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WHAT FUELS OUR FUTURE?

BY

LIEUTENANT COLONEL ROBERT L. JARVIS
United States Army

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This study project reviews the recent history of fuels usage and product evolution (since WW II) and presents current doctrine. The conclusion and recommendation of this project is that the Army of 2001 should have a single fuel on the battlefield. This fuel should be readily available at a reasonable cost, worldwide. The fuel chosen should be safe to transport and store while meeting the requirements of a wide variety of military equipment. This project also addresses current misconceptions, perceived problems and issues to be resolved about a single fuel concept.

Both commercial jet fuel (Jet A1) and its military counterpart, jet propulsion fuel (JP8) offer a safe, relatively available, versatile and logistically supportable compromise to the varying needs of the majority of ground and air equipment.

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USAWC MILITARY STUDIES PROGRAM PAPER

WHAT FUELS OUR FUTURE ?

AN INDIVIDUAL STUDY PROJECT

by

LIEUTENANT COLONEL ROBERT L. JARVIS
UNITED STATES ARMY

COLONEL TERRY L. WAGNER
PROJECT ADVISER

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U.S. ARMY WAR COLLEGE
CARLISLE BARRACKS, PENNSYLVANIA 17013

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INTRODUCTION

Whoever said that "We are our own worst enemy" never realized how applicable that statement is to the ongoing controversy of which petroleum fuels will be used by the U.S. Army as it transitions into the 21st century.

This paper first presents a short historical recapitulation of U.S. Military fuel trends since World War II. A more detailed analysis of petroleum issues of the last decade then bring the reader up to the present day. The remainder of the paper, and the real purpose of this project, extrapolates where the U.S. Army should proceed with respect to "What Fuels our Future".

This subject is of significant strategic importance for several reasons. The fuel used by an armed service impacts vitally on the capability of that service on the battlefield. Fuel type is directly related to interoperability with other sister services and, to a great extent, other allied countries as well.

Another significant consideration is the cost of petroleum products. The Department of Defense spends, in peacetime, approximately six billion dollars a year on bulk fuels.[1] This multi-billion dollar annual expenditure is directly related to the types and quantities of the fuels purchased (see Appendix VII).

The safety characteristics of different petroleum products influence how they must be handled, stored and used. POL products require significantly different care, both in the supply system and in the equipment of the primary user depending on their safety factors. The capabilities of both Tacticians and Logisticians may be drastically affected by what bulk petroleum products are procured.

These considerations, and many more, form a complex matrix of questions that must be factually and objectively addressed in choosing the proper fuels. Operation Desert Shield/Storm has brought the petroleum issue to the forefront of current military logistical challenges.

The scope of the research for this project is limited to events occurring before February 1991.

This paper is written in a non-technical style to facilitate reading and comprehension. It is specifically intended for the fuel user and consumer in the military, not the technical expert. The bibliographical sources, endnote references and Appendixes are recommended for a more detailed look at the subject.

Petroleum, Oil & Lubricants are known by the military acronym, POL. A user friendly compendium of common petroleum (POL) definitions and useful explanations is contained in Appendix 1, Glossary of Non Technical Petroleum Terms. This glossary is provided as a handy take-away guide. The author highly recommends the document entitled "INFORMATION ON JP-8 AND THE JP-8 DEMONSTRATION PROGRAM"[2] which is listed in the bibliography, as being a particularly informative article for the interested reader.

ASSUMPTIONS

This subject matter necessitates some basic assumptions. Future military equipment and the energy outlook, both worldwide and domestic, are taken into consideration for the next two decades. The use of assumptions has been kept to a minimum.

A. The supply of crude oil on the world market will continue to undergo sporadic fluctuations in availability and price. Petroleum products will continue to be available on a general trend similar to the last twenty-five years of declining reserves and increasing prices.

B. No profound energy or equipment "wildcard" technologies will be found or discovered. There will be no drastic change to the continued, practical use of petroleum products in the internal combustion engine, ie; no nuclear powered 1.5 kw generators.

C. Energy and equipment technology may undergo moderate changes and discoveries. Significant sunk costs for the Department of Defense (DOD) vehicle and equipment fleet will preclude implementation of changes to the existing fleet. The use of current fossil fuels in equipment on hand will continue through the turn of the century.

D. U.S. Department of Defense (DOD) energy requirements will not change drastically over the next two decades. This assumption does not preclude potential surges for events such as Operation Desert Storm or decreases due to the downsizing of the force as currently projected over the next five years

BACKGROUND

During the Second World War, petroleum accounted for over half of all supply tonnage shipped overseas. That was about sixteen times the tonnage of the food shipped to Europe.[3] The U. S. Army of World War II was powered primarily by motor gasoline (Mogas). Refer to Appendix I, the Glossary of non technical petroleum terms, for a more detailed explanation of the military fuels discussed in this paper. Refineries around the world mass produced Mogas.

The relatively simple requirement to logistically support only one primary fuel contributed greatly to the historic achievements of the Allied Forces. Although it was highly volatile and inherently dangerous, Mogas was the product used in tanks and most other tactical and non-tactical vehicles of that era. The jet engine was still not widely used. Air forces were still using aviation gasoline (Avgas) for reciprocating engines. Avgas is an extremely volatile and dangerous product to store and use.

The Korean conflict, following close on the heels of World War II, saw little change in the fuel types or consumption patterns of the military from the previous decade. An exception to this was the introduction of jet aircraft. The introduction of jet fuel to the POL inventory, and its impact, is discussed in detail in the following discussion of the Vietnam period.

The Vietnam era saw the military use of three primary fuels; motor gasoline (Mogas), diesel fuel (DF2) and Jet Fuel (JP4).[4] Mogas, as mentioned above, now only partially satisfied the needs of increasingly thirsty ground equipment. Vehicles and equipment powered by diesel fuel were using vast additional amounts of petroleum. DF2, being less volatile than gasoline, is a relatively safe and stable fuel to procure, store and use.

The tremendous amount of air assets that were employed during this period were now primarily powered by jet engines. The fuel used for these jets in all U.S. Services for land based aircraft, is known as JP4. JP4 consists of a blend of kerosene and a gasoline type blending stock.[5] The primary attractions of JP4 are ready availability and relatively low cost (see Appendix VII). Over one-half of the 180 million barrels (that is over 6 billion gallons) of bulk petroleum purchased annually for the DOD has been JP4. The major drawback of JP4 is it's inherent volatility. The U. S. Air Force Tactical Air Command Capability Request indicated that over half of the aircraft combat losses during the Vietnam conflict were caused by gunfire induced fuel fires and explosions.[6] JP4 is more likely to catch fire and, once ignited, more likely to continue burning or explode than commercial jet fuel.

