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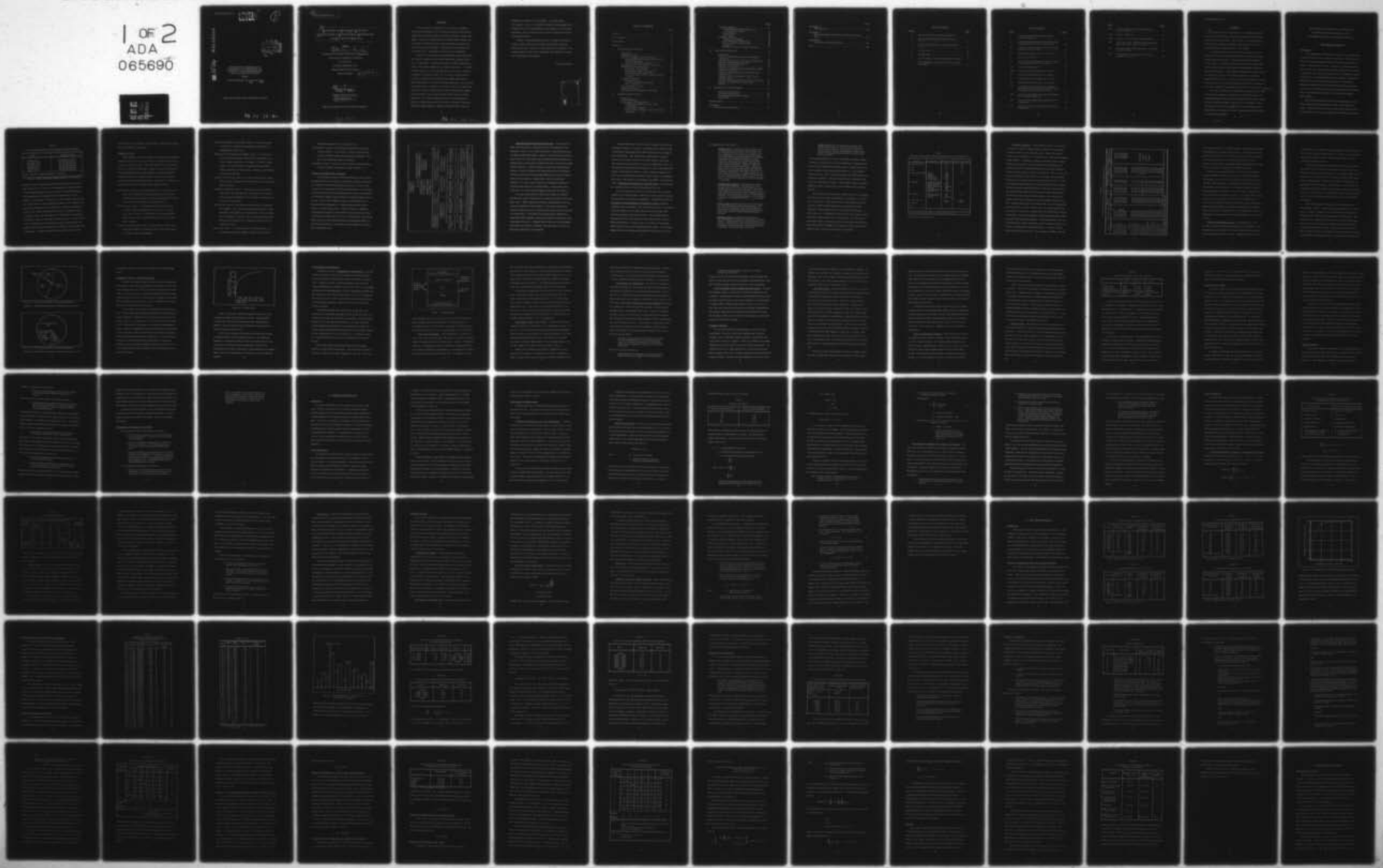

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DEPARTMENT OF DEFENSE BULK PETROLEUM: AN INVESTIGATION OF INVENTORY LEVEL DETERMINATION AND ALLOCATION OF STORAGE

THESIS

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⑭ AFIT/GOR/SM/78D-12

⑥ DEPARTMENT OF DEFENSE BULK PETROLEUM: AN INVESTIGATION OF INVENTORY LEVEL DETERMINATION AND ALLOCATION OF STORAGE.

THESIS

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Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
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In Partial Fulfillment of the
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by

⑩ Craig M. Northrup
Captain USAF

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PREFACE

It was personally gratifying for me to be able to complete a study that both fulfilled part of a degree requirement and provided an opportunity to practically apply many newly "mastered" analysis techniques. The most satisfying aspect of the entire effort, though, was in meeting the challenge that came with undertaking a project about which I had no prior knowledge. While this may have increased the frustration factor, in hindsight I can say it was all worthwhile.

Because of my initial lack of understanding of fuels management, the eventual completion of this thesis required the continuing assistance of many people. Captain Gordon Spray at DFSC opened doors to all the "right" people and became a friend in the process. As a DFSC computer analyst, Mr. Fred Murphy went out of his way to oblige all my ridiculous requests for data. Mr. Lou Martz at Detachment 29 was solely responsible for providing me the unique opportunity to gather individual Air Force base fuel usage predictions. Major Charles Cummings and Mr. Paul Wagner, who form the AFLC command fuels section, were always willing to take of their valuable time to explain fuels operations as they viewed it based on their years of practical experience. Mr. Ronnie Vandagriff, the Base Fuels Management Officer at Wright-Patterson Air Force Base, was totally cooperative and almost understanding as I blindly searched his files for that one insight that would make it all fit together. As thesis advisor, Dr. Edward J. Dunne, Jr. provided the perspective and guidance that eventually led to the accomplishment of this project. To all of these individuals, and to all those others that I have certainly overlooked, a most heartfelt thanks.

Finally, it is totally appropriate that I recognize my family for having to endure all these many months of living with a part time father and husband. Whether it be the blank stares over dinner or the weekends spent at home so Dad could study, they tolerated it all and were unflinching in their support.

Craig M. Northrup

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ABSTRACT

This study analyzes the procedures for establishing authorized fuel levels at DoD facilities to determine if present petroleum inventories represent actual needs. Three aspects of the formula that is used by both the Defense Fuel Supply Center and the Air Force in computing peacetime operating stocks were studied.

To estimate the effect of costs to the government of various inventory policies, the storage of petroleum was modeled in a linear programming fashion using a transportation model that minimized storage costs. A hypothetical scenario consisting of locations using/storing bulk petroleum was described and subsequently modeled as a transportation problem. The conditions delineating this scenario were then changed to reflect several alternate methods of calculating required inventory levels. The value of the objective function for each of these scenarios was measured against the minimum cost solution of the original conditions to determine the net effect on storage costs.

The study concludes that (1) utilization of existing storage could be improved if assignment of tankage was centrally determined, (2) supplementing present inventory determination and storage procedures with more analytic techniques could improve the credibility of these calculations, and (3) the cost implications of less stringent inventory requirements, while often overlooked, represent measurable savings of considerable magnitude.

DEPARTMENT OF DEFENSE BULK PETROLEUM: AN INVESTIGATION OF INVENTORY LEVEL DETERMINATION AND ALLOCATION OF STORAGE

I. THE RESEARCH PROBLEM

Introduction

The management of bulk petroleum resources by the Department of Defense (DoD) is a task of immense proportions. Some measure of the scope of this undertaking is illustrated by the inventory data in Table I. These petroleum stocks, consisting of 27 different types of fuel stored at over 1200 reporting locations, represent that necessary to support the daily operating activities of DoD. In addition, included in these levels is a predetermined amount of petroleum continuously held in reserve should wartime mobility plans be implemented. Although the individual services determine their own operating and reserve levels, the primary DoD agency having operational responsibility for maintaining this inventory is the Defense Fuel Supply Center (DFSC).

The motivation behind this thesis is the large amounts of DoD dollars required to maintain inventory levels of the magnitude in Table I. While in its broadest terms possible improvements in DoD fuel management is the research problem, this chapter introduces the

Table I

Total Worldwide Bulk Petroleum Monthly Closing Inventories

Month	Closing Inventory
October 1977	85,781,672 Barrels
November 1977	87,314,349 Barrels
December 1977	89,216,625 Barrels
January 1978	90,448,498 Barrels
February 1978	88,569,835 Barrels
March 1978	87,496,126 Barrels
Note: One barrel refined petroleum = 42 gallons.	

Source: Defense Energy Information System, Oct 77-Mar 78

specific research problem and identifies those objectives upon which this study was based. However, to understand the research problem or the resulting objectives, there are aspects of the DoD bulk petroleum management environment that need to be discussed. Consequently, a presentation of the objectives will be foregone until near the end of this chapter so that a detailed description of the conditions leading to their development can be completed. Following a definition of terms, those aspects presented in this chapter are DFSC operations, managerial control, the determination of requirements, and planning for storage. Based on a knowledge of these aspects, it is then possible to form a statement of the problem that, while recognizing the complexity of the bulk fuels environment, is realistic in terms of the scope of this study. Leading from this are the specific objectives of the research effort. This chapter concludes with a section on the assumptions and limitations of this study.

Definition of Terms

This definition of terms has been incorporated into this beginning chapter to insure that it is not overlooked, as is often the case when it precedes or follows a report. This is not intended to be an exhaustive glossary of bulk fuels terminology. Rather, the terms in this section have been included because of their unique or specialized meaning. Following each term is found the number of the page on which that word is first used following this section. On that page, an asterisk (*) will indicate that word is included in the definition of terms.

Aviation Fuel Logistical Area Summary (AFLAS)--(page 39) An automated report published quarterly depicting total aviation fuel prepositioning and peacetime inventory requirements by location. An Air Force document that is classified SECRET.

Bulk Petroleum--(page 5) Liquid petroleum products which are normally transported by pipeline, rail tank car, road tank truck, barge, harbor or coastal tanker and oceangoing tanker and stored in a tank or container having a fill capacity greater than 55 gallons.

Defense Fuel Region (DFR)--(page 25) Decentralized, field organizations representing the Commander, DFSC, with regional petroleum logistic support responsibility.

Defense Fuel Support Point (DFSP)--(page 12) Any bulk terminal (commercial or military) storing DFSC owned product for redistribution to base level.

Integrated Material Management (IMM)--(page 5) The exercise of total Department of Defense management responsibility for a Federal supply group/class, commodity, or item by a single agency. It normally includes computation of requirements, funding, budgeting, storing, issuing, cataloging, standardizing, and procuring functions.

Inventory Control Point--(page 10) A central activity which consolidates inventory requirements and has authority over that product while in inventory.

Obligational Authority--(page 7) Those funds on account with the United States Treasury which the government has set aside for various approved expenditures, one of which is to support various stock fund operations.

Pipeline Fill--(page 22) The amount of product which is required to fill a pipeline. The amount is determined by the inside volume and length of the pipeline and is unavoidable as long as the pipeline is operational. The line could be drained by pumping water through it but would have to be refilled with products before it could deliver again.

