand
4. 1000-Gallon Additive Tank
5. Equipment Installation Cost

b. Additive Cost

At current cost, the price of the additive is approximately $26 per gallon. At a blending of 256 ppm per gallon, the total fuel price increases to 0.7 cents per gallon.

c. Cost of Filter / Coalescer Retrofit

Surfactant in the *+100 additive* package disables vehicle onboard water coalescers used to separate water from the fuel as it passes through the vehicle's filtering system. Therefore the cost of retrofitting the entire Army inventory of combat and tactical vehicles with a new generation of filter/coalescers was calculated. The cost was estimated at $18 million for combat tracked vehicles and $44 million for tactical wheeled vehicles. The assumption was for a complete filter/coalescer retrofit prior to the introduction of JP-8+100 to prevent the passage of water, which could seize injection pumps and injectors in diesel engines shortly after introduction. Replacement cost was determined by multiplying the present cost of filter/coalescers for the different vehicle models by the Army's equipment density and then doubling the cost to allow for the incremental cost of *+100* compatible filter/coalescers over current components. Not included in these calculations are filter/coalescers in ground support equipment.

d. Additional Costs

Initially, the assumption was made that the Army would incur additional costs for replacement of plugged filters due to the suspension of particles and sediment caused by the surfactant in the *+100 additive*. However, inspection results of vehicle on-board fuel tanks, tankers, pods, and other fueling equipment did not support our initial assumption.

Bulk fuel distribution systems were not included in our investigation. Additional costs may be incurred if the JP-8+100 were distributed through the existing bulk systems.

6. Conclusions and Recommendations – Ground Equipment

- Inspection of vehicles and equipment concluded that engine cleanliness is not a root cause of maintenance actions
- No cost benefits were identified to support JP-8+100 implementation
- Current filter/coalescers will be disabled if JP-8+100 is used
- JP-8+100 should not be adopted for ground equipment

VI. TASK 4: SHORT-TERM IMPACTS

A. Aviation

The purpose of this investigation was to identify possible concerns other than materials compatibility issues, i.e., operational concerns and issues unique to the Army that were not covered in the Air Force investigations of JP-8+100. Four issues were identified:

- open-air refueling
- Forward Area Refueling Equipment (FARE)
- accidental refueling of Army helicopters with JP-8+100
- defueling JP-8+100

1.Open-air refueling

The concern about open-air refueling was identified as a concern because in the past, open-air refueling of Army helicopters was very common, and the potential for dirt and other foreign objects in the fuel tank was quite high; also, humid air was a source of water contamination. One of the side issues with the *+100 additive* package is that it contains a very powerful surfactant. It is known from Air Force experience that use of JP-8+100 will clean fuel systems and suspend fine particles in the fuel. Thus, if there were fine silt in the bottom of the fuel bladders, there is a strong possibility it would become dispersed into the fuel and accelerate filter plugging. Pressurized refueling of helicopters has been standard practice since the late 1980s. Open-air refueling is now only used if there is a malfunction of the pump or valve, a relatively rare occurrence. Nevertheless, it seemed prudent to inspect the condition of fuel bladders on various helicopter types under different climactic conditions, i.e., dry and dusty vs. humid. Visits were made to Ft. Rucker (Al), Ft. Campbell (Ky), Ft. Hood (Tx), and Ft. Stewart (Ga). At each, as many types of aircraft as possible were inspected for debris in the fuel cells. This was done either by boroscope or direct visual and physical inspection when the fuel cells were found empty. With one exception, all aircraft were found to have fuel cells that were free of silt and debris. The one exception was a CH-47 that had what appeared to be small metal filings distributed on the bottom, perhaps wear metal from abrasion. The inspections were extended to refueling trucks and the 600-gallon fuel cells used on CH-47s for forward area refueling. The fuel tanks were found to be free of silt or debris; the tanks in the refuelers were bright and shiny.

This is not to say that there aren't helicopters with silt in the bottom of the fuel cells, but it would appear they are the exception.

2. FARE systems

The concern about the FARE systems is that they contain a filter coalescer for removing any water that might become entrained in the fuel after it was put in the fuel cell. If there were an influx of humid air with altitude changes, moisture could drop out upon cooling. The surfactant in the *+100 additive* package disarms standard filter coalescers so that water would then pass through.