The commercial airline industry uses a relatively stable and safe jet fuel which is known as Jet A1, a kerosine base product. It is interesting to note that the civilian airlines use Jet A1 because of safety concerns, even though Jet B fuel (a civilian equivalent of the volatile JP4) could be procured cheaper.[7]

The U.S. Army has, since the middle 1970's, attempted to reduce it's use of Mogas as a combat fuel and has primarily used diesel fuel for ground equipment and JP4 in Army aircraft. The 1980's saw an attempt to further reduce the number of fuels required by exploring the concept of a single fuel on the battlefield.[8]

DISCUSSION

The desire of the U.S. Air Force for a safer jet fuel and the Army effort to reduce the number of bulk fuels on the battlefield resulted in a safety and logistics synergism for military petroleum in the 1980's. The concept of a single fuel on the battlefield was not only proposed, but refined (no pun intended) during this decade. This became a very simple premise of using one, safe, primary fuel to power the vast majority of ground and air equipment on the potential battlefield of tomorrow.

There is concern as to the impact on the entire petroleum industry, if the Department of Defense were to "compete" with the civilian markets (primarily the airline industry) in procuring the same part (kerosene) of the crude oil barrel. Estimates from the 1970's were most pessimistic, especially concerning a Conus conversion from JP4 to JP8. The 1980's saw less disastrous predictions, with an emphasis on "phasing in" the switch of products to allow the petroleum industry to adapt. A short quote from a background page of the 1988 "Conus JP4 to JP8 Conversion Study" shows the revised, and decreased apprehension to such a change:

> "A conversion from JP4 to JP8 would increase the demand for kerojet blend components by about 9 percent. Such a conversion phased over a period of three to five years would have a minor impact on the overall market...the kerojet demand by commercial airlines grew by about 30% during the period from 1983 through 1986. This increase, which was much greater than the increase involved in a JP4 to JP8 conversion, was accommodated by the petroleum industry without a significant impact." [9]

The conversion in Europe to JP8 actually resulted in an increase in competition. Previously, one or two bidders could supply all U.S. needs for JP8, while the conversion from JP4 to JP8 has resulted in up to a dozen contract awards for JP8.[10] One of the key concerns to any Conus conversion will be the political/economic sensitive issue of what will happen to any domestic refiners who cannot supply JP8 and depend on their livelihood from DOD JP4 contracts? This is an issue that will have to be addressed over the next decade.

The elimination of multiple fuels significantly reduces the constraints on the logistician and tactician. Balancing requirements against limited POL storage and distribution assets will be more easily accomplished, ensuring that no requirement will go unfulfilled.[11]

This concept was clearly stated in 1988 when DOD Directive 4140.43, Fuel Standardization, was published. The stated purpose of this Directive was to revise policy on fuel standardization with a goal of minimizing the number and complexity of petroleum fuels required.[12] Two of the policies stated in the Directive were indicitive of the importance of the subject and the path to be taken. The first policy stated that fuel is a critical resource. To increase flexibility and logistics supportability, the Military Services shall design weapon systems and support equipment, and the Unified Commands shall develop operation plans (OPLANS), to *minimize the number of fuels required* (author's italics) in joint and combined operations.[13] To highlight the probability of the single fuel on the battlefield being a version of JP8 or Jet A1, another policy statement in the Directive was that "combat and combat support vehicles and equipment shall be capable of achieving acceptable operational performance using either kerosene type turbine fuels (such as JP8) or distillate type fuels (such as DF2 Diesel fuel) and commercial equivalents" (such as Jet A1 or commercial Diesel fuel).[14]

Standardization must be striven for within both the Army (Armor, Artillery, Infantry, etc.) and Joint (Army, Air Force, Navy) operations arena. All the services within DOD must place interservice rivalry aside. The amount of duplicate specifications must be reduced. Service or branch parochialism must be replaced with a spirit of cooperation and interoperability. Once the U.S. (all Armed Services) has embarked on a single course of action in regard to fuels, a common approach can be suggested and worked on with our international allies.

The attainment of the single fuel on the battlefield concept was well on track by the late 1980's. Many of the issues concerning use of JP8 as a ground fuel are addressed in Appendix II. In the ARMY Greenbook of 1989, the Deputy Chief of Staff for Logistics (DCSLOG) of the Army, Lieutenant General (LTG) Ross indicated that the single battlefield fuel concept was a "logistical consideration"[15] while the Army Greenbook for the following year quotes LTG Ross as saying that the single fuel on the battlefield program is "one of two petroleum initiatives being implemented".[16]

By mid-1990 the European Theater was converting to use of a primary single fuel, JP8. Limited JP8 conversion was occurring in other overseas locations as well. A major study (known as the JP8 Demonstration Program[17]) to provide information on the use of JP8 in diesel fuel consuming vehicles was conducted at Fort Bliss, Texas from the autumn of 1988 until it was curtailed by the deployment of test units to Operation Desert Shield/Storm in the late summer of 1990.[18] This program, in addition to confirming acceptability for using JP-8 as a diesel fuel alternate, was also to:

* Develop fuel consumption data for ground vehicles/equipment using JP-8.
* Define the need for possible changeover procedures of vehicles/equipment when JP-8 replaces diesel fuel.
* Instill confidence in the user-community that JP-8 is "okay".[19]

This last comment is a key one. Many misconceptions regarding fuels must be laid to rest. As an example, a student at the U.S. Army War College recently commented that he had heard that this JP-8 fuel was like "whale oil".

The Fort Bliss demonstration program continued with no major "show stoppers" until interrupted by Desert Shield/Storm. Successful vehicle and equipment operation using JP-8 was documented (see Appendix II) and Fort Bliss requested authority to continue using JP-8 in lieu of diesel fuel for the next several years.[20] The concept of eventually replacing multiple fuels with a single fuel on the battlefield was now significantly tested and documented.

The major military requirements for the next decade include several fuel challenges. Converting the multifuel fleet to operate efficiently on a primary kerosene-base fuel, such as JP8 or Jet A1, is an initial goal. Some families of vehicles/equipment will need such items as filters and fuel pumps modified or replaced. The phasing out of the majority of the equipment that uses Mogas, coupled with no new purchase of Mogas consuming equipment, should result in Mogas consumption moving from the bulk to the packaged fuel category.

The conversion to a single fuel will require increased command emphasis on fuel servicing vehicle cleanliness standards at the wholesale level (Corps and above), and to a certain degree at the retail (Division and below) distribution level. Many of these vehicles may have to be maintained at "aviation" standards because the refueling of both ground and aircraft equipment can be accomplished from the same source. Command emphasis must change the mindset of "oldtimers" that ground refuel equipment is "dirty" and that aircraft refuelers are "clean".[21] The continued search for a small, lightweight generator, that is not gasoline powered must be accomplished. These are but some of the challenges that remain to be tackled.

Some issues have turned out to be "double edged". The substitution of JP-8 for diesel fuel in Europe in the M-1 tank solved cold weather starting problems that had plagued armor units every winter. This conversion also helped to reduce the "exhaust smoke" signature of many vehicles. However,while these were considered to be improvements, the use of JP-8 also reduces the ability of the armor forces to purposely generate smoke. This is increasingly seen as a major negative issue.

The key for the future is the integration of fuel-related requirements issues in the earliest stages of the acquisition process for our next generation of vehicles and equipment. Equipment and vehicle specifications must call for operability on a single common fuel (JP8) at the outset of equipment design.