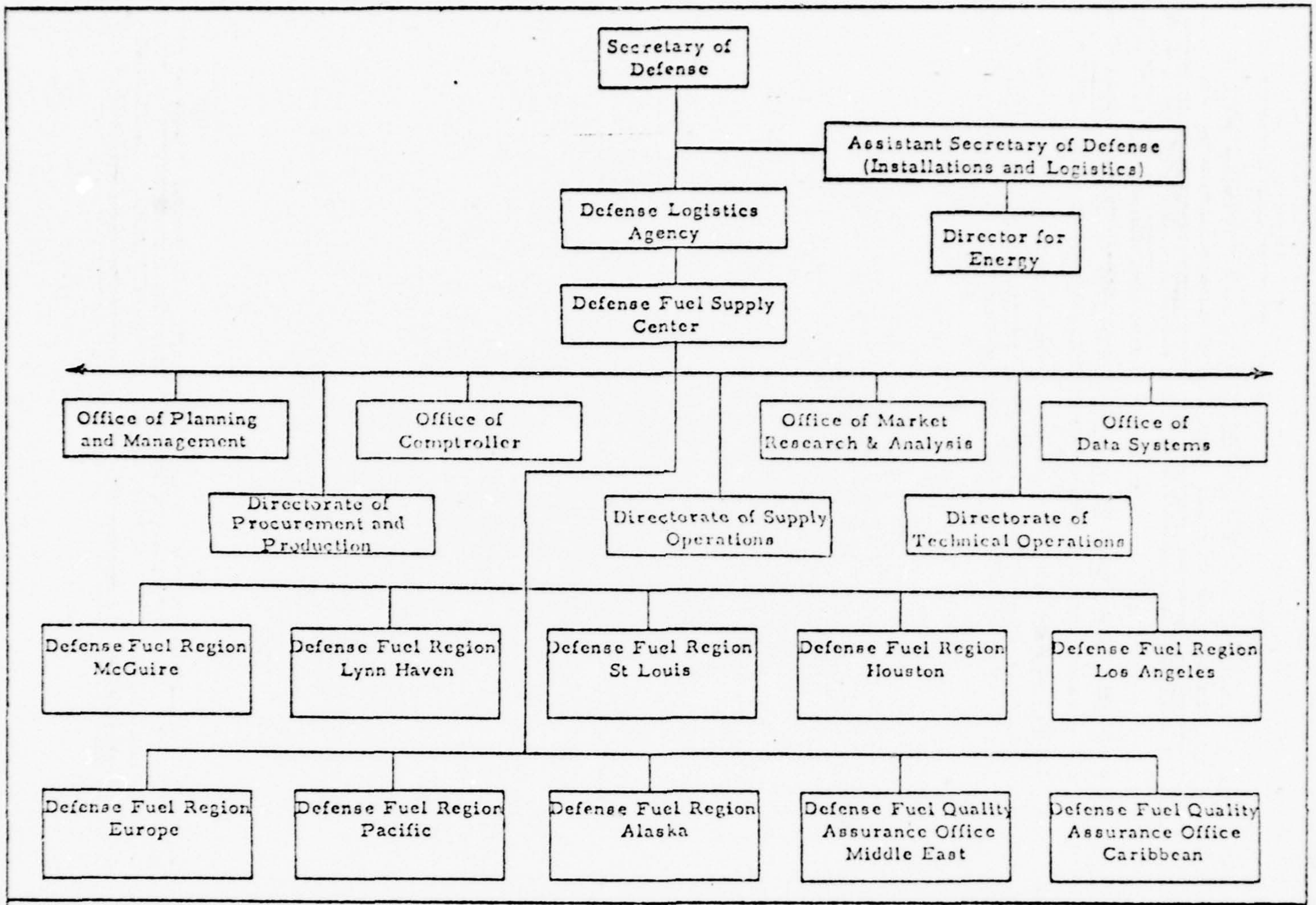
Stock Fund--(page 7) A working capital account whereby the cost of consumable materials is held in suspense from the time of acquisition until the items are issued for use.

Tank Bottoms--(page 22) That quantity of liquid that is below the suction manifold or drawoff line of a storage tank and which cannot be withdrawn under normal operating conditions. Bottoms can be withdrawn using a sump pump.

Throughput--(page 12) A measure of the amount of product passing through a terminal, determined as (Input + Output) ÷ 2.

Defense Fuel Supply Center Operations

The Assistant Secretary of Defense (Installations and Logistics) through the Director for Energy is responsible for policies and guidance relating to DoD petroleum logistics programs, systems, and procedures for insuring their effective implementation. In accordance with DoD directives these responsibilities have further been assigned to the Defense Logistics Agency (formerly the Defense Supply Agency). On July 1, 1973, the Commander, DFSC, was designated as the Integrated Material Manager for *bulk petroleum products by the Defense Logistics Agency (DLA). Figure 1 provides a simplified organizational perspective of these Federal agencies and some detail of the structure of DFSC (Ref 1:I-1-18). An examination of the specific stated objectives of the *Integrated Material Management (IMM) concept for bulk petroleum is also helpful in understanding the organization of DFSC (Ref 2:I-2).



Note: Certain organizational detail within DFSC has not been included (this incompleteness is shown by the arrows on each end of the horizontal line under DFSC).

Figure 1. DoD Organization for Energy Management

Integrated Material Management Objectives. One objective of IMM is the elimination of individual service *stock funding of bulk petroleum. Prior to 1973, DFSC functioned to centrally procure and coordinate product distribution. However, it performed very few functions in the area of operations single management and acted only as a billing agency in the transfer of funds between the services' stock funds and the contractor. Under the present concept, the Bulk Petroleum Category of the DLA Division of the Defense Stock Fund (hereinafter called the Fuels Stock Fund) provides DFSC with the means to finance bulk petroleum products, transportation, and other associated expenses. For Fiscal Year 1978 the total *obligational authority of the Fuels Stock Fund was 2.8 billion dollars, a figure which represented about 3% of the total DoD budget for that year (Ref 3:Encl 1).

A second stated objective of IMM is the funding of worldwide operating and reserve inventories in storage and in transit by the Fuels Stock Fund. DFSC maintains ownership of bulk petroleum from procurement to delivery to base boundary. This mode of operation in which the military services own and manage on base stocks is referred to as IMM Phase I. Currently in the planning stage, IMM Phase II would allow DFSC visibility of petroleum products to the point of actual consumption (Ref 2:I-2). Although Phase II has yet to be fully defined by the Office of Secretary of Defense, DLA ownership of on base aviation and marine fuels can be expected.

Another IMM objective is direct sale of products by DLA to the consuming activities. In essence, a wholesale-retail-consumer type relationship is established between DFSC-military service-organization of final usage. This requires the retailing agency to budget, control, and account for the cost of all fuels ordered, rather than allow them to obtain the goods free or at non-compensatory rates. It also places the retail agency in the position of critic of purchase price, quality, and timeliness of delivery. Hence, while the separate services are more easily held accountable for their actions, coincidentally they enforce some degree of accountability upon DFSC. DoD Directive 7420.1, Regulations Governing Stock Fund Operations, recognizes this as a specific objective of stock fund operations (Ref 4:4).

Closely related to the direct sale of bulk fuels and a necessary condition for its implementation, IMM has as another specific objective common pricing, procedures, and standards. DoD Manual 4140.25-M, Procedures for the Management of Petroleum Products, explicitly establishes this commonality. The common pricing aspect is manifested in the determination of a standard price for each of the nine DFSC centrally managed fuel product categories. These standard prices represent the actual retail charges to DoD agencies upon receipt of a DFSC issued product. In effect, they are a measure of the expense DFSC incurred in procuring and delivering that product. The following listing is those cost elements which DFSC is authorized to recover in the standard price (Ref 3:Encl 3).

Product costs are based on current contract costs. A weighted average product cost is developed for each petroleum category (JP4, JP5, Avgas, etc.). To compensate for cost increases during a fiscal year, the weighted average product cost is adjusted. The adjustment considers DOE policy changes related to crude oil prices, legislation affecting crude oil and petroleum products, and crude oil price increases by OPEC. Example: DFSC contracts with a Caribbean refinery for 1 million gallons of JP4 at .394 cents per gallon FOB refinery. During the same period it has under contract a US East Coast refinery for 1.5 million gallons JP4 at .356 cents per gallon FOB refinery. Based on these two buys only the weighted average product cost for JP4 is .372 ((.394 X 1,000,000 + .356 X 1,500,000) ÷ 2,500,000).

Transportation expenses are based on past experiences for each category. Past experience is adjusted to provide for rate changes within the period included in the price study. Example: In the above case, DFSC incurs $36,000 tanker expenses (36 hours steaming time at $1,000 per hour) + $10,000 pipeline expenses. A transportation expense of .019 is added to the price of each gallon ($46,000 ÷ 2,500,000 gallons).

Service costs are based on service costs included in the stock fund budget for petroleum products. Service costs are pro-rated to each category based on inventories on hand in the contractor operated terminals (a discussion of terminal operations follows shortly).

Wholesale losses are based on past experience. Past experience is adjusted to exclude non-recurring losses. A wholesale loss factor is developed for each category. Such losses are the result of product evaporation in transit and storage, product degradation in the pipeline, and similar type occurrences.

> Retail losses (retail loss allowance) is based on the retail loss allowance of .005 times the dollar value of the projected sales for each category. Office of the Secretary of Defense-Comptroller has determined that the retailing agencies should not be held accountable for this loss.

It is perhaps significant to observe that DFSC's operating expenses (overhead + personnel costs) are not included in the standard price. It is also noteworthy that the standard price is actually only an estimate of present costs based on past experience. In an attempt to capture the most current costs, price studies are made quarterly by the DFSC comptroller. All price changes must be approved by the Office of the Secretary of Defense. Each product category, products within the category, and its most recent standard price is found in Table II.

The remaining stated objectives of IMM reflect the consolidation possible when management responsibility is centralized. The first of these objectives is a single point for the receipt and payment of all contractor billing involving deliveries to the Fuels Stock Fund. Another is a single billing point for all Fuels Stock Fund Sales. A third objective is consolidation of individual service *inventory control points into a single DoD inventory control point. The reduction in personnel ceilings commensurate with these activities represents the final stated objective of IMM. The realization of these objectives by DFSC has led to increased effectiveness through IMM.

Table II

Petroleum Products for Which DFSC Has IMM Responsibilities and Their Standard Price

Category	Product Names	Product Codes	Standard Price Per Gallon
1. Aviation Gasolines		AVT	.557
2. JP4		JP4	.420
3. JP5		JP5	.441
4. Automotive Gasolines	Premium Regular Unleaded Combat Type I Combat Type II	MGP MGR MGU MG1 MG2	.543
5. Distillates	Marine Diesel Fuel Arctic Diesel Fuel Winter Diesel Fuel Regular Diesel Fuel Kerosene Navy Distillate Fuel Light Fuel Oils	DFM DFA DF1 DF2/DF4 KSN NDF FS1/FS2	.441
6. Residuals	Navy Special Fuel Low Sulfur Fuel Oil Fuel Oil	NSF FSL FS4/FS5/FS6	.414
7. Lubricating Oils		Not Available	Not Available
8. Crude Oil			
9. JP8			

Note: (1) Certain low useage fuels are not listed, (2) DFSC coordinates procurement but has no IMM responsibilities for chemicals and solid fuels such as coal.

Source: DFSC Price Bulletin No. 77-1

Terminal Operations. The distribution system for bulk petroleum fuels to support worldwide military requirements necessarily includes a network of bulk fuel tank farms. These are normally referred to as terminals or, more specifically, *Defense Fuel Support Points (DFSPs). In addition to acting as distribution points between wholesaler and retailer, these terminals serve as depots for the storage of DLA fuel awaiting distribution and also store inventories which exceed the military services' tank capacity. DLA, by law, cannot own real property and, therefore, must obtain use of terminals owned by the government and commercial contractors (Ref 1). This has resulted in the following three tiered classification of terminals: GOCO (Government Owned and Contractor Operated); COCO (Contractor Owned and Operated); GOGO (Government Owned and Operated). The GOCO terminals represent those that have been formally permitted to DFSC by the military services through Real Property Permits. Although DFSC does not own the facility, it is fully responsible for its operation. In those locations where government facilities are not available or previously committed and where DFSC determines that a need exists, commercial tankage is contracted for specified amounts of storage and *throughput capability. As discussed earlier, the cost of operating these COCOs and GOCOs is then recaptured by DFSC as a service cost adjustment to the standard price. A listing of GOCOs and COCOs is found in Table III. The remaining 65 DFSPs, referred

Table III

Location, Capacity, and Cost of CONUS GOCOs and COCOs as of FY 1978

Location	Contract Period	Capacity (Barrels)	Cost ($)	Cost/BBL ($)	Estimated Annual Throughput (Barrels)	Additional FY 78 Expenses, Repairs, etc. ($)
GOCOs						
Searsport, ME	10/77-10/78	900,000	360,000	.400	1,500,000	700,000
Melville, RI	7/76-6/81	1,300,000	291,000	.224	600,000	1,400,000
Charleston, SC	8/76-8/81	560,000	201,000	.360	2,600,000	500,000
Lynn Haven, FL	12/76-12/81	562,000	201,000	.360	750,000	585,000
Pt Tampa, FL	12/76-12/81	336,000	143,000	.420	1,300,000	410,000
Harrisville, MI	11/77-1/78	400,000	47,000	.480	165,000	325,000
Cincinnati, OH	11/76-11/81	501,000	245,000	.490	800,000	435,000
Mikileto, WA	5/77-5/82	750,000	226,000	.300	150,000	335,000
Norwalk, CA	5/76-6/81	890,000	390,000	.440	12,000,000	535,000
COCOs						
Jacksonville, NJ	2/77-1/78	123,600	119,000	.965	482,000	
Burlington, VT	9/77-8/78	30,500	28,975	.950	72,000	
Newington, NH	7/77-7/78	360,000	165,000	.460	960,000	
Piney Point, MD	7/77-6/78	384,000	335,000	.870	1,826,000*	
Plattsburg, NY	8/77-7/78	480,000	249,000	.520	897,000	
Pt Mahon, DE	9/77-8/82	216,000	389,000	1.800	1,495,000	All Expenses Included In Cost of Contract
Verona, NY	9/77-6/78	295,000	138,000	.470	1,100,000	
Pt Reading, NJ	7/77-6/78	645,000	1,450,000	2.250	2,565,000*	
Beaufort, NC	8/77-7/78	600,000	356,000	.590	1,600,000	
Doraville, GA	4/77-3/78	189,000	328,000	1.740	320,000	
Montgomery, AL	4/77-3/78	60,000	98,000	1.630	265,000	
Pt Everglades, FL	4/77-3/78	375,000	398,000	1.060	800,000	
Pensacola, FL	8/77-7/78	64,000	70,000	1.100	141,000	
Escanaba, MI	1/77-1/78	640,000	200,000	.310	800,000	
Grand Forks, ND	10/74-10/79	270,000	128,000	.470	584,000	
Nebraska City, NE	2/77-1/78	139,000	157,000	1.130	75,000	
Conway, AK	2/77-1/78	160,000	125,000	.780	708,000*	
Drumwright, OK	3/77-2/78	315,000	158,000	.610	111,000	
Pasadena, TX	10/77-9/78	260,000	369,000	1.420	1,498,000	
San Antonio, TX	11/77-10/78	140,000	140,000	1.000	485,000*	
Ozol, CA	5/76-5/77	1,000,000	258,000	.260	1,759,000	

*Additional throughput charges incurred totaling $221,000.