The evaluation of a FARE was not within the scope of the program, so they remain an issue that should be evaluated in any follow-on study.

3. Accidental refueling with JP-8+100

Army helicopters are most likely to be accidentally refueled with JP-8+100 during joint exercises with the Air Force; other possibilities include transient aircraft at air bases, Air National Guard bases, or civilian airports with military into-plane contracts. The question is what to do and what not to do, from a technical standpoint.

The fact that there are no compatibility or performance problems with any aircraft systems eliminates any concern for operational problems. The one exception is if the aircraft has a dirty fuel tank, in which case the filter might go into premature bypass. This seems unlikely based on the state of cleanliness found in helicopter fuel cells. Therefore, it is concluded that it would still be safe to operate the aircraft and burn the fuel off rather than delay the mission by defueling and refueling. Some airports may not be equipped to defuel JP-8+100. There are no concerns about refueling the aircraft with

JP-8 since JP-8 and JP-8+100 are completely miscible and compatible. The pilot should make a note of the accidental refueling with JP-8+100 and report it upon returning to base to avoid any defueling problems.

If the aircraft makes it back to base without having to refuel again, it will still have JP-8+100 in the fuel cells. Since no Army base is prepared to defuel JP-8+100, it is best to simply refuel with JP-8 and continue to fly. After two or three refuelings, the JP-8+100 will be sufficiently diluted as to be ineffective.

4. Defueling

The problem with defueling JP-8+100 is that if simply mixed back into a storage tank, it will contaminate the fuel in the tank and potentially cause problems with filter-coalescer units. If defueling an aircraft accidentally contaminated with JP-8+100 is necessary, the fuel should be either defueled into another aircraft or disposed of as hazardous waste.

B. Army Ground Vehicle Evaluations

The evaluation of short-term effects of JP-8+100 on Army ground vehicles was reported separately in TFLRF Report No. 347, entitled "Initial Effects of Converting Army Diesel Powered Ground Vehicles to Operate on JP-8+100 Fuel." The work and results are summarized as follows.

Several diesel-powered vehicles obtained from a local Army reserve unit were tested using commercially available particle-counting equipment. Fuel-borne particle counts were recorded for each vehicle, first utilizing the original diesel fuel then switching to JP-8+100. Data collected from these experiments were then compared for any increase or decrease in fuel-borne contaminants resulting from the introduction of JP-8+100 to the fuel system. Fuel samples collected from each test case were also evaluated in the laboratory for water and gravimetric particulate content.

This project resulted in a set of data that documents the effect on fuel-borne contaminant levels resulting from operation of a previously diesel-fueled vehicle with JP-8+100 aviation fuel. The collected data illustrate that there is generally an observable increase in fuel-borne particulates during the initial circulation of JP-8+100 throughout vehicle fuel systems previously operated on diesel fuel for extended periods of time. The laboratory analyses of the collected fuel samples also show that there is generally an increase in the fuel-borne water content when a vehicle is converted to operation with JP-8+100.

The results of this project show that some diesel vehicles may be at risk for increased fuel-injection system contamination and wear when initially exposed to JP-8+100 aviation fuel.

VII. CONCLUSIONS

The Army is at potential risk of exposure to JP-8+100 because of the large number of fuel transfers from the Air Force. Eighty percent of the transfers go to Army aviation. Army Special Forces are considered to be most at risk because the Air Force is responsible for delivery and refueling in some operations. Special care must be taken during planning and liaison to avoid these refuelings.

Accidental refueling of Army ground equipment could be detrimental if not prepared, and could lead to immediate shutdown. If there is any water in the fuel tank, it will be picked up and dispersed into the fuel by the surfactant in the *+100 additive* package. Furthermore, the water coalescer onboard the vehicle will be disarmed by this same surfactant. Thus the water will pass through to the pump and injector system where it could cause immediate damage to some systems. Although a new generation of coalescers has been developed, it would be expensive to retrofit all Army ground equipment. No potential benefits of JP-8+100 could be identified for Army ground equipment.