The paradigm of a single fuel on the battlefield was cracked, if not broken, with the Iraqi invasion of Kuwait and subsequent deployment of U.S. forces in August of 1990. Old misconceptions and new deployment-related fuel challenges surfaced. These ranged from armor concerns over a lack of smoke generating capability using JP-8, to rumors of ruined engines and decreased power from the use of JP-8. The result, in December of 1990, was a compromise decision to allow Division Commanders the option of a "fuel of choice" rather than a single fuel concept.[22] This decision was both practical and timely. It allowed the ground commander to select the fuel option with which he is most comfortable. The mission of the logistician was made more complicated by the presence of multiple fuels on the battlefield, but the drawbacks are mitigated by the petroleum supply and logistics infrastructure in the Desert Storm Theater of Operations.

Operation Desert Storm was fought with some U.S. Army Divisions using primarily Diesel Fuel while other Division Commanders have "chosen" jet fuel (JP8 or Jet A1). The very special circumstances of having this theater in such an oil rich area of the world has facilitated this choice as a viable option. In most other areas of the globe, this "fuel of choice" decision would severely constrain already limited combat service support personnel and equipment. The use of a "fuel of choice" in Desert Storm should not be used as a precedent in considering future battlefield fuel options.

During any transition from one system to another, it is only reasonable to expect the user to place more reliance on systems used in the past rather than something new. This is true of the fuel-using community in Saudi Arabia during the present crisis and explains many commanders' reticence to try anything new or different.

Unfortunately many situations arise in the heat of potential combat that cloud the real issues and problems. The "Fog of War" is true not only in the combat arms, but in the POL logistics community. A few equipment operators have added transmission fluid or engine oil to vehicle fuel tanks to "solve" perceived lubricity problems in JP8/Jet A1 fuels.[23] Some equipment operators have removed or bypassed fuel and/or air filters to reduce perceived restrictions in hopes of temporarily increasing performance.[24] The use of unauthorized additives and incorrect/inadequate operator preventive maintenance (PMCS), exacerbated by harsh environmental factors, significantly contributes to equipment failure. It is often only later that the true culprit may be found. The rumors of "bad fuel" or "that damn jet fuel" become fact, even after subsequent investigations may show otherwise.

"What Fuels our Future" must result from the significant lessons learned from Desert Storm in the fuel and logistics community as well as the important work done within NATO and the U.S. during the last decade. Most importantly, our future fuel choices must be based on satisfying the needs of the combat fuel users. That demands satisfactory answers to the users concerns and questions. As of December 1990, there appeared to be a basic misunderstanding of the Jet A1/ JP8 capability to satisfy diesel engine requirements. Compounding the problem in the Desert Storm theater were significant non-fuel factors such as excessive sand and dirt contamination and possible preventive maintenance shortfalls.[25]

CONCLUSION

The outcome of Desert Storm was in the hands of the Allied Coalition of Forces as this paper was written. The future of military petroleum logistics will hopefully include validation of the decision to pursue a single fuel on the

battlefield, but we are not there yet. Significant issues remain to be resolved. Smoke generation for armor forces is a pertinent example. Conversion to a single fuel must be phased in over at least a 3 to 5 year period of time. This deliberate and announced period of transition time will allow the petroleum industry the requisite time to retool and plan for the DOD entry into a new market area. Only then will the real impact be seen on product availability and price of the respective petroleum products. Despite the challenges mentioned, the benefits of a single fuel on the battlefield far outweighs the negatives (see Appendix II).

The vast quantities of fuel required for the air and ground forces of a modern and high tech force, coupled with the constraints of limited Combat Service Support (CSS) personnel and equipment, make it imperative that these issues be satisfactorily resolved. Petroleum/fuel logistics must not become a "war stopper" in a potential conflict.

Future wartime theaters, where petroleum products might not be locally available or where distribution and storage may be extremely constrained, compel that we strive for a simplified and usable fuel logistics policy --A SINGLE FUEL ON THE BATTLEFIELD.

RECOMMENDATIONS

The eventual attainment of a single fuel on the battlefield concept must be based on a thorough analysis of the results of the lessons learned from Operation Desert Storm. The petroleum/fuel logistics community must capture these lessons learned and then insure that the fuel user (and acquisition community) is well acquainted with the facts of the issues. Every effort must be made within the Army and the joint arena and with allied forces to resolve differences in requirements and capabilities with respect to fuel.

Future equipment and weapons system procurements must include the fuel issue as an integral part of the Integrated Logistics System (ILS) during the acquisition process. Fuel needs and requirements must be considered from the earliest research, design and development stages.

The phasing out of Mogas consuming equipment from the inventory should continue as rapidly as possible. The conversion of diesel fuel and multi-fuel equipment to permit the use of the same single fuel should be continued. In many cases this requires only modification of existing fuel pumps, filters and maintenance schedules. The continued worldwide conversion to JP8 should be continued. In the U.S., a phased approach should be used over the next 3 to 5 years. "Testing the water" can be accomplished incrementally by converting the U.S. by location on a time-phased schedule. That will allow the lessons learned from the first buy to be applied to subsequent procurements.

If we make modifications to some of the equipment we already have, educate our fuel consumers, and design and buy smart in the future, petroleum logistics (A SINGLE FUEL ON THE BATTLEFIELD CONCEPT) can be a "combat multiplier" to a robust U.S. Army on the battlefield of the 21st century.

Lieutenant Colonel (now Colonel) Dick Dacey closed his 1989 ARMY LOGISTICIAN article, "Single Fuel Battlefield", with the following anecdote. General Patton once said. **"MY MEN CAN EAT THEIR BELTS, BUT MY TANKS GOTTA HAVE GAS!"** With the right single product fueling the battlefield, it's a safe bet that the next commander will have to only worry about what will keep up his troops' pants.[26]

GLOSSARY OF NON TECHNICAL PETROLEUM TERMS:
(THE JARVIS MINI-POL DICTIONARY)

Barrel (BBL): The normal unit of measure of bulk petroleum liquids. It equals 42 U.S. standard gallons. It should not be confused with a drum or 55 gallon drum which is an actual container (but may not contain exactly 55 gallons).

Class III (POL): The U.S. Army supply system has nine classes or categories of supply. Class I is food and rations, Class VI is personal demand items (hence the Class VI store), while the class of supply that concerns us here is Class III. Petroleum, Oil & Lubricants (POL) is explained further on but the major distinction in POL supply is whether it is a bulk or packaged product:

Bulk Product: Any product that is transported or stored in containers of 500 gallons or more. This can be such means as pipelines, rail tank cars, barges or ocean going tankers. This scale of transport and storage allows great use of economies of scale and consolidation of logistics resources.

Packaged Product: Normally includes items packaged by the manufacturer and bought, stored, transported, and issued in containers or packages of 55 gallon capacity or less. Exception are the collapsible containers (blivets) used to hold up to about 500 gallons of products, which are usually considered packaged product.