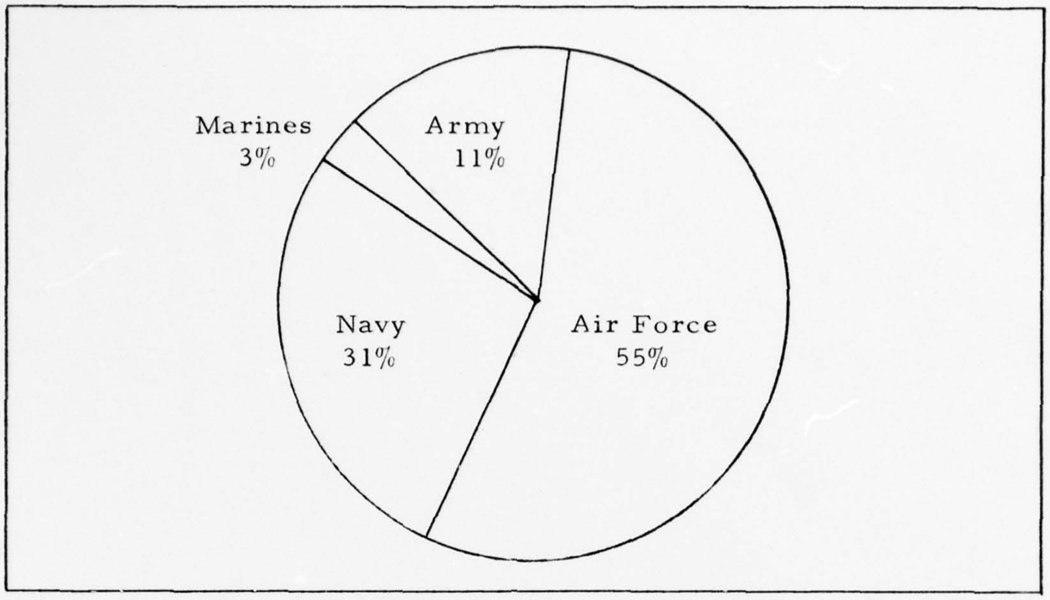
to as GOGO terminals, are owned, operated, and remain the financial responsibility of the owning military service. Although these GOGOs contain DFSC owned fuel, the military service has the final authority as to what types of fuel are stored and how the tanks are used. Because of this, the Navy has adapted a philosophy different from the Air Force towards the operation of its CONUS terminals.

Within the Zone of the Interior, all Air Force terminals are operated by DFSC as GOCOs (the Army has no CONUS terminals). Consequently, the Air Force is not required to fund monies for the operation of these facilities. When IMM was implemented, the Navy also turned over the operation of its terminals to DFSC. However, shortly thereafter they asked for the return of these terminals and have operated them as GOGOs ever since. Thus, while the Navy may keep the price of its primary use fuels (JP5 and DFM) down a few mills because DFSC incurs little service costs in their management, they must annually budget for terminal operations and maintenance. Under this concept of operation the Navy does experience a degree of independence in the operation of its terminals that the Air Force does not enjoy.

DFSC and the Military Services. As implied earlier, the secretary of each of the military departments is responsible for the management and ownership of war reserve and peacetime operating stocks of petroleum products on base. Depending on the amount of product used, the complexity of this responsibility varies between the services and among operational functions. Figures 2 and 3 provide an insight of how product useage is divided among the services and operational functions (Ref 5:7).

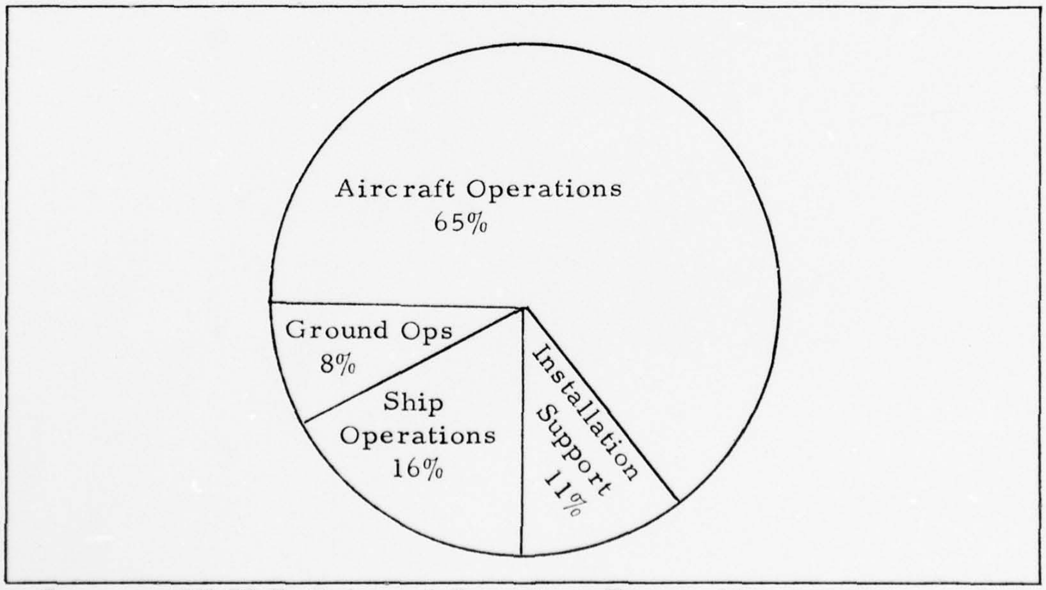
The interaction between DoD and DFSC is founded on a need by the military for fuel and the associated procurement, storage, and distribution functions that DFSC provides. As might be expected from Figures 2 and 3, both the Air Force and Navy maintain rather large staffs of approximately 30 people each at DFSC. Together with the inputs from other DoD agencies, these staffs act as a focal point for collecting and relaying to DFSC requirements for peacetime consumption and war reserve stocks. In its broadest sense, it is the establishment of these levels that determines the level of service that DFSC must provide.

This logically leads to a discussion of the determination of requirements. However, before investigating this issue, it is necessary to recognize a condition of the bulk fuels environment that has implications for DFSC management and research in this area. This condition is that, despite the large number of products and locations serviced, only several products are heavily used and relatively few locations distribute large amounts. This phenomenon is not uncommon in management and can be exploited to provide insight into particular philosophies of managerial control. Consequently, a discussion of



Source: FY 77 DoD Annual Report on Energy Management

Figure 2. DoD Petroleum Demand by Military Service FY 1977



Source: FY 77 DoD Annual Report on Energy Management

Figure 3. DoD Petroleum Demand by Operation Function FY 1977

managerial control has bearing on the study and is pertinent at this point.

Managerial Control for DoD Bulk Petroleum

Effective management requires that the amount of management effort applied vary in direct relationship to the importance of the item being managed (Ref 6:28). But it is also true that unless each item is under a reasonable degree of control, the aggregate will not be under adequate control (Ref 7:19). Some approach is needed to isolate those items requiring extremely precise control as opposed to those items that can be controlled with less precision.

A concept that can be useful in management control is Pareto's law. The law states that the significant elements in a specified group usually constitute a relatively small portion of the total items in the group. Figure 4 is an example of a curve based on Pareto's law (Ref 8:129). When Pareto's law applies, the message for management is clear: identify the significant elements and concentrate control efforts on those elements. These control efforts may include documentation required, management information requirements, amount of automation allowed, and centralization/decentralization of management authority. By use of control techniques of this sort, the cost of control is minimized while still recognizing the most important items for increased scrutiny.

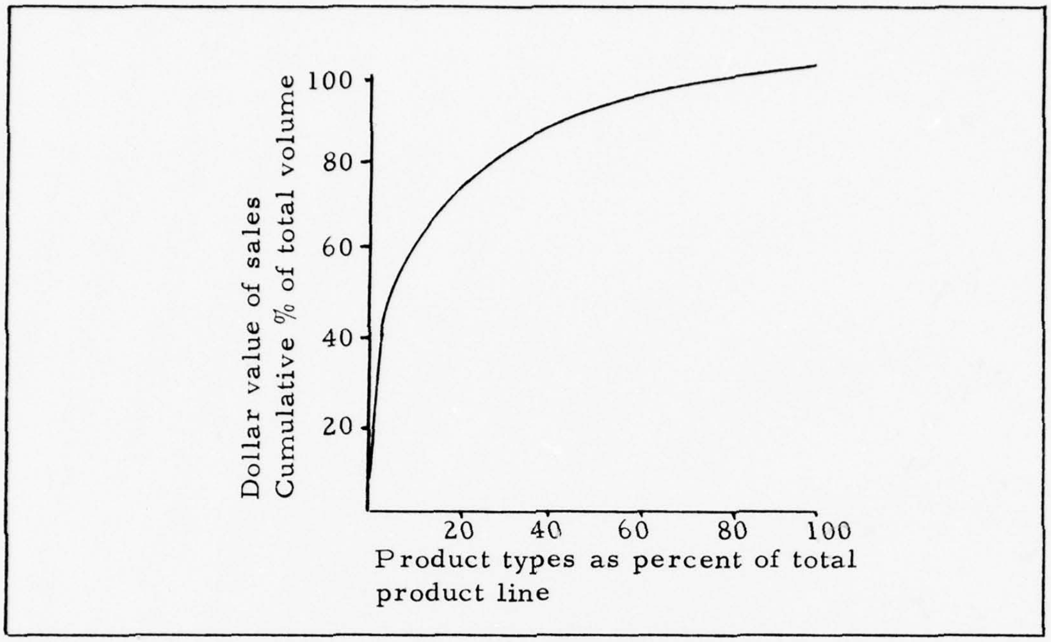


Figure 4. A Pareto Curve

DFSC is well aware of the aforementioned variability of consumption by product type and usage by location. Although DFSC certainly takes this fact into consideration when managing these aspects, it does so based on practical experience and observation without formalizing Pareto's law.

This Pareto concept was introduced early in the study because it supplied direction to the subsequent research. The significant elements for managerial control can also be viewed as the most logical areas for concentration when investigating a multi-product geographically diversified organization. As discussed next, the determination of inventory requirements was examined for feasible alternate methods.

Determination of Requirements

DoD Directive 4140.2, Management of War Reserves, cites that the basic objectives of DoD are to be prepared to support national policy and defend successfully the security of the nation in emergencies. A primary element of material readiness is the sound and careful establishment of adequate reserve stocks (Ref 9:1). In keeping with this policy, prepositioned war reserve requirements (PWRR), the fuel required to carry out the initial stages of a war, are computed by the armed services by grade of product and location using pre-D-day worldwide material policies, approved force structure, and joint service war plans.

Peacetime operating stock (POS) levels, the quantity of fuel authorized to sustain daily operating activities during peacetime, are computed on the basis of average daily consumption, resupply quantity and time frame, and authorized deviations. Peacetime operations must be supported daily; therefore in using base tank capacity, the services assign POS requirements first and use any remaining capacity to store prepositioned war reserve (Ref 10:2). A convenient method for conceptualizing this process is the tankage model presented in Figure 5.