JP-8+100 is not detrimental to the performance, reliability, or safety of Army aircraft. There is a potential for significant savings of unscheduled hot-section maintenance of T700 engines. There are some unique operational concerns, notably with defueling and FARE systems. The JP-8+100 should simply be burned off in flight; defueling should be avoided, but can be accomplished into another aircraft if necessary. Operational aspects of FARE systems with JP-8+100 would have to be evaluated before the Army could adopt JP-8+100 for aviation use. A field demonstration is necessary to verify the potential maintenance savings; FARE operations could be evaluated at that time.

Army Special Forces were briefed on the risk of exposure to JP-8+100 when operating with the Air Force, and guidance was provided on how to minimize risk to a mission.

VIII. RECOMMENDATIONS

It is recommended that the Army maintain its “no-use” policy for JP-8+100. Although JP-8+100 is not detrimental to the performance, reliability, and safety of Army aircraft, there is no firewall to guard against contamination of Army ground equipment. Furthermore, there currently is no reliable field test to detect the presence of the *+100 additive* package.

If an accidental refueling occurs, it should be documented, and the Army Petroleum Center contacted immediately for guidance.

It is suggested that aircraft that are accidentally refueled be allowed to operate without restrictions in order to burn off the fuel in flight, thus avoiding issues of defueling. The aircraft should be considered free of JP-8+100 after three refuelings with JP-8. If defueling is necessary, it should be either into another aircraft or the fuel should be treated as hazardous waste.

It is suggested that if ground equipment is exposed to JP-8+100, it be defueled immediately and the filter/coalescer be replaced. The fuel should be disposed as hazardous waste.

A field demonstration of the effects of JP-8+100 on aviation equipment is recommended.

IX. REFERENCES

[1]. Visit Report to Ft. Lee VA on 5 Nov 1998, Subject: Attend Meeting to Obtain Information being Solicited for Task 1 of the JP-8+00 Phase I Investigation.

[2]. Email from Lonnie Ashbrook (APC) on 12 Nov 1998, Subject: FW:Shared Fuel Supplies and Fuel Transfer Methods.

[3]. Email from Sandra Potvin (APC) on 22 Dec 1998, Subject: RE:Followup on Fuel Transfer Questions.

[4]. Email from Sandra Potvin (APC) on 25 Nov 1998, Subject: RE:Followup on Fuel Transfer Questions.

[5]. Email from Sandra Potvin (APC) on 18 Dec 1998, Subject: RE:Followup on Fuel Transfer Questions.

[6]. Record of Telephone Conversation on 19 Nov 1998 to LTC William Jenks (QM School and Center).

[7]. Record of Telephone Conversation on 1 Dec 1998 to CDR L. Kojm (SOCOM HQ).

[8]. Record of Telephone Conversation on 24 Nov 1998 to SFC J. Henry (528th Special Operations Support Battalion).

[9]. Record of Telephone Conversations on 30 Nov and 1 Dec 1998 to SFC J. Henry (528th Special Operations Support Battalion).

[10]. Record of Telephone Conversation on 7 Dec 1998 to CPT B. Cooper (160th Aviation Regiment).

[11]. Record of Telephone Conversation on 10 Dec 1998 to MSGT D. Fenton (Logistics Group, AFSOC).

[12]. Record of Telephone Conversation on 15 Dec 1998 to LCDR Bill Dunning (Logistics Group, NAVSPECWARCOM).

[13]. Record of Telephone Conversation on 16 Dec 1998 to Senior Chief P. Foley (Combat Service Support Team, NAVSPECWARCOM).

[14]. Email from CPT Monty Yoder on 6 January 1999, Subject: FW: Identifying the CONUS Common Service Fuel Facilities.

[15]. Email from CPT M. Yoder (QM School) on 8 Jan 1999, Subject: RE:FW:Identifying the CONUS Common Service Fuel Facilities.

[16]. Email from Kay Kimbrough (Kelly AFB) on 11 Jan 1999, Subject: RE:Listing of Air Force-Army Fuel Transactions.

[17]. Email from Kay Kimbrough (Kelly AFB) on 19 January 1999, Subject: RE: Thanks Again (File 1).

[18]. Email from Kay Kimbrough (Kelly AFB) on 19 January 1999, Subject: RE: Thanks Again (File 2).

[19]. Special Bulletin – Listing of U. S. Army Fuel-Consuming Mobility and Combat Support Equipment, U. S. Army TARDEC Fuels and Lubricants Research Facility (SwRI), September 1996.