Distillation: The main process used to make petroleum products from crude oil in a Refinery. Similar to the enterprise of making "moonshine" whiskey by vaporizing a liquid and then condensing it's components. This apparatus became known as a "Still" because of the method used, distillation. The type of refined petroleum product is based on the distillation range (point from initial boiling to final product evaporated). Products with a "wider" boiling or distillation range are more plentiful per refined barrel of oil than those with a "narrow" boiling range. (Also see Appendix V & VI)

Crude Oil: Naturally occurring hydrocarbon substance found in many parts of the world, but only economically recoverable in a lesser number of areas. Used to make fossil fuels (petroleum products). Basis for nearly all of the refined products which operate the internal combustion and turbine engines. There are many types of crude oils. Some of the most common ways of identifying crudes are either/or categories such as:

Light/Heavy Crude: Crude oil that contains more components for making easily combustible fuels and actually weighs less per gallon because it is less dense is known as "light Crude". A crude oil that yields less desirable petroleum products per barrel because it is denser or heavier is "heavy crude" and it is therefore less desirable to Refiners.

Sweet/Sour Crude: A way of measuring the amount of sulphur in a crude oil. Low sulphur (sweet) crudes are easier to refine and therefore more desirable. High sulphur (sour) crudes take more effort and sophisticated equipment to refine.

Flash Point: The lowest temperature at which a liquid petroleum product produces vapor to ignite (flash) under specified conditions. This is the most common test for measuring volatility and to a great extent, it is a measure of the safe handling/use properties of a petroleum product.

Fuel: Also called a product (see Product, below), petroleum fuel or POL product. As used in this context a product is any type of refined hydrocarbon fuel from crude oil that is used as an energy source for engines.

Military Fuels: The US military has established standards for the quality of the petroleum products it buys. These are called Specifications, also known as specs.. These fuels are usually similar to those used commercially but may contain additives or additional specifications because of unique military needs and applications. Military fuels are known by acronyms, which is how they are listed below. (Also see Appendix III & IV) Some of the most common military fuels are:

AVGAS: Aviation gasoline (Avgas) is a highly volatile product that is best equated to a very high octane gasoline. Declining use in the military has reduced it's use and it will probably cease being a bulk fuel and become a packaged product for use in limited applications and quantities.

Diesel Fuel: Diesel fuel is a less volatile and relatively stable product that is similar to the commercial diesel fuel found in gas stations and truck stops. It is not suitable for use in engines designed for gasoline use only. There are various grades military Diesel known as DF2 (NATO code F54, for ground equipment use), DFM (NATO code F76, for marine use), and DFA (for extreme cold weather use).

MOGAS: Motor gasoline (MOGAS) is similar to the commercial gas station equivalent and is now procured primarily in the unleaded regular and mid-grade type. The US Army is phasing out the procurement of MOGAS using equipment but many admin vehicles and small generators remain in the inventory. It's use, similar to AVGAS, will probably not cease entirely but diminish and may become a packaged product.

Jet Fuels: Jet fuels were originally designed for use in turbine engines, although wider applicability is now common. A more detailed look at the properties of these jet fuels can be found in Appendix III, IV, V, and VI. US military jet fuels are known by designations such as JP4 (Jet Propulsion Fuel with an arbitrary number added for additional specificity.)

JP4: The "original" military jet fuel. Based on a combination of low grade gasoline feed stock and Naptha. The use of the gasoline component causes the JP4 to be relatively inexpensive and easy to obtain but highly volatile and unstable. It was the standard jet fuel for the U.S. Army and Air Force until the 1980's when ongoing safety and single fuel concepts have caused it's continued use to be questioned. The commercial equivalent of JP4 is known as JET B but is not used by commercial airlines due to safety considerations. (NATO code F-40)

JP5: The U.S. Navy refused to use JP4 on board ships for safety reasons and developed JP5 for shipboard use. JP5 is a kerosene based turbine fuel with a flash point of 140 degrees Fahrenheit, which makes it a safer but more costly and difficult to procure product. (NATO code F-44)

JP8: Initially developed by the U.S. Air Force as a safer alternative jet fuel to JP4. JP8 is a kerosene based jet fuel similar to commercial jet fuel (which is known as JET A-1) but having additives such as anti-icers, anti-corrosives, and anti-static properties. JP8 does not have as restrictive specifications as JP5 and should be relatively available yet reasonably priced. JP8 has application for use in both turbine and non-turbine engines. U.S. Forces in USAEUR were converting to a single fuel concept (using JP8) when Desert Shield/Storm commenced. (NATO code # F-34)

Product: Also called a fuel (see Fuel, above), petroleum product or POL product. As used in this context a product is any type of refined fuel from crude oil that is used as an energy source for engines.

POL: Military abbreviation/acronym for Petroleum fuels, Oil, and Lubricants. Can be used to mean any type of refined petroleum product.

Refining: The physical process of converting crude oil into usable POL products. See "Distillation" for the main process used to Refine POL products. (Also see Appendix V, VI & VII)

Volatility: In this context a high volatility product would be likely to vaporize easily and burn or explode at room temperature (also see flash point) and then likely remain burning once started (motor gasoline and military jet fuel JP4 are good examples of a high volatility fuel). While a less volatile product, like commercial jet fuel or military JP8 is produced from a different component of the crude oil barrel and less likely to catch fire or explode. (Also see Appendix IV, V, VI and VII)

SOURCE:

Some information for this glossary was extracted and extrapolated from FM 10-70-1, "PETROLEUM REFERENCE DATA", but the majority of the definitions and explanations are those of the author. This glossary is intended to be informative rather than technically authoritative. Every effort has been made to insure accuracy of contained information. February 1991.

USE OF JP-8 FUEL IN GROUND EQUIPMENT

The following is a listing of questions with answers frequently raised regarding use of JP-8 fuel in diesel fuel consuming vehicles and equipment. These responses have been coordinated with the US Army Tank-Automotive Command and Headquarters, US Air Force.

a. **What is JP-8?**

Answer: JP-8 is a kerosene-type aviation turbine fuel. It is procured under MIL-T-83133 and is interchanged within NATO under NATO Code Number F-34.

b. **What is the difference between JP-8 and JET A-1?**

Answer: JET A-1 is essentially identical to JP-8 except it does not contain the three additives required in JP-8; namely, the fuel system icing inhibitor, corrosion inhibitor, and static dissipator additive. JET A-1 is the standard fuel used by all commercial airline companies worldwide, except within the US where JET A is principally used. JET A-1 differs from JET A only in its lower freeze point requirement; i.e., -40°F versus -53°F for JET A versus JET A-1.

c. **What is the difference between JP-8 and JP-4?**

Answer: JP-4 is not a kerosene-type aviation turbine fuel, but instead is approximately a 40:60, 50:50, or 60:40 mixture of kerosene with naphtha (e.g.,a gasoline-type blending stock). It is called a "wide-cut fuel". JP-4 is procured under MIL-T-5624 and has been interchanged within NATO under NATO Code Number F-40. It is not usually considered as an acceptable substitute for diesel-fueled equipment. F-40 has been the standard aircraft fuel for NATO aircraft until 1986 when NATO nations agreed to the conversion from F-40 to F-34.