Each DFSC terminal and DoD operating location maintains inventory to support POS requirements. The format used by DFSC in arriving at a POS level is found in Appendix A, page 104. Also in the

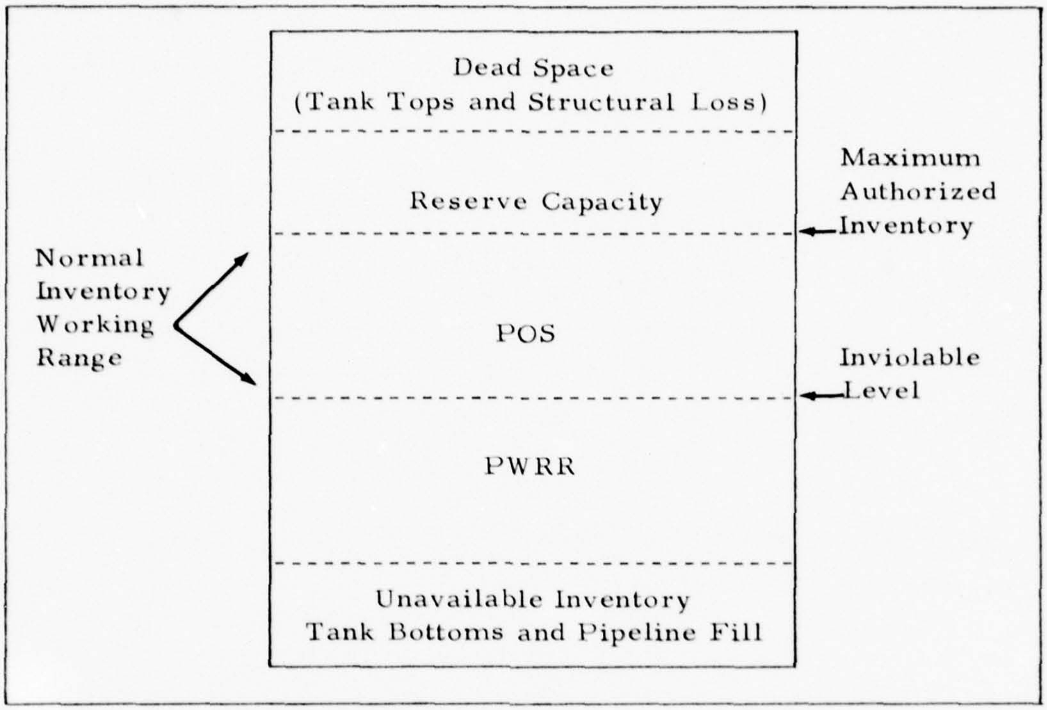


Figure 5. Tankage Model

same appendix, page 103, is Air Force Form 761, Bulk Fuels Peacetime Operating Stock (POS) Computation. Both procedures are essentially the same. Three specific steps in this calculation and the use of peacetime assets for war reserve planning are discussed next.

Forecasting Consumption. POS computations are made twice a year. The 15 July report precedes the period of 1 October to 31 March and the 15 January report covers the period of 1 April to 30 September. Each time a computation is made, the individual completing the form forecasts that installation's consumption of each individual fuel product for the upcoming six month period (line two). According to current

Air Force directives, the determination of requirements should include such factors as issue experience, projected mission/program changes, and Air National Guard/Reserve annual training support (Ref 11:1-19). On line three of the form, the daily demand rate (DDR) is calculated by dividing line two by 180 days. The DDR then becomes the primary factor from which the final accountable POS level is determined.

Because the six month forecast becomes such a critical element in the computations to follow, any errors in this figure affect the entire requirements determination procedure. Yet, the projection itself must be relatively subjective because of the amount of personal judgment involved. This raises several important questions. Specifically, how well are the base fuels management officers and terminal operations managers able to predict usage? Do they tend to over or under estimate demand? If so, is it significant?

Determining a Safety Level for POS. A safety level for POS is computed on line five of the formula. Two multiplicative factors, 2.25 and .25, are used. Research into the derivation of these multipliers failed to produce any documented or consistent explanation. Recently, the DFSC Management Support Office of the Directorate of Supply Operations circulated a Memorandum for Record expressing concern over the validity of the safety level formula (Ref 12:Encl 1).

Safety stock is defined as the inventory maintained to protect against the uncertainties of demand between reorder and replenishment. In general, the amount of safety stock held is dependent on the particular demand pattern exhibited by the issuing agency. Instead of the procedure described on line five of the formula, the fitting of actual demand to a theoretical probability distribution would provide a concise mathematical approach to the calculation of a safety stock.

*Tank Bottoms and *Pipeline Fill. The Air Force formula for computing POS includes a factor which increases the requirements by the quantities in pipelines and storage tank bottoms (lines 11 and 12). Such fuel is considered to be inaccessible under normal operating conditions and therefore not available as either POS or war reserve. In a 1975 report entitled Bulk Fuels Need to Be Better Managed the General Accounting Office (GAO) criticized this procedure as unnecessarily inflating inventory requirements (Ref 10:12). The GAO's reasoning was that, where war reserve fuels are stored in the same system as POS, the pipeline fill and tank bottom quantities could be considered as war reserve during peacetime. Conversely, in an emergency, when POS would not be needed, the fuel from pipelines and tank bottoms could be considered as POS and would not be needed as war reserve. DoD countered by stating:

> Adaption of such a practice would effectively reduce the assured PWRR level at any storage location where, at the time of the emergency, POS should happen to be at minimum levels-a cyclic occurrence (Ref 10:23).

The GAO's response to this was:

> Although POS may sometimes be at minimum levels and be insufficient to displace the entire quantity in

> pipelines and tank bottoms, this is not a common occurrence (Ref 10:16).

In any event, the GAO went on the emphasize, special methods did exist for retrieving such fuel in an emergency should POS not be available to displace pipeline and tank bottom war reserve quantities.

Use of Peacetime Assets to Support Wartime Activity. Wartime fuel planning assumes no allowance for POS when PWRR levels are calculated. Being unable to forecast actual individual POS levels, the war plans assume the most conservative condition of no POS available to support PWRR. Although this will be the case in only a few locations, the risk is deemed such that any cost savings is outweighed by the strategic implications of not having enough PWRR when needed. The dilemma, if there is one, is that, in the aggregate, considerable amounts of POS will be available.

Planning for Storage

If every DoD facility had enough tankage to store all its fuel requirements, each base would be self sufficient and, except for resupply, little coordination would be required. Unfortunately, the real world is much more complex. In the case of DFSC, every DFSP maintains war reserve fuel for at least one military installation. As regards the Air Force, approximately 75% of all bases either store fuel for another base or have portions of their fuel requirements stored at other locations. The process of determining who stores how much for whom is the subject of this part of this introductory chapter. In addition, two problem areas relating to planning for storage are also developed. One is the problem of analyzing long term storage investment projects. Also, the possible changeover to a sole jet fuel has significant implications to the storage of fuel.

Allocating Storage. At the operating level, the Air Force base/Army post/Navy port or air station fuels manager allocates his storage as best fits his installation's needs and reports any shortfalls or excesses in capacity to his service. The service then attempts to match available storage with bases requiring it. Failing in this endeavor, any shortcoming is reported to DFSC as a terminal storage requirement (DD Form 1887, Appendix A, page 100). DFSC supply specialists consolidate the requirements, compute POS storage requirements for terminals, and assign the total requirements to available storage in a worldwide storage program. There is also a procedure whereby the services report any tankage that they consider as excess to DFSC (DD Form 1888, Appendix A, page 101). In theory, DFSC then coordinates the usage of these tanks to store another service's fuel. As determined from conversations with various fuels managers, this procedure of insuring maximum tank utilization appears seldom used.

When total storage requirements exceed the combined capacity of on base storage and government owned terminals, DFSC obtains additional storage capacity through contracts with commercial terminals. At the present time there are 6.8 million barrels in the CONUS alone under lease to meet these excess requirements (Ref 13:139). There are circumstances, particularly in Europe, where the available government and commercial tankage will not be sufficient to cover all the requirements. In this case, DFSC obtains the service's agreement to allow a portion of the war reserve requirement to remain uncovered. Such action normally requires a waiver from the Office of the Chief of Staff of the affected service.

The DFSC *Defense Fuel Regions (reference Figure 2) publish annually Emergency Distribution Plans (EDP) to inform all operators of tankage storing fuel for another location of the planned distribution pattern and primary mode of transportation of fuel in an emergency. The plan advises the operations manager of how much fuel is to be moved where in an emergency. Appendix A, page 102, contains a sample EDP.

Long Term Investment Decisions. The relocation process just described is a direct result of a shortage of government fuel storage at or near needed locations. One solution to this is simply for the DFSC to acquire additional tanks. This can occur in two ways. Most obviously, money could be appropriated to build new tanks where needed. Also possible is the reclaiming of surplus government fuel storage, i.e. when a military base closes, before the Government

Services Agency auctions it off to the public. The problem is that presently decisions to secure additional storage are made without being able to integrate such a choice into the entire storage network to measure its overall effect.

Both of these type of projects require large amounts of capital investment. The cost of new tankage is estimated at $12.00 a barrel (Ref 14:125). Depending on its condition, it can take up to $250,000 to rehabilitate and bring up to prescribed standards surplus tanks. As regards such projects, the question that a single manager for storage needs to answer is, "Will the large capital investment that acquiring additional tankage requires be offset by a reduction in overall system storage cost when viewed over a period of years?" A possible change in operating procedure that may temper any such long term storage decision is the introduction of JP8.

The Use of JP8. The proposal for Air Force and Navy conversion from JP4 and JP5 to JP8 has been researched and discussed for many years. As shown in Table IV, each fuel has different properties. Because of its more stable composition, JP5 was adapted for use by the Navy in 1952 due to the need for a less hazardous fuel for shipboard use (Ref 15:6). Air Force concerns over fuel icing problems at cold weather locations due to JP5's higher freezing point and worries about the higher energy ignition systems JP5 requires due to its higher flash point stifled any efforts at establishing a common military jet fuel.

Table IV

Different Properties of JP4, JP5, and JP8

	JP4	JP5	JP8
Flash Point	-20°F	140°F	105°F
Freeze Point	-72°F	-40°F	-58°F
Blending Ingredient	Naphtha+Kero	Kerosene	Kerosene
Production Capacity	Sufficient	Limited	Large Potential
Users	USAF	USN	NATO

As the specifications in Table IV indicate, the use of JP8 could be considered a compromise. Beginning in the summer of 1978, NATO introduced JP8 as its standard fuel. A complete conversion is planned by 1980 (Ref 15:6). With few exceptions, all USAF and USN jet aircraft could be simply modified to use JP8. Despite the difficulties such a large scale transition will likely generate, coordinating the procurement, distribution, and storage of only one jet fuel can be expected to greatly streamline DFSC operations and increase management efficiency.

In the area of storage allocation, it is anticipated that much consolidation of tankage will be possible. Present Navy operating policy prohibits the introduction of JP4 into any storage system containing JP5. The concern is that the less stable JP4 will contaminate the equipment and make it unsuitable for the use of JP5. Due to similar worries about product degradation, the Navy hesitates to allow its fuel to be stored in Air Force tanks. In itself, this may not seem that important. Yet, these two fuels represent about 60% of the total inventory of bulk fuels. In the aggregate, any consolidation of JP4 and JP5 will affect the entire storage situation.

Statement of the Problem

As seen in Table 1 on the second page of this thesis, the average inventory for this six month period is about 88,000,000 barrels, a figure which it is assumed is representative of a 12 month average. Analysis of the cost of capital and rate of return requirements for the petroleum industry suggest that it costs about $4.00 to hold one barrel of crude oil in inventory for one year (Ref 14:vi). If DoD's average inventory is considered in light of industry's holding cost, the cost of maintaining this inventory level is $352,000,000. Of course, the petroleum industry's expenses do not necessarily reflect the costs of the government. However, the analogy serves to emphasize the amount of capital investment such a program requires. What is known with certainty is that the government does experience an opportunity cost loss with owning this massive inventory. Based on the assumed 12 month average, a price per barrel of refined product of $18.00, and a discount rate of 10%, the annual opportunity cost alone to the government is $158,400,000.

In addition to opportunity and other intangible costs, there are storage costs which are a specific out-of-pocket expense to the DoD. Because DFSC has no operational control over the storage of fuels on bases or at GOGO terminals, there is no single bulk petroleum storage manager. The net result is a piecemeal approach to allocating storage that may oftentimes only suboptimize the entire scheme (Ref 16:299). Therefore, when DFSC must prepare an economic analysis of a proposed change to the storage network, such as contract revision for a COCO terminal or one of the long term capital investment projects just discussed, it is necessarily unable to evaluate this choice for its effect on the entire storage picture.

Within this context, the research problem that exists is that of allocating storage so as to decrease DoD's total expenditure to maintain its petroleum inventories. Because it is the inventory levels that determine the storage requirements, the research problem needs to be approached in two steps. At the first step the research question is, "Do present inventory determination methods provide justifiable requirements?" At the second step the question is, "Once inventory levels have been assigned, is there a concise analytical tool to enable evaluation of alternative storage options within the entire storage network?"

Specific Objectives

The primary objective of this study was to investigate the establishment of inventory requirements and the resulting storage of these levels to determine if there were possible areas for increased efficiency. The following five objectives were deemed a logical sequence to approaching this problem:

1. Develop an understanding of the operation of DFSC and its relationship with those DoD agencies it services.

This objective has been developed in this opening chapter.

2. Considering the geographic and product diversity of the bulk petroleum inventory, examine the applicability of managerial control techniques based on a Pareto type distribution.

Although DFSC intuitively recognizes this condition, formal identification of the significant product and geographic elements may add to an understanding of its usefulness for managerial control. The identification of significant elements also provided a convenient framework in which to view any subsequent research.

3. Examine present and possible alternate methods of determining operating inventory requirements.

In particular, those aspects identified in this chapter were analyzed. This included comparing predicted consumption versus actual consumption (Objective 3A), developing an empirical based method for identifying a safety level for POS (Objective 3B), and examining the issue of tank bottoms and pipeline fuel (Objective 3C).