d. **What is the difference between JP-8 and JP-5?**

Answer: JP-5, like JP-8, is a kerosene-type aviation fuel. However, it differs from JP-8 in having a higher flash point specification requirement; that is, 140°F minimum versus 100°F minimum for JP-5 vs JP-8. This fuel is used for all sea-based aircraft in lieu of JP-8 because of safety requirements for on-board aircraft carrier operation. JP-5 is procured under MIL-T-5624 and is interchanged within NATO under NATO Code Number F-44.

e. **What is the difference between JP-8 and diesel fuel?**

Answer: JP-8 is primarily a kerosene whereas diesel fuels are generally either a distillate blend, a distillate and kerosene blend, or a kerosene blend depending on the grade of diesel; i.e., DF-2, DF-1, or arctic grade diesel fuel (DFA). In most instances, DFA and some DF-1 fuels are essentially kerosenes which are very similar to JP-8 fuels.

f. **What was the basis for conversion from JP-4 to JP-8?**

Answer: The initial rationale for converting from JP-4 to JP-8 within NATO was twofold; (1) aircraft battle damage data had shown that JP-8 was an inherently safer fuel (i.e., less susceptible to ignition and sustained fires) and, (2) JP-8 in being essentially "identical" to JET A-1 would be commercially available worldwide. JP-4 is not available at most commerical airports.

g. **When was this conversion to JP-8 initially considered?**

Answer: The issue was initially raised within NATO in 1975. The actual ratification to convert from F-40 (JP-4) to F-34 (JP-8) for all military land-based aircraft occurred in April 1986.

h. **When did this conversion also consider the possible changeover from DF-2 to JP-8?**

Answer: With the introduction of the M1 Abrams Tank into NATO in late 1981, cold starting problems occurred due to the waxing of the standard diesel fuel used by all NATO countries which is interchanged under NATO Code Number F-54. This military diesel fuel was and continues to be the best "low temperature" diesel engine fuel available within the NATO countries as other commercial diesel fuels have considerably higher wax content. This fuel waxing problem initially affected the starting of M1s and other gas turbine powered ground equipment operated by US Forces. The problem was temporarily resolved by blending all F-54 diesel fuel with either JP-8 or JP-5 as a means to reduce the waxing tendency. This blend, later termed the "M1 Fuel Mix", became a standardized procedure for the US Army that was exercised from November through April annually since 1982. Other NATO countries later began to experience similar low temperature operability problems which prompted the standardizing within NATO on this fuel blend for winter operation; namely, NATO Code Number F-65 which is a 50:50 mixture of F-54 and either F-34 or F-44. With all NATO forces experiencing some degree of low temperature operability problems due to fuel waxing and cold starting, consideration was then given to standardizing on JP-8 which would allow the realization of a "one fuel forward" concept. This quickly became a NATO initiative and has been strongly supported by all NATO countries.

i. **Can diesel engines use JP-8?**

Answer: **Yes.** Using JP-8 is essentially no different than operating diesel engines on DFA or DF-1, both of which are "kerosene-base" fuels.

j. **Can turbine engines use JP-8?**

Answer: **Yes.** Gas turbine engines were initially developed on a kerosene base fuel and therefore can accommodate all turbine fuels.

k. **Are there adjustments to make if JP-8 fuels are used in diesel engines?**

Answer: **No.** Most engines do allow for use of the three grades of diesel fuel DF-2, DF-1, or DF-A interchangeably without any adjustments being required. Because of the lower volumetric heat content of JP-8 (i.e., The BTU/gal value) compared to DF-2, some reduction of maximum engine power may occur; however, for part-load operations, the operation will adjust automatically by increasing the fuel flow (i.e., pressing the accelerator pedal/rack further).

l. **Will JP-8 run hotter?**

Answer: **No.** However, if diesel engines are mechanically adjusted (i.e., settings fixed for JP-8) to optimally use JP-8 100% of the time, switchings back to DF-2 may produce some overfueling at the maximum "throttle" setting which could cause excess smoke and, under the most extreme conditions, over-temperature.

m. **Will engines generate more exhaust smoke when JP-8 is used?**

Answer: **No.** From the limited data generated to date on monitoring exhaust emissions from laboratory engine tests, use of JP-8 tends to significantly lower the overall emissions and smoke levels.

n. **Will using JP-8 in lieu of diesel fuel give lower mileage?**

Answer: From laboratory testing (i.e., engine dynamometer tests) completed thus far, some increase in fuel consumption has been evidenced because of the approximately 2% difference in volumetric heat content; however, vehicle testing is required to fully quantify this apparent fuel consumption increase as any engine efficiency improvement realized with using JP-8 may offset this. Controlled field testing of selected representative combat and tactical vehicles is planned to quantify this question of fuel consumption, increase.

o. **What is power loss?**

Answer: Most engine power generally equates to acceleration, maximum speed, peak torque speed, and horsepower output (e.g., draw-bar pull horsepower, gross brake horsepower,etc.). Any decrease in any of these is usually regarded as a "power loss".

p. **Is JP-8 "compatible" with diesel fuel system materials (e.g. fuel lines, filters, seals, etc.)?**

Answer: **Yes.** JP-8 is completely compatible as kerosene is generally blended with distillate fractions as part of the diesel fuel pool to lower the wax content as a means to "winterize" diesel fuels. There is no incompatibility with changeover from diesel fuel to JP-8.

q. **Can JP-8 be used in other equipment (i.e., combat service support, etc.) that has been designed to use diesel fuel?**

Answer: For a vast majority of all diesel fuel consumers, JP-8 can be substituted with no problems whatsoever. However, there are a few items within the inventory which have been identified thus far that will not function satisfactorily with JP-8. The Vehicle Engine Exhaust Smoke System on the M1 tank has been shown to not produce satisfactory smoke with JP-8. An effort has been recently initiated to develop a suitable fix, either mechanically or with a fuel additive to resolve this problem. Additionally, a few of the combat service support equipment (e.g., M1950 Squad Stove, M2 Burner, etc) will not work with JP-8 since they were designed for gasoline rather than DF-2.

r. **Can new engines use JP-8 and not have warranty provisions become void?**

Answer: **Yes and No.** There has been no warranty issues raised with using JP-8 in "new" engines except for the General Motors Corporation's 6.2L which is the powerplant for the Commerical Utility Cargo Vehicle (CUCV) and High Mobility Multipurpose Wheeled Vehicle (HMMWV). The limitation on warranty provisions on this engine was initially identified with using JP-8 when the prevailing ambient temperatures were above 71°F. This limitation was proposed because the fuel injection pump manufacturer (Stanadyne) maintained that severe wear would result due to the JP-8's lower viscosity not providing sufficient lubrication. However, a rather severe field test was recently conducted at GM's Desert Proving Ground in Mesa, Arizona involving three CUCVs, two being operated on JP-8. The 10,000 mile endurance test was conducted during the hottest time of the year and the vehicles were subjected to all modes of extremely severe duty vehicle operation. At the completion of this test, inspection revealed no pump wear whatsoever. This has questioned the validity of the warranty concern initially raised. This warranty issue is still under consideration.