4. Formulate a mathematical model that allocates storage in an optimal manner.

5. With the model, examine the cost sensitivity of the fuel storage network to change in inventory requirements and different storage options.

This provided a means of measuring the effect of and analyzing changes or improvements in operating procedures or storage facilities. These changes were (a) POS based on a more accurate consumption forecast (Objective 5A), (b) an allowance for tank bottom fuel in computing POS (Objective 5B), (c) an allowance for expected levels of POS when computing PWRR (Objective 5C), (d) the introduction of JP8 as the sole jet fuel (Objective 5D), and (e) securing additional storage (Objective 5E).

In pursuit of these objectives, the second chapter discusses the methodology that was followed in analyzing the problem. The third chapter presents the results of the analysis, and the final chapter, conclusions.

Assumptions and Limitations of the Study

The assumptions made in this study are as follows:

1. The research is based on current DoD and military policy and directives. They are not in the process of being changed.

2. Phase II of IMM will be implemented. DFSC will assume an increasing role in the management of all on base stocks of marine diesel and aircraft fuels.

3. There is no difference between the data as reported and the actual conditions from which it was observed. In reality, some differences could be possible due to data collection errors, posting mistakes, non standard procedures, etc. The analysis refers to all reported information as actual.

The limitations of this study are as follows:

1. Specific war readiness material requirements are classified. In order that the thesis remain unclassified, this fact may limit the scope somewhat.

3. Due to availability of and familiarity with Air Force procedures, much of the research and data collection was done in this environment. Although the methodology is applicable to all DoD agencies, they did not receive equal emphasis.

II. RESEARCH METHODOLOGY

Introduction

No single methodology could accomplish the objectives of this study. Rather, the research was a collection of different types of analysis applied to various assortments of data with the ultimate goal of integrating these into a practical analysis of DoD petroleum operations. Therefore, this chapter is organized to follow objectives two through five as they were presented in Chapter I. Each major heading is identified with a specific objective and the methodology/ies used in accomplishing that objective. To establish some consistency and because of the arrangement of the data, the research was based on information from the period of 1 October 1977 to 31 March 1978 when applicable.

Pareto Distribution

As regards the second objective, both total usage by product type and consumption by geographic location were examined for a Pareto type distribution. To test this hypothesis, data was extracted from the Defense Energy Information System (DEIS) by computer routines designed for the purposes of this report. Computer processed and stored on magnetic tape, the DEIS is generated on the last Friday of every month and serves as the primary management information tool for DFSC. Among the information it provides for each installation by product type are the following: monthly opening inventory, monthly total consumption, monthly receipts, monthly ending inventory, and average daily consumption. A representative page from the DEIS is found in Appendix B, page 106.

DFSC procures and distributes 27 different fuel products (Table II). For the six month period October 1977 to March 1978, the total consumption of each of these products at the retail level was derived. This data was then compiled in cumulative amounts in a table and graphed in the manner of Figure 4. Related to this, but perhaps of more concern to DFSC, would be the issues at the wholesale or DFSP level. These were determined and analyzed in the manner just discussed. Although issues by DFSC should approximate consumption at the retail level, some discrepancies were expected. The large majority of these can be accounted for by changes in opening/closing inventories, shipments direct from contractor (DFSP bypassed), or products in transit.

Retail distribution of bulk fuels is accomplished through approximately 1200 locations. Using the DEIS once again, the total consumption of all fuels at each of these installations during the October-March period was calculated. It was then possible to rank them in an effort to determine the most significant locations in terms of fuel consumed. In the same manner, issues at 110 DFSPs were analyzed. In the following chapter, the relationship between cumulative quantity and locations is summarized in Tables X and XI.

Determining POS Requirements

Objective three was concerned with examining the formula for deriving POS levels. In an effort to determine if the formula represented actual operating needs, three aspects of the calculation were investigated.

Predicted Consumption versus Actual Consumption. To enable a comparison of the forecast and actual usage, it was necessary to gain access to existing POS computations. This was done with the cooperation of Detachment 29, the Air Force liaison to DFSC. Among its other responsibilities, this organization is charged with the biannual validation of Air Force POS computations. The forms remain on file at Detachment 29 for one year and then are discarded. Instead of this normal disposition and to support this study, Detachment 29 agreed to supply the original 15 July 1977 POS computations for all CONUS Air Force bases. These forms provided the projected six month requirements for each of these bases for the period 1 October 1977 to 31 March 1978.

The actual usage of petroleum by these locations during this time period was established using the DEIS. As in the earlier product and location analysis, a special program was designed; this time to compute the actual average daily consumption over a six month period.

Comparing information from the DEIS and Air Force Form 761s (POS computations), it became possible to examine each location for projected and actual consumption during the six month period covered by the 15 July 1977 POS computations. To simplify the task, JP4 was the only fuel considered. It was then possible to make some observations regarding the accuracy of demand rate forecasts for JP4. Without specifying locations, the results are presented in tabular form in the next chapter.

A Safety Stock Formula. The area of concern here was the seeming arbitrary derivation of the present POS safety level. If it could be shown that the daily demand for fuel fit some specific distribution, e.g. a normal distribution, a much more precise safety stock formulation could be used. For a normal distribution, the calculation would be made in the following manner (Ref 7:80-93):

$$\text{Safety Stock} = K\sigma_y$$

where K = service level constant

σ_y = standard deviation of demand during the replenishment cycle

The service level is a term that defines the percentage of the time that demand during the replenishment cycle must be met with no shortages. The relationship between service level in percent and the appropriate constant is a function of the area under the normal curve. Table V illustrates some common service level values.

Table V

Service Level Values

Service Level in Percent	Service Level Constant-K
50	0
85	1.04
90	1.28
95	1.65
100	4.00

The formula is somewhat incomplete in that the standard deviation of demand during the replenishment is unknown. Knowing the daily standard deviation, σ_x, the conversion can be made in the following manner (Ref 17:245):

Let L = replenishment cycle in days

x_i = demand per day during the replenishment cycle

Y = total demand during the replenishment

$$= \sum_{i=1}^{L} x_i$$

Then $\mathrm{Var}(Y) = \mathrm{Var}(\sum_{i=1}^{L} x_i)$

$$= \sum_{i=1}^{L} \sigma_i^2$$

But all x_i are assumed normally distributed independent random variables with common mean (μ_x)

and variance (σ_x^2).

$$\mathrm{Var}(Y) = L\sigma_x^2$$

and

$$\sigma_y = \sqrt{L}\,\sigma_x$$

Consequently, the formula of interest becomes:

$$\text{Safety Stock} = K\ \sqrt{L}\ \sigma_x \tag{1}$$

To determine if formula (1) was applicable, the normality of demand for fuel had to be examined. The chi square test for goodness of fit was employed to test this hypothesis. The demand data for performing this test was collected at two Midwestern Air Force bases. At each location the daily consumption of JP4 for a continuous four month period was compiled from the Air Force Form 1237, Inventory (Fuels/Missiles Propellants), Column G, Net Issues. This form may be found in Appendix C, page 110, along with the observed values for bases Alpha and Bravo.

Testing for normality using the chi square goodness of fit can be found in numerous statistics textbooks (Ref 18:186-195; 19:576-581). It will not be covered in detail here. However, the following description emphasizes the critical points:

Data: the data consist of N independent observations of a random variable. Each of the observations is grouped in one of C classes.

H_o: the data are observations on a normally distributed random variable.

Test Statistic:

$$T = \sum_{j=1}^{C} \frac{(O_j - E_j)^2}{E_j} \qquad (2)$$

O_j = observed frequency

E_j = expected frequency = $P_j^* N$

Decision Rule: reject H_o if T exceeds the $X^2_{1-\alpha}(C - K - 1)$ degrees of freedom

C = number of classes

K = number of parameters to be estimated (in this case both the mean and variance of the sample data must be estimated, therefore K = 2).

Fuel Available to Displace Tank Bottoms and Pipelines. The issue that needed to be addressed was whether operating at minimal POS levels was a frequent and cyclical condition (DoD's position) or uncommon occurrence at each location (GAO's response). In either case, if at such a time there would be sufficient fuel to displace tank bottoms and pipelines, then some readjustment of required POS could be possible. Using the *Aviation Fuel Logistical Area Summary (AFLAS) and Form 1237s, one methodology for answering this question might be:

1. Determine the maximum authorized inventory (reference Figure 5) for the period of interest from the AFLAS.

2. Subtract POS as indicated in the AFLAS from the maximum inventory level to compute the inviolable level (reference Figure 5 again).

3. Determine the actual inventory for the period by reference to the Form 1237.

4. Subtract the inviolable level from the actual inventory. Large positive differences indicate high POS levels. This would be the amount of fuel available to displace tank bottoms and pipelines. Differences close to zero indicate operating at minimal POS levels. Negative numbers indicate PWRR fuel is being used to maintain POS (MAJCOM waiver must be in effect).

A thorough investigation would necessarily include examining many bases over a period of many months. The frequency of differences close to zero would provide information about the occurrence of operations at minimal POS levels.

It is beyond the scope of this report to conduct such an investigation. Also, the secret classification of the AFLAS precludes its use in this analysis. But, due to the sharp differences in opinion about the usefulness of tank bottom and pipeline fuel between GAO and the DoD and the large inventories of fuel involved, some initial research was conducted in this area. The purpose was to determine if an indepth quantitatively based investigation would be feasible and worthwhile.

A selected number of Air Force bases were informally surveyed by mail (see Appendix D). From those bases responding, a limited amount of data, consisting only of the highest observed JP4 physical inventory and lowest observed JP4 physical inventory from the Form

1237 for the period 1 October 1977 to 31 March 1978, was collected. For the purpose of analysis, several broad assumptions were made:

1. The facility did reach its maximum authorized inventory level during the six month period. This is represented by the highest observed physical inventory.

2. The maximum authorized inventory level did not change during the six month period. The first question on the survey was used to disqualify those cases where this was not the case.

These assumptions allowed use of the general methodology described earlier without reference to the AFLAS. The POS level was as reported on the Form 761 (POS computation) received from Detachment 29. Because only the single minimum inventory level was reported, no conclusions about the trend of the POS level at a base could be made. What could be determined was whether that base was operating at a level below, near, or above a minimal POS level for JP4 at the time it experienced its lowest inventory. Of specific interest was whether this minimal amount of POS fuel would be sufficient to offset any allowances for tank bottoms or pipeline.

The survey concluded with two questions regarding the feasibility of using pipeline and tank bottom fuel as usable. These were intended to highlight the operational considerations that such a change in policy would affect. They also supplied a feel of how such changes might be accepted in the field. Selected comments from the respondents are included along with the results of the survey in the following chapter.

Model Development

In conjunction with the fourth objective of this thesis, a mathematical model that would allow a centralized manager such as DFSC to allocate storage in an optimal manner and make cost comparisons of different storage plans was developed. Assignment of tankage to total base level requirements is essentially a problem in allocation of resources. It may be possible to apply the linear programming model. A special formulation of linear programming is the transportation problem, which can be applied to this special case. In particular, the general transportation problem is concerned with distributing any commodity from any group of supply centers, called sources, to any group of receiving centers, called destinations, in such a way as to minimize total distribution costs (Ref 20:112). The correspondence in terminology between the storage example and the general transportation problem is summarized in Table VI.

Formulating Allocation of Storage as a Transportation Problem. Letting Z be total storage cost and x_{ij} $(i=1, 2, \ldots, m,\ j=1, 2, \ldots, n)$ be the number of barrels stored at location i for location j, the linear programming formulation of the problem becomes:

$$\text{Minimize } Z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij}$$

$$\text{Subject to } \sum_{j=1}^{n} x_{ij} = s_i \quad \text{for } i=1, 2, \ldots, m$$

Table VI

The Fuel Storage Allocation Problem in General Transportation Problem Terminology

Fuel Storage	General Transportation Problem
Barrels of fuel	Units of a commodity
i storage points	m sources
j operating locations	n destinations
storage capacity at i	s_i supply from source i
requirement at j	d_j demand at destination j
some measure of storage cost per barrel at location i for location j per year	c_{ij} cost per unit distributed from source i to destination j

$$\sum_{i=1}^{m} x_{ij} = d_j \quad \text{for } j=1,2,\ldots,n$$

$$x_{ij} \geq 0 \quad \text{for all } i,j$$

This results in the cost and requirements table as found in Table VII.

The methodology for solving a transportation type problem is found in most any linear programming or operations research text (Ref 20:119-135; 21:227-251). Computer algorithms that handle transportation models are also available. As described in reference 22, the Basic mode of the Create computer system provides a user oriented routine to solve these types of problems. The technique

Table VII

Costs and Requirements

Locations with storage	Locations with storage requirements				Supply of storage
	1	2	...	n	
1	c_{11} x_{11}				s_1
2					s_2
. .					. .
. m				c_{mn} x_{mn}	. s_m
Demand for storage	d_1	d_2	...	d_n	$\sum_{j=1}^{n} d_j$ \ $\sum_{i=1}^{m} s_i$

used to solve the examples in the study was the transportation simplex method. Solutions are presented without the intermediate steps in their calculation.