s. **What problems have occurred to date in substituting JP-8?**

Answer: JP-8 "per se" has not been in widespread use. Therefore, no direct feedback can be provided as to how it performs in vehicles and equipment. However, all Army equipment operating in Alaska the past several years have been successfully using JET A-1 which easily meets the requirements for DFA. No problems have been reported and CUCVs have been operating successfully year round on this JET A-1. Moreover, US Marine Corps and Army vehicles and equipment have previously accepted JP-5 as an approved alternate fuel for diesel fuel consuming equipment. As was explained previously (see question d), JP-5 and JP-8 are very similar except for flash point minimum requirements and differing freeze points.

t. **Will JP-8 be used worldwide?**

Answer: Current plans call for the conversion from JP-4 to JP-8 worldwide. Regarding the parallel conversion from DF-2 to JP-8 for ground equipment, the conversion within NATO is expected to commence on or about FY1991 because of existing stocks of DF-2 remaining within the war reserves and those operational issues mentioned above that need resolution. However, US operations within the United Kingdom have already converted from DF-2 and JP-4 to JP-8. SOUTHCOM intends to begin conversion to JP-5 no later than FY1990 for both air and ground equipment. CENTCOM has already been storing JET A-1 for aircraft and will now address conversion of its ground requirements against JET A-1. PACOM currently plans to begin a phased conversion to JP-8 in FY 1989.

u. **Are other nations using JP-8 as a ground fuel?**

Answer: **Yes.** France, United Kingdom, Norway, and Netherlands as well as the United States show NATO Code Number F-34 (i.e., JP-8) as an acceptable alternate for NATO Code Number F-54 (i.e., our DF-2). Other NATO nations are in process of completing engine/component tests to confirm the suitability in using JP-8 for ground equipment.

v. **What is the "one fuel forward" concept?**

Answer: The one fuel forward concept means a single fuel is used in the forward area for fueling all ground and aircraft systems. Changing from DF-2 to JP-8 at this time will not allow full implementation of this concept as there still exists a small percentage of gasoline consumers (e.g., mobile power generators, some combat service support equipment, etc.) in the field. However, these gasoline consumers are expected to be phased out and eventually replaced with diesel fueled counterparts. The eventual implementation of this one fuel forward concept is viewed as a significant "combat multiplier" and will afford many significant logistical advantages.

w. **Can JP-8 be substituted in gasoline-consuming equipment?**

Answer: **Yes and No.** As stated previously (see question q), JP-8 can be used in a majority of soldier support equipment as those items generally allow for multifuel operation (i.e., able to burn gasoline, kerosene, etc). However, JP-8 cannot be used in any gasoline fueled mobile power generator sets or any other hardware equipped with a gasoline fueled engine.

x. **Will diesel fuel continue to be used?**

Answer: **Yes.** Certain locations such as those within the US are not at this time targeted for conversion from diesel fuel to JP-8. Because of the unknowns as to where hostilities can occur, vehicles and equipment will have to rely on host nation support or locally available fuels and therefore will have to use diesel fuel.

z. **Are there benefits in using JP-8 as a diesel fuel?**

Answer: **Yes**. There are numerous advantages. Since JP-8 is a more highly refined fuel than DF-2, it will cause the following major benefits automatically to be realized -

- Reduced engine combustion-related component wear.
- Reduced nozzle fouling/deposit problems in both diesel and gas turbine engines.
- Reduced potential for fuel system corrosion problems.
- Increased fuel filter replacement intervals.
- Reduced exhaust emissions and signature.
- Extended oil change intervals and filter replacement intervals.
- Reduced fuel related low temperature operability problems; eliminate fuel-waxing.
- Reduced potential for microbiological growth problems in fuel tanks.
- Reduced water entrainment/emulsification problems in vehicle fuel tanks.
- Increased storage stability capability.
- Improved fuel/lubricant related cold starting.

aa. **Is JP-8 more volatile than diesel fuel?**

Answer: **Yes and No**. If one measures volatility using distillation and flash point values, JP-8 could be considered somewhat more volatile than diesel fuel as it has a lower "boiling" range (i.e., 290° to 580°F versus 340° to 690°F for JP-8 versus diesel fuel, respectively) when compared to diesel fuel. Further, the flash point minimum limits also reflect this small increase in volatility as the flash point minimum limits for JP-8 versus diesel (DF-2) are 100°F and 133°F, respectively. However, both JP-8 and diesel fuel including JP-5 are considered as low volatility fuels when compared to either JP-4 or gasolines as the former fuels (i.e., JP-8/JP-5 and diesel fuel) have no vapor pressure values when subjected to the standard ASTM D323 Reid Vapor Pressure technique. For example, ASTM D323 values for JP-4 are normally 2.6 psi whereas gasolines range from an average 10.3 psi for summer blends to an average 14.2 psi for winter blends. Because of the absence of any Reid Vapor Pressure values, JP-8 is considered to be a "low volatility" fuel which is not subject to the same potential flammability hazards as is JP-4 or gasoline. The small differences in flash point and distillation are not considered to be significant relative to having JP-8 classified as a volatile fuel.

SOURCE:

US Army Belvoir RD&E Center
and
Belvoir F&L Rsch Facility (SwRI)
24 March 1988

FUELS DEFINITIONS

FUEL	SPECIFICATION	INTERCHANGED AS NATO CODE NO	COMPOSITION	"MILITARY" ADDITIVES REQUIRED
JP-4	MIL-T-5624	F-40	50:50 MIX OF NAPHTHA & KEROSENE	YES
JP-5	MIL-T-5624	F-44	KEROSENE	YES
JP-8	MIL-T-83133	F-34	KEROSENE	YES
JET A-1	ASTM D1655	F-35	KEROSENE	NO
JET A	ASTM D1655	NO	SAME AS JET A-1 BUT ALLOWS A -40°C MAX FREEZE POINT	NO
DF-A	VV-F-800	NO	KEROSENE	NO