Required Inputs. For each base considered, the inputs to the model consist of storage capacity (s_i), fuel requirements (d_j), and storage costs (c_{ij}). The s_i can be determined from the DFSC 506 Report, Bulk Petroleum Storage Facilities. Appendix B, page 108, is a sample page from this annual document. The d_j are documented by the various services. In the case of the Air Force, the AFLAS is a convenient source for supplying this information. The c_{ij}s were not as readily available and not nearly as precise as the d_j and s_i.

For the purpose of the report, storage costs were somewhat narrowly defined as the explicit expenses to the government of storing a unit of petroleum for one year. These costs include, but are not limited to, tank inspection, corrosion control, tank maintenance, and tank cleaning. They are a function of tank age, tank design, weather extremes, type of fuel stored, etc. Any costs having to do with receiving or distributing fuel are considered operating expenses and are not affected by storage decisions. Also excluded from consideration in the model are the transportation costs associated with moving the fuel to the base of intended use should war plans be implemented. This model minimizes the day to day storage expenses, not the cost of a one time contingency.

A more comprehensive approach to the issue of cost which would also be compatible with the model is the idea of holding cost. Previously, it was noted that the petroleum industry considers its holding cost for one barrel of crude petroleum at $4.00 per year. In addition to storage costs, other elements of holding costs applicable to fuels include quality deterioration and loss while in storage, cost of ownership of tanks, and opportunity costs of the money invested in the inventory (Ref 20). In developing a model based on storage cost alone, the analysis has implicitly assumed that this is the only variable in the holding cost equation. That is, of all those costs just discussed, all but storage cost tend to be the same at any location.

In the special case of a COCO terminal, a cost per barrel stored can be computed directly (Table III). However, all COCOs maintain some specified throughput capability for the government at some unspecified cost that is included in the contract price. Thus, the total contract price must be adjusted downward by some amount before computing a cost per barrel stored.

Those functions comprising the storage costs at a government operation are primarily a civil engineering duty. At Air Force bases these tasks are the responsibility of the liquid fuels maintenance officer. Detailed accounting records of his expenditures were not available. It was through a personal discussion with such individuals and civil engineering cost accountants that realistic cost estimates were obtained.

Before proceeding further, acknowledgment of limitations to this approach need to be recognized:

1. At this stage of model development, no specific storage cost information was available.
2. This model makes centralized storage allocation decisions. This is not compatible with the present base-service-DFSC hierarchy of planning for storage.
3. The model recognizes only one homogeneous commodity. Actually there are 27 distinguishable fuel types that must be allocated.
4. The size of the model if all or even a partial number of locations are included creates computational difficulty.

None of these was deemed insurmountable. Further discussion is deferred to the concluding chapter.

The Scenario. Despite these limitations, the transportation model approach to allocating storage appeared theoretically feasible. But in any operationally oriented research effort, the theory is only relevant if it can be shown to be a practical solution to the problem at hand. The difficulty in this case was to isolate a representative subset of the entire DoD bulk fuels complex that would be suitable for implementing this model. This was further complicated by the security classification of the material involved and the limited cost information available. Therefore, a set of hypothetical conditions were developed that were deemed a realistic condensation of the actual situation. The presentation of the scenario is described in general terms here and analyzed in the following chapter.

The scenario consisted of eight locations with requirements for JP4 and differing amounts of storage available. It is presented in the order of a description of conditions, restrictions, general and specific assumptions, and summarized in a cost and requirements table. The objective was to allocate the total requirement for JP4 storage among the eight locations so as to minimize the total storage cost per year. Although the conditions and other parameters of the scenario are abstractions of reality, every aspect was researched so as to mirror as closely as possible actual bulk fuels operations. Once the scenario was described in detail, a solution based on a transportation problem type formulation was determined to demonstrate the methodology.

Sensitivity Analysis

One concern repeated several times up to this point is that DFSC is unable to judge any single change in operations or facilities for its effect on the overall storage scheme. An advantage of being able to model the storage network in a linear programming format was that the objective function (minimize cost) provided a measure of the sensitivity of the system to change. Certain factors which are candidates for change or subject to improvement have been discussed. One at a time these aspects were included in the conditions of the hypothetical scenario to analyze their overall effect.

Predicting Consumption. The hypothetical POS inventory requirements of the scenario were adjusted by a percentage factor simulating that the Daily Demand Rate (DDR) could be more accurately predicted. Based on the data gathering results, it was possible to estimate a factor by which the forecast DDR could be expected to be in error. A certain amount of the POS level is a direct result of the DDR (up through line 7 of the formula). After adjusting the POS for those elements in its calculation not related to DDR (tank bottoms, pipeline, and authorized deviations), it was possible to estimate how much a more accurate prediction of consumption would effect the actual POS. This in turn effected storage requirements, which resulted in a net change to the total storage cost for the scenario.

Tank Bottoms and Pipeline Fill. The hypothetical POS inventory requirements were adjusted downward by some percentage simulating that tank bottoms and/or pipeline fill were considered usable fuel in the computation of POS. To estimate a realisitic allowance for these quantities, the 15 July 1977 Form 761s (POS computations) were utilized. From these documents the total amounts of fuel set aside as tank bottoms (line 11), pipeline (line 12), and POS (line 14) at CONUS Air Force bases was calculated and summarized in a table. Based on the data and survey comments regarding the feasibility of using these quantities, a percentage factor representing a partial allowance for tank bottoms and pipelines was determined by which all the POS requirements of the scenario were adjusted downward. The storage requirements were then adjusted to reflect these new levels and a new system storage cost calculated.

<u>The Use of POS to Offset PWRR</u>. The expected value of the POS on hand at any location on any one day will tend toward the true mean of the POS level when a sufficiently long enough period of time is observed. That is (Ref 17:148):

$$E(POS) = \mu_{POS} = \lim_{n \to \infty} \frac{\sum_{n=1}^{\infty} K}{n}$$

K = observed value

n = number of days

Despite such a concise statistical approach, the variability that will inevitably and randomly occur around the mean prevents expected POS levels from being used to offset PWRR.

A single percentage amount was chosen that represented a hypothesized reduction in PWRR due to an allowance for POS levels. This simulated an operating policy that recognized the considerable amounts of POS that would be available on D-Day. The PWRR for the location of the scenario were adjusted downward by this amount. Storage requirements were adjusted and a minimum cost was calculated based on an optimal reallocation of storage. It should be emphasized that the purpose of this exercise was simply to indicate the relative magnitude of the dollar savings that might be realized should such a change be implemented. Any savings must be considered in light of the operational limitations associated with this alternative.

Storing JP8. Having assumed that JP8 will become the sole jet fuel, the restriction on the incompatibility of JP4 and JP5 was eliminated. The sensitivity of storage costs to this change in operating procedure was investigated.

Modeling a Long Term Capital Investment. When choosing among alternatives which require a large immediate payout that will result in decreased future expenses, there is a tendency to overemphasize the one time expenditure and underemphasize the future savings. To avoid this, DoD economic analysis procedures are based upon developing a cash flow for each of the alternatives and then using present value techniques to compare costs (Ref 23). The transportation model developed here is compatible for this type of analysis.

Recreating the earlier scenario, a condition was added whereby that at some one time cost, K_i, additional tankage was secured at location i. Associated with this acquisition was some estimated yearly unit storage cost, c_{ij}. The objective of this was to determine if, that as a result of this new condition, storage costs were reduced sufficiently to justify the K_i. Because the one time cost, K_i, did not fit a linear programming formulation, the transportation model was not strictly applicable. However, the following methodology, based on the guidelines for DoD economic analysis, overcame this problem and was used in analyzing the proposed additional tankage:

1. A time horizon of n years was estimated over which it was reasonable to assume that there would be no change in requirements or capacity for the scenario. The remaining useful life of all physical assets was assumed greater than the value of n.

2. The n payments of each c_{ij} represent a cash outflow of n rents. The discounted total of such a stream of payments, designated c_{ij}, is:

$$c_{ij}' = (c_{ij}/R)\ (1 - (1 + R)^{-n}) \qquad (3)$$

where R = discount rate established for DoD economic analysis

This formula can be found in many finance textbooks as the present value of an ordinary annuity.

3. Including the added condition, each c_{ij} of the model was replaced by its c_{ij}'. The transportation simplex was then implemented to determine the optimal allocation of storage and the associated cost in present value dollars, designated z_i'.

4. Provided that the new location entered the solution, a new total system cost, designate Z_i', was calculated:

$$Z_i' = K_i + z_i' \tag{4}$$

   Note that because the K_i is a current expenditure, it was not discounted.

5. The cost of this scenario without the new condition and for a single year had been previously calculated as Z_j. Its discounted value, Z_j', for n years was determined:

$$Z_j' = (Z_j/R)(1 - (1 + R)^{-n}) \tag{5}$$

6. Z_j' was compared with Z_i' to determine if adding tankage decreased storage costs to offset K_i (Z_j' greater than Z_i').

While this methodology adheres to analysis guidelines and is sufficient for analyzing a single project in a limited scenario, the fixed cost element is never included in the optimization process. It is simply a cost comparison of two storage options with an investment cost added to one. The fixed charge mixed integer linear programming model is a much more robust way to formulate the problem that would allow for this fixed cost condition. Therefore, a portion of the analysis was devoted to an investigation of this type of approach to determine if such a formulation using a transportation model was possible. It was recognized that, if feasible, the solution procedure for this type of problem exceeded the computational scope of this report. The primary purpose was not to solve the problem but to show that a long term capital investment decision with a fixed set up charge could be modeled in a mixed integer format suitable for a transportation model. Chapter III reports on the results of this research.

This concludes the research methodology chapter. It has been concerned with explaining the How behind the research; the techniques and data sources used to accomplish the objectives of the study. Chapter III to follow presents the What; an explanation of the results coming from the methodologies described in this chapter.

III. ANALYSIS AND RESULTS

Introduction

This chapter presents the results of the analysis effort. The findings are presented in the order in which they were discussed in Chapter II and include a summary of the results. So as not to lose sight of the initial goals of the research effort, each of the sections has been identified with a specific aspect of the objectives initially stated in Chapter I. Because it was felt that identifying particular locations with operational data would add nothing to the report and might create some uneasiness, no installations are mentioned by name.

Objective 2/Significant Product and Geographic Elements

The results of summarizing six months of DEIS consumption and issue data to identify the significant elements are presented in four tables. Table VIII is based on retail consumption by product type. Table IX concerns the same statistics for issues at the wholesale level. Consumption by retail locations is the subject of Table X and Table XI presents data based on issues by wholesale locations. Because the objective was simply to recognize the significant elements and examine the shape of the distribution, much rounding and truncating of data was accomplished to simplify the presentation of the results. Figure 6 approximately depicts the results of Table VIII. Although similar type

Table VIII

Total DoD Retail Consumption by Product

Product	Number of Locations	Consumption MBbls	Cumulative Percent of Products	Cumulative Percent of Consumption
1. JP4	377	43267	3.7	42
2. MGT	664	21231	7.4	63
3. DFM	512	11423	11.1	74
4. JP5	345	8972	14.8	83
5. FSR	125	4436	18.5	87
6. FS2	141	3236	22.2	90
7. DF2	488	2247	25.9	92
8. FSD	222	2171	29.6	94
9. FS6	59	2052	33.3	96
18 other products		4318	100	100
		103353		

Source: DEIS, October 1977-March 1978.

Table IX

Total DFSC Wholesale Issues by Product

Product	Number of Locations	Issues MBbls	Cumulative Percent of Products	Cumulative Percent of Issues
1. JP4	93	33889	3.7	57
2. DFM	45	11059	7.4	76
3. JP5	52	10104	11.1	93
4. NSF	17	1137	14.8	95
5. MG1	22	901	18.5	96
6. DFW	3	795	22.2	97
21 other products		1479	100	100
		59364		

Source: DEIS, October 1977-March 1978.

Table X

Total DoD Retail Consumption by Location

Cumulative Number of Locations	Cumulative Consumption MBbls	Cumulative Percent of Locations	Cumulative Percent of Consumption
40	29910	3.33	36
80	46170	6.66	55.5
120	56580	10.0	68
160	63660	13.33	76.5
200	68600	16.66	82.5
240	71920	20.0	86.5
280	74490	23.33	89.5
320	76370	26.66	92
360	78130	30.0	94
400	79570	33.33	95.5
793 other locations	82990	100	100

Source: DEIS, October 1977-March 1978.

Table XI

Total DFSC Wholesale Issues by Location

Cumulative Number of Locations	Cumulative Issues MBbls	Cumulative Percent of Locations	Cumulative Percent of Issues
11	25460	10	46
22	36060	20	65
33	41780	30	76
44	46400	40	84
55	49630	50	90
66	51310	60	93
77	52560	70	95
33 other locations	55150	100	100

Source: DEIS, October 1977-March 1978.