SOURCE: INFORMATION ON JP-8 AND THE JP-8 DEMONSTRATION PROGRAM, JUNE 1990

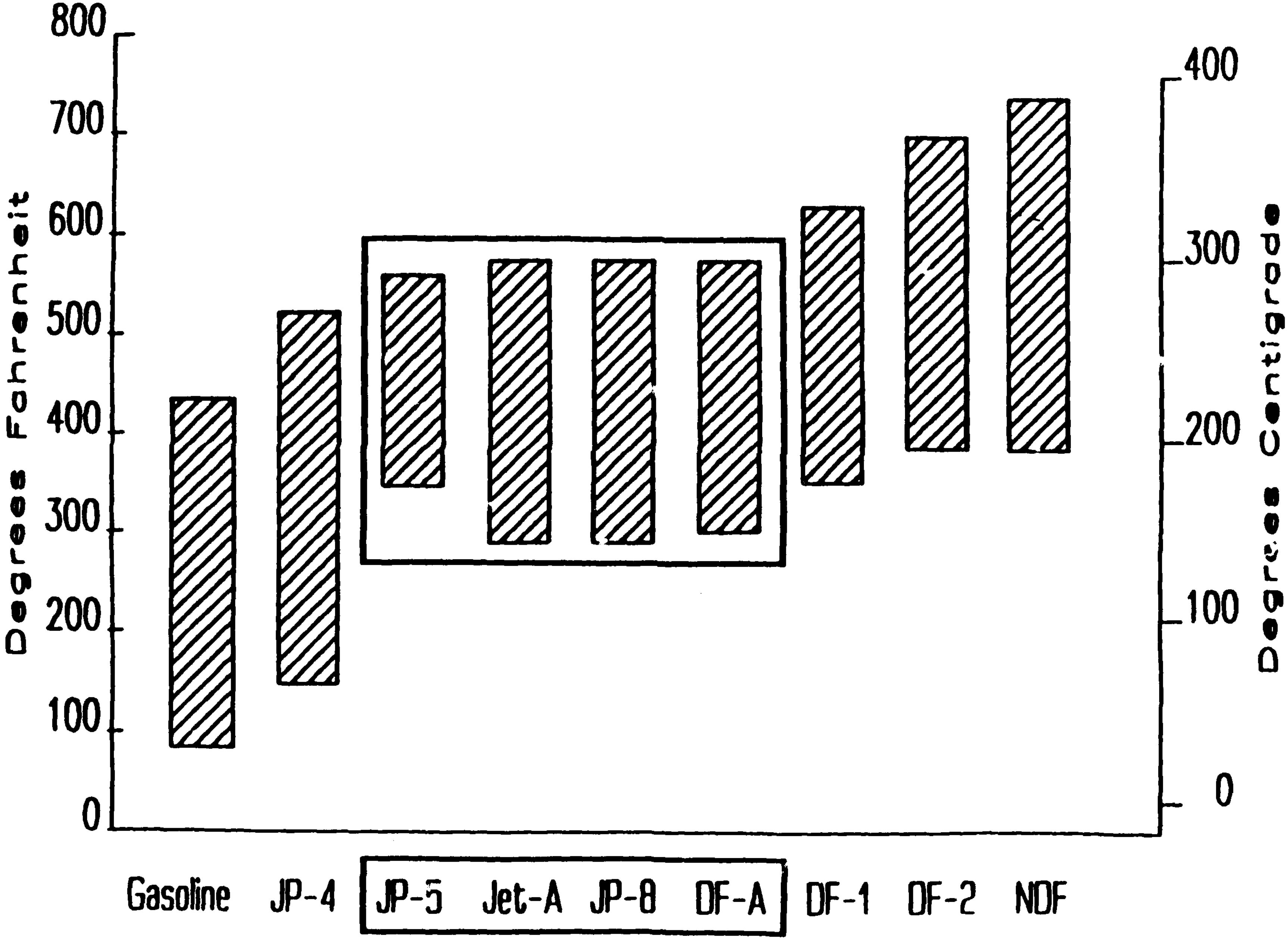
KEY PROPERTY COMPARISONS FOR DIESEL & AVIATION TURBINE FUELS

PROPERTY	U.S. DF-2	NATO DF F-54	WINTER MIX F-65	JP-8 (F-34)	JP-5 F-44	JP-4 F-40	JP-8 DEMO FUEL: FT. BLISS FEB 89	JP-8 DEMO FUEL: FT. IRWIN MAY 89
GRAVITY, °API	34.5	38.3	41.9	45.4	41.1	55.3	41.9	37.9
VISCOSITY @ 40°C, cSt	2.8	3.0	2.2	1.2	1.5	0.56	1.6	1.7
NET HEAT OF COMBUSTION (CALC, Btu/GAL)	(130,319)	(127,776)	(125,457)	(123,138)	(125,270)	(118,124)	125,941	128,431
% LESS Btu/GAL THAN DF-2	0	2.0	3.7	5.5	3.8	9.4*	3.3	1.4