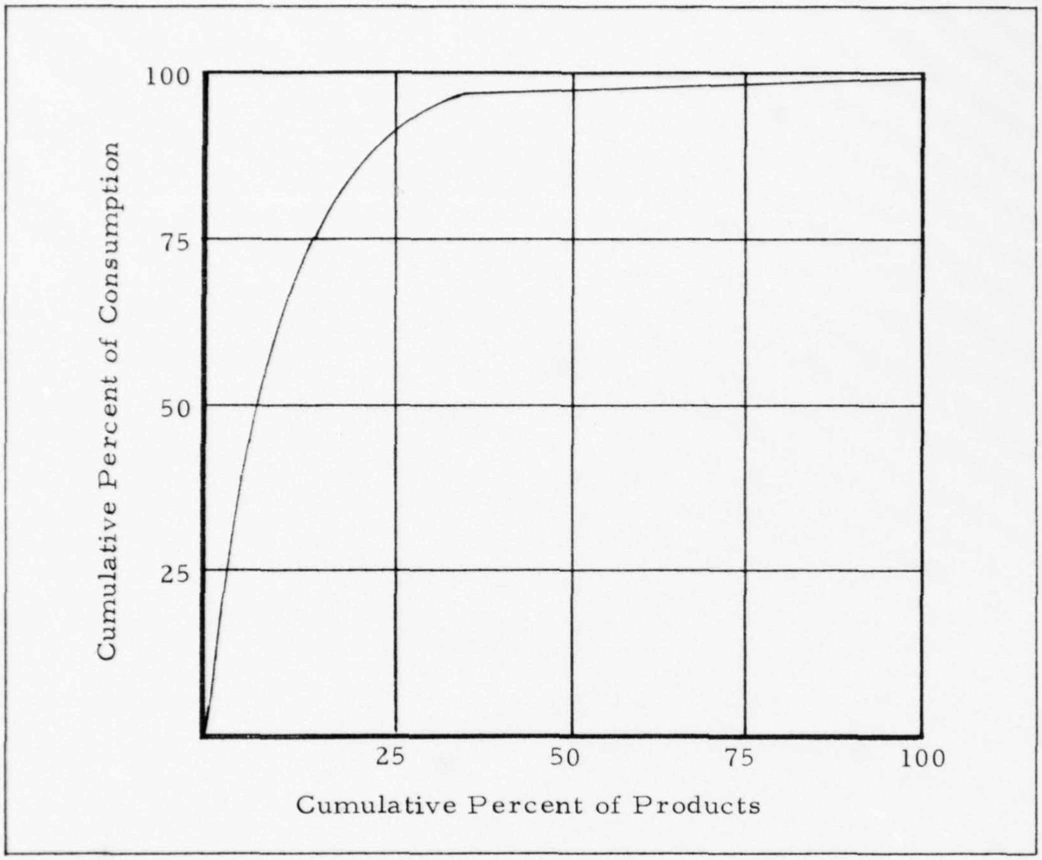


Figure 6. The Distribution of Retail Consumption by Product

graphs could be made of the other tables, these would closely resemble each other due to the obvious Pareto type distribution present in each case. To avoid this redundancy, Figure 6 can be considered representative of all the data in Tables VIII through XI. The conclusion in each case is the same; the significant elements, while representing a small percentage of the total, account for a large percentage of consumption or issues.

Objective 3A/Forecast versus Actual Consumption

Only the 104 CONUS Air Force bases forecasting a daily demand rate for JP4 greater than 250 barrels were examined. Because these bases account for the bulk of JP4 consumption, the CONUS bases with a DDR less than this were not included in the sample. The results are presented in Table XII. The bases are arranged according to forecast DDR with the highest demand rate being first in the table. The difference between actual and forecast (column 2 - column 3) is in column 4 and the percent by which forecast differed from actual is in column 5 ((column 4 ÷ column 3) X 100). In either case, a plus indicates demand overstated and a minus signifies demand understated.

The percentages in column 5 range from a low of -13% to a high of +297%. There were no locations which underestimated DDR by more than 25% and 41 which overestimated DDR by more than 25%. Twenty one bases forecast demand within 5%. Figure 7 summarizes the results in column 4 of Table XII in a histogram based on 5% intervals. The net difference between forecast daily usage and actual daily usage (column 4) was +24658 barrels, or 15% of actual DDR.

Objective 3B/Testing for Normality

The consumption data for Air Force Base Alpha is included in Appendix C. The mean and standard deviation of these 119 data points was determined and can also be found in the appendix. As discussed in

Table XII

Actual and Forecast Daily JP4 Consumption All CONUS Air Force Bases Projecting a Daily Demand Rate More Than 250 Barrels

Rank	Forecast Bbls	Actual Bbls	Forecast - Actual Bbls	(Forecast - Actual)/ Actual Percent
1	7145	7347	- 202	- 3
2	5291	3962	+ 1329	34
3	5167	4982	+ 285	4
4	5149	4754	+ 398	8
5	5111	3621	+ 1490	41
6	4782	3784	+ 998	26
7	4739	4457	+ 282	6
8	4389	3975	+ 414	10
9	3968	3722	+ 246	7
10	3639	2558	+ 1081	42
11	3333	1729	+ 1604	93
12	3326	3351	- 25	0
13	3307	3304	+ 3	0
14	3254	3150	+ 104	3
15	3243	2922	+ 321	11
16	3090	2354	+ 736	31
17	3083	3174	- 91	- 3
18	3042	2934	+ 108	4
19	2976	2159	+ 817	38
20	2944	3076	- 132	- 4
21	2938	2644	+ 294	11
22	2924	2507	+ 417	17
23	2923	2623	+ 300	11
24	2902	2238	+ 664	30
25	2890	2613	+ 277	11
26	2822	2306	+ 516	22
27	2802	2544	+ 258	10
28	2760	2081	+ 679	33
29	2630	1335	+ 1295	97
30	2563	2937	- 374	- 13
31	2517	2052	+ 465	23
32	2513	2944	+ 569	29
33	2468	2163	+ 305	14
34	2383	2343	+ 40	2
35	2366	2536	- 170	- 7
36	2333	2152	+ 181	8
37	2305	2315	- 10	0
38	2222	1994	+ 228	11
39	2167	1328	+ 839	63
40	2139	2111	+ 29	1
41	2111	1725	+ 386	22
42	2050	1643	+ 407	25
43	1984	1492	+ 492	33
44	1949	1324	+ 625	47
45	1944	1986	- 42	- 2
46	1942	1716	+ 226	13
47	1844	1810	+ 34	2
48	1667	1280	+ 387	30
49	1611	1714	- 103	- 6
50	1583	1280	+ 303	24
51	1538	1557	- 19	1
52	1448	1196	+ 252	21
53	1255	1360	- 105	- 8
54	1250	1233	+ 17	1

Table XII (Cont'd)

Rank	Forecast Bbls	Actual Bbls	Forecast - Actual Bbls	(Forecast - Actual)/ Actual Percent
55	1194	948	+ 246	26
56	1167	882	+ 285	32
57	1111	1099	+ 12	1
58	1096	1217	- 121	- 10
59	1070	1063	+ 7	0
60	1058	1010	- 48	- 5
61	1027	898	+ 129	14
62	1006	1112	- 106	- 10
63	980	753	+ 227	30
64	944	714	+ 230	32
65	926	906	+ 20	2
66	833	667	+ 166	25
67	754	190	+ 564	297
68	722	581	+ 141	24
69	716	673	+ 43	6
70	698	491	+ 207	42
71	667	485	+ 182	38
72	615	244	+ 371	152
73	608	501	+ 107	21
74	529	520	+ 9	2
75	529	364	+ 165	45
76	529	392	+ 137	35
77	503	537	- 34	- 6
78	476	410	+ 66	16
79	463	424	+ 39	9
80	428	460	- 32	- 7
81	423	336	+ 87	26
82	417	316	+ 101	32
83	397	329	+ 68	21
84	389	217	+ 172	79
85	372	230	+ 142	62
86	370	299	+ 71	24
87	369	372	- 3	0
88	356	252	+ 104	41
89	337	236	+ 101	43
90	334	280	+ 54	19
91	333	244	+ 89	37
92	333	226	+ 107	47
93	333	300	+ 33	11
94	331	268	+ 63	24
95	327	206	+ 121	59
96	319	234	+ 85	36
97	298	253	+ 45	18
98	290	254	+ 36	14
99	288	101	+ 187	185
100	278	90	+ 188	209
101	277	94	+ 183	195
102	255	172	+ 83	48
103	254	185	+ 69	37
104	251	148	+ 103	70
Total		160430	+24658	15%

Source: Air Force Forms 1237, 15 July 1977 and DEIS October 1977 - March 1978.

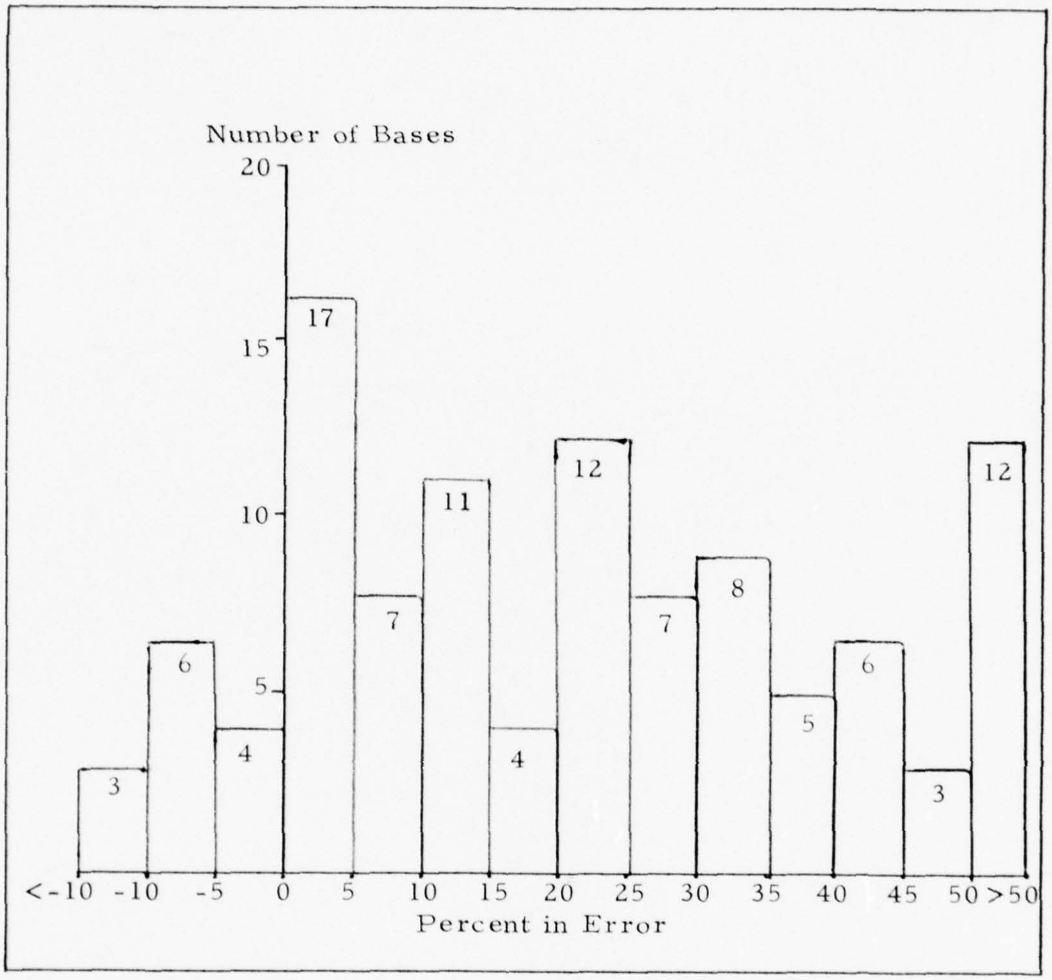


Figure 7. The Distribution of Percent Error in Forecasting Consumption

Chapter II, the chi square goodness of fit test was used to investigate the normality of this data as a prerequisite to using equation (1). Arbitrarily, the observations were divided into intervals of 10,000 gallons. As shown in Table XIII, the p_j^* were then calculated.

Table XIII

Air Force Base Alpha Theoretical Probabilities per Consumption Interval

Class Boundary	$(b_j - \overline{X})/S_x = X_p$	$F(X_p)$	Interval	P_j^*
$b_1 = 20000$	-1.27	.1020	< 20000	.1020
$b_2 = 30000$	- .39	.3483	20000 - 30000	.2463
$b_3 = 40000$	.50	.6915	30000 - 40000	.3432
$b_4 = 50000$	1.38	.9162	40000 - 50000	.2247
			> 50000	.0838

From Table XIII, the E_j and O_j were compiled into Table XIV.