*ESTIMATED

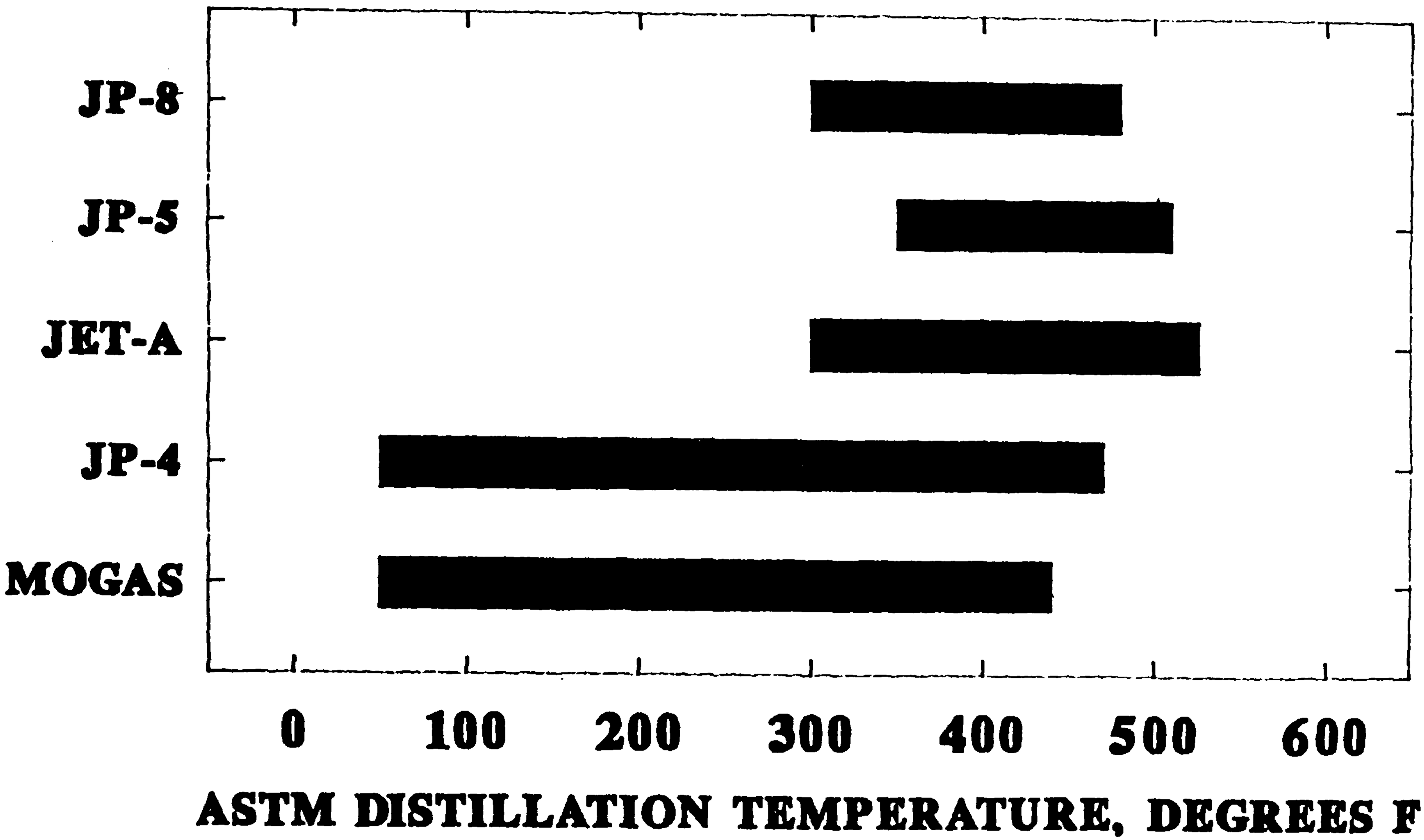
SOURCE: INFORMATION ON JP-8 AND THE JP-8 DEMONSTRATION PROGRAM, JUNE 1990

BOILING RANGES OF FUELS



SOURCE: INFORMATION ON JP-8 AND THE JP-8 DEMONSTRATION PROGRAM, JUNE 1990

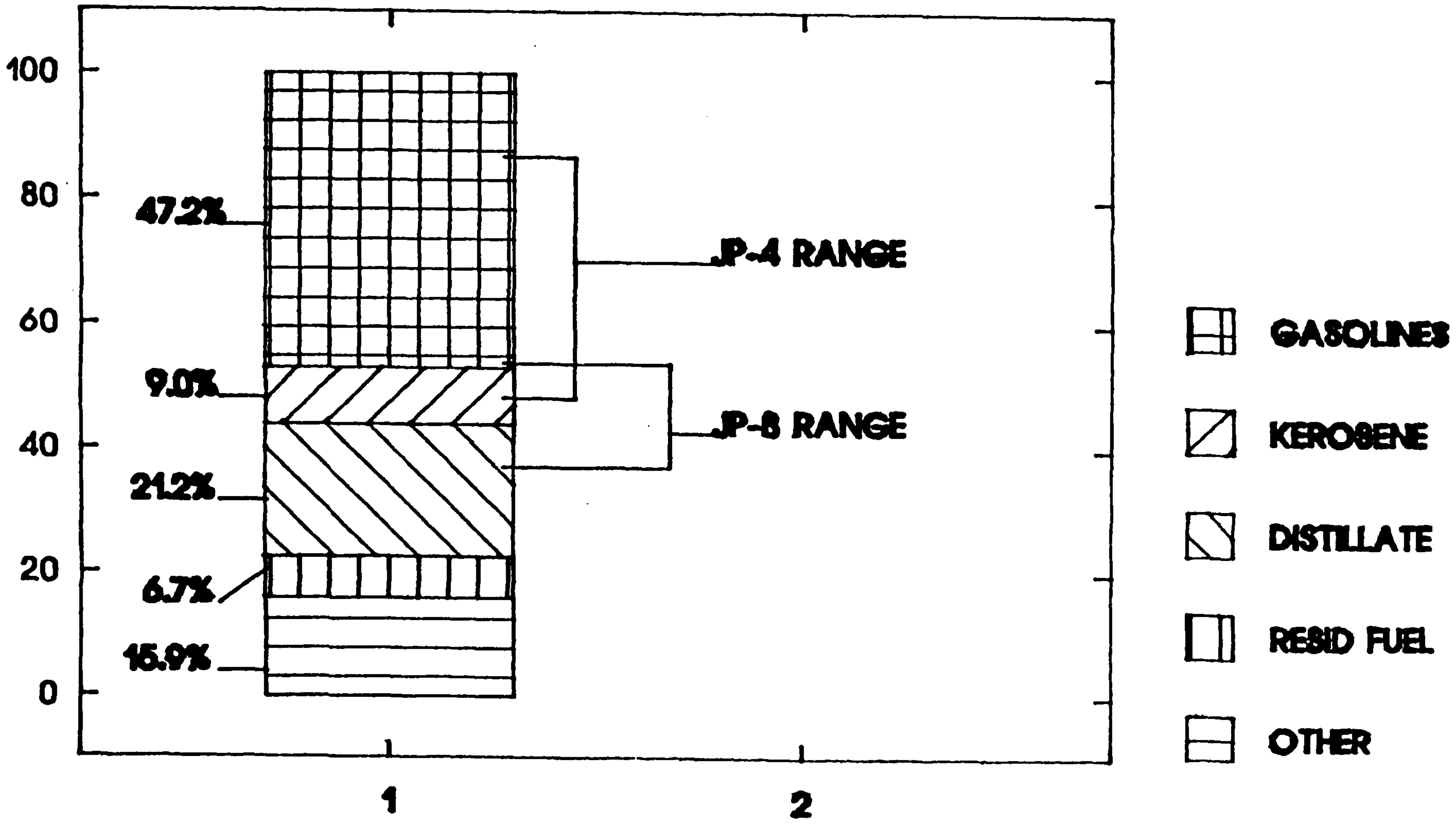
PRODUCT DISTILLATION RANGES



SOURCE: CONUS JP-4 TO JP-8 CONVERSION STUDY, OCTOBER 1988

APPENDIX VI

AVERAGE BARREL OF CRUDE
U.S. Refinery Yield 1986



SOURCE:

CONUS JP-4 TO JP-8 CONVERSION STUDY
OCTOBER 1988

ENDNOTES

1. MORE THAN FUEL IN THE PIPELINE." MILITARY LOGISTICS FORUM, JULY/AUGUST 1987, p. 54.

2. U.S. Army Belvoir RD&E Center, INFORMATION ON JP-8 AND THE JP-8 DEMONSTRATION PROGRAM. (hereafter referred to as "The JP-8 Demonstration Program").

3. LTC (now COL) Richard Dacey and CPT Greg Rosenthal, "The Single-Fuel Battlefield," ARMY LOGISTICIAN, JANUARY-FEBRUARY 1989, p. 2.

4. Dacey, p. 2.

5. The JP-8 Demonstration Program, p. 21.

6. LtGen Charles C. McDonald, Department of the Air Force, letter to Director, Defense Logistics Agency, 04 October 1988.

7. Ibid.

8. E. Owens, M. LePera, and S. Lestz, Use of Aviation Turbine Fuel JP-8 as the Single Fuel on the Battlefield, p. 1.

9. McDonald, p. 3.

10. Interview with Mr. Donald E. Peschka, Bulk Fuels Division, Defense Fuel Supply Center, Cameron Station, Va., 15 March 1991

11. Dacey, p. 4.

12. U.S. Department of Defense, Department of Defense Directive Number 4140.43, p. 1. (hereafter referred to as "DoD Directive 4140.43").

13. DoD Directive 4140.43, p. 1.

14. DoD Directive 4140.43, p. 2.

ENDNOTES (continued)

15. LTG Jimmy D. Ross, "Maintaining High-Quality Goal in Facing Challenges of 1990's," <u>ARMY</u>, OCTOBER 1989, p. 138.

16. LTG Jimmy D. Ross, "Logistics: Maintaining the Momentum," <u>ARMY</u>, OCTOBER 1990, p. 146.

17. The JP-8 Demonstration Program, unnumbered page.

18. The JP-8 Demonstration Program, unnumbered page.

19. The JP-8 Demonstration Program, p. 2.

20. The JP-8 Demonstration Program, p. 2.

21. Dacey, p. 5.

22. Maurice E. Lepera, Fuels and Lubricants Division, TROSCOM, trip report to CG, TROSCOM, 17 December 1990.

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24. <u>Ibid</u>, p. 3.

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