Table XIV

Air Force Base Alpha Expected and Observed Frequencies

Class	Expected	Observed
< 20000	12.1	10
20000 - 30000	29.3	34
30000 - 40000	40.8	37
40000 - 50000	26.7	30
> 50000	10	8

Then T was calculated using equation (2):

$$T = \sum_{j=1}^{C} \frac{(O_j - E_j)^2}{E_j} = 2.28$$

The critical region of size .05 corresponds to values of T greater than 5.99, the .95 quantile of a chi square random variable with C - K - 1 =

5 - 2 - 1 = 2 degrees of freedom. These results indicate that with some degree of confidence, it can be concluded that the data comes from a distribution not greatly different from that specified by the null hypothesis. Therefore, H_o is not rejected and the normality conditions for equation (1) appear to have been satisfied.

According to the POS computation for this base for the period 1 October 1977 to 31 March 1978, the authorized safety stock was 91854 gallons. From this same form the replenishment time (L) is given as 1.5 days. For a service level of 100% (K = 4) the new safety stock is:

$$\text{Safety Stock} = K\sqrt{L}\,\sigma_x = 4 \text{ X } \sqrt{1.5} \text{ X } 11308 = 55398 \text{ gallons}$$

For Air Force Base Bravo the data is also found in Appendix C. The analysis of this data was performed as for Air Force Base Alpha. Rather than repeat the process, only the expected and observed frequency table is presented with the resulting value of T. The critical region of size .05 corresponds to values of T greater than 12.59, the .95 quantile of a chi square random variable with C - K - 1 = 9 - 2 - 1 = 6 degrees of freedom. Therefore, H_o is not rejected and equation (1) could be applicable.

According to the POS computation for this base for the period 1 October 1977 to 31 March 1978 the authorized safety stock was 122514 gallons. From this same form the replenishment time (L) is

Table XV

Air Force Base Bravo Expected and Observed Frequencies

Class	Expected	Observed
< 20000	9.8	11
20000 - 30000	10.7	16
30000 - 40000	16.6	11
40000 - 50000	20.9	23
50000 - 60000	21.4	19
60000 - 70000	18.0	14
70000 - 80000	12.4	15
80000 - 90000	6.9	8
> 90000	5.1	5

$T = 6.75$

given as 1.5 days. For a service level of 100% ($K = 4$) the new safety stock is:

$$\text{Safety Stock} = 4 \text{ X } \sqrt{1.5} \text{ X } 22306 = 109277 \text{ gallons}$$

Present Air Force operating policy requires and sound fuel management insures that peacetime flying operations will not be curtailed due to local temporary shortages of fuel. At both bases Alpha and Bravo the use of a service level constant equal to 4 was included so as to establish a confidence of 100% that no shortages would occur during the replenishment cycle (see Table V). In choosing a service level constant leading to a safety stock for a DFSC terminal, the fact that it is part of an interrelated distribution network holding many complementary products could be rationale for choosing a lesser service level constant. For instance, it could be reasonable to accept a lesser confidence of shortages for a DFSP having many terminals nearby which could provide temporary backup.

Objective 3C/Survey Results

The survey instrument designed to gauge the tank bottom and pipeline issue consisted of five questions and is included in Appendix D. Of the 25 bases selected, 11 fuels officers completed and returned the survey. The sample size was reduced somewhat when one major command specifically declined to authorize its bases to respond. Upon taking this action, this command transmitted the following message:

> This subject was adequately covered in the Air Force response to a similar GAO study. Stockage requirements, minimum levels, and related peacetime operating stocks have been continually studied due to the cost of product and equipment. There appears to be little if any found that has not already been thoroughly evaluated.

Although such skepticism is easily understood, it may be noted that because of the very reasons cited in this message and the continuing unresolved nature of this subject, further research, besides being most probable, also appears warranted.

The responses were divided into two categories. The first group consisted of those bases reporting no changes in authorized inventory levels during the six month period (question 1) and were therefore considered as operating under normal conditions. It was felt these bases would best fit the assumptions outlined in Chapter II, that is, the response to question 2 represented an inventory at or near the maximum authorized level. In the six situations where such was the case, the methodology to determine minimal POS levels was utilized. Using survey questions 2 and 3 plus the POS computations, the results are summarized in Table XVI. In only one case would the fuel have been sufficient to displace tank bottoms and pipeline. In the other cases were these unusable amounts not included in POS, these bases would have been below their inviolable level.

Table XVI

Survey Results for Bases Operating Under Normal Conditions

Fuel available to displace tank bottoms and pipelines when minimal POS occurred (Ques 3 - (Ques 2 - POS)) Gallons	Adjustment for tank bottoms and pipeline in POS (Form 761, lines 11 and 12) Gallons	Available fuel sufficient to displace these amounts?
+ 722000	227136	Yes
+ 183000	233528	No
+ 375000	735924	No
+ 30000	235158	No
+ 10000	89754	No
- 49000	342342	No

The second category of respondents consisted of the five remaining bases reporting programmed or unforeseen conditions that resulted in an inability to maintain established inventory levels. Among those conditions given were; product from supplier unacceptable due to poor quality, tanks temporarily out of service for leak repair or cleaning, supply delay caused by bad weather, and pipeline breakdown. In all cases, temporary MAJCOM waivers for specified amounts of fuel were granted that, in effect, reduced the PWRR to allow POS to be drawn from these stocks until the condition was rectified. Thus, all five of these bases would show varying negative values in the second column of Table XVI.

As regards the percentage of tank bottoms that could be pumped out with available equipment (question 4), the responses fell in a range of 0% to 100%. A rather large number (7 out of 11) placed the percentage above 90%. The feasibility of using pipeline fill (question 5) was answered with 9 "No" and 2 qualified "Yes." Comments regarding this entire issue were also solicited. Some selected responses are:

> The fuel in tank bottoms, in mose cases, would not meet quality requirements.
>
> Including tank bottoms and pipeline fill as usable fuel in POS and PWRR does not give a true picture of usable stock.
>
> It is not considered feasible to recover pipeline fill due to small amount and problems with air elimination when filling piping again.
>
> It (tank bottom and pipeline fuel) is unusable inventory for all practical purposes.

Objective 4/A Scenario

In this section a hypothetical scenario is developed so that allocation of storage using a transportation model can be explained. The locations making up the scenario and the initial conditions are included in Table XVII. The only fuel product included in the scenario is JP4 and Air Force bases are the primary locations. In addition to these conditions, there were some restrictions imposed on the scenario. These restrictions are:

1. Location E is too far from location A to make storage feasible.
2. Location D is too far from location A to make storage feasible.
3. At location F the JP4 requirement is in conjunction with that location's use as a wartime staging and recovery point in current war plans. The 75 MBbl capacity is unusable due to the incompatibility of JP4 with JP5.

The general assumptions applicable to any scenario using this model are as follows:

1. All tankage is continuously divisible. That is, no partial tanks are allowed. This insures that a full tank concept is maintained. For instance, if 30 MBbls are to be stored at a location with 50 MBbls storage, this amount exactly fills those tanks to be used and all costs of the remaining tanks are avoided.
2. Capacity given is maximum fill level (shell capacity - unusable space not to include tank bottom) of all tanks suitable for the product being allocated.
3. The locations describing the model represent the entire system. This establishes a boundary across which there is no interaction.

Table XVII

Scenario Conditions

Location	Description	POS (MBbls)	PWRR (MBbls)	Capacity (MBbls)
A	Air Force Base (SAC)	50	215	75
B	Air Force Base (MAC)	60	240	275
C	Air Force Base (TAC)	25	50	80
D	Air Force Base (ANG)	12	10	30
E	Army Airfield	5	5	15
F	Naval Air Station	0	150	75
G	GOCO terminal	40	0	200
H	COCO terminal	30	0	250

4. Each base must remain self sufficient for POS. That is, despite the cost each base must have the facilities to receive, store, and distribute POS. As a result, the capacity available for storage to be used in the model equals Total Capacity - POS. This will prevent the optimization process from excluding any location where it is known operations must be sustained.

5. Sufficient throughput exists at all locations to maintain stock rotation.

6. The origination cost of fuel to any location in the scenario is the same. That is, the price of fuel delivered to A equals the same as if it were delivered to any other base in the scenario.

7. All costs of existing facilities are sunk costs. They have no residual value.

The specific assumptions of this scenario are as listed below. Although the cost data are listed as assumptions, this is only because it would be difficult to verify their specific origin. Despite this, they are based on extensive research and the opinions of those most knowledgeable in the field.

1. All government storage facilities consist of surface 10 MBbl welded tanks with a floating root design. They are all of approximately the same age and experience similar climactic conditions.

2. The cost of storing one bbl of fuel in the tank described in (1) is .30 per year. Based on the best available information and as validated by base civil engineers, this amount was determined as follows:

   Recurring Storage Expenses per Tank

   Tank cleaning--once every three years, 120 direct labor hours
   Tank painting--once every five years, 200 direct labor hours
   Inspection and preventive maintenance--once every month, 4 direct labor hours
   Unscheduled maintenance-as needed, totals 40 direct labor hours per year

   Therefore

   Total direct labor per year = 168 hours per tank

   If

   Direct labor is costed at $12 per hour
   Direct material is costed at $4 per direct labor hour
   Civil engineering overhead (grounds maintenance, utilities, etc.) is costed at $2 per direct labor hour

   Then

   Total annual storage cost per 10 MBbl tank = 168($12) + 168($4) + 168($2) = $3024

   And

   Annual storage cost per barrel = $3024/10000 barrels per tank = .30

3. The storage cost at a GOCO terminal is as derived for (2) with the exception that contractor wage rates, as disclosed by recent requests for bids relating to fuels handling, are about 80% of that paid by the government.

   Therefore

   Total annual storage cost per 10 MBbl tank = 168($9.6) + 168($4) + 168($2) = $2621

   And

   Annual storage cost per barrel = $2621/10000 barrels per tank = .26

4. The contracted cost per barrel stored at the COCO in the scenario is $1.00. As estimated by DFSC, approximately 40% of a COCO contract is to support throughput. Therefore, the actual amount attributable to barrel as storage is ($1.00)(60%) = .60

5. .01 in annual administrative expenses are incurred for each barrel not stored at the using facility. This cost is the result of EDP preparation and DFSC command and control structure for EDP implementation. As verified by the Defense Fuel Regions, the agencies having primary responsibility for EDP preparation, this cost was calculated as follows:

   Total annual manpower for EDP preparation = 3750 manhours at $10 per hour = $37500

   Total annual administrative expenses (mailing, printing, etc.) = $5000

   DFSC staff expenses (three full time positions) = $60000

   Therefore

   Total EDP preparation expenses = $102500 per year

   If

   The total number of barrels included on EDPs is estimated at 15,000,000

Then

Annual EDP expense per barrel not stored where
required = \$102,500/15,000,000 bbls
= .007
≈ .01 for the purposes of clarity in this report

All the elements required for a transportation model formulation to this scenario were now available. Rather than laboriously form the objective function and constraint equations, the information was collected in a cost and requirements format much like Table VII of Chapter II. In this way it was relatively simple to compute the optimal allocation of storage, which is indicated in the appropriate boxes of Table XVIII. Immediately preceding the table, the value of the objective function, or Z, is calculated. This is the minimum cost to store this fuel as determined using a transportation simplex approach. Actually in this instance, as in some of the cases to follow, it was possible to determine the solution without rigorously following the simplex method. The organization of the information into a table was sufficient to enumerate a solution. Because the POS amounts had been deleted from the optimization scheme (general assumption 4), it was necessary to add the storage costs associated with this inventory back into the minimum cost solution to get a true total storage cost.

Table XVIII illustrates two characteristics of the transportation model that need further explanation. The first is the use of the "Big M" Method to identify certain infeasible combinations of destinations and suppliers. In this case, locations D and E were previously

Table XVIII

Scenario Costs and Requirements (MBbls)

Locations with Storage	Locations Requiring Storage						Supply of Storage
	A	B	C	D	E	F	
A	.30 25	.31	.31	M	M	.31	25
B	.31	.30 215	.31	.31	.31	.31	215
C	.31 5	.31	.30 50	.31	.31	.31	55
D	M	.31 8	.31	.30 10	.31	.31	18
E	M	.31 5	.31	.31	.30 5	.31	10
G	.27 160	.27	.27	.27	.27	.27	160
H	.61 25	.61 12	.61	.61	.61	.61 150	220
Demand for Storage	215	240	50	10	5	150	

Minimum annual storage cost $= Z_o = 305(.30)+18(.31)+160(.27)+187(.61)+\text{POS}$
$= 254.35+152(.30)+40(.26)+30(.60)$
$= 328.35 = \$328,350.$

restricted as not suitable for storage of fuel destined for location A. A second aspect of the model that has not been discussed is the introduction of dummy locations to insure that supply equals demand. Although not included in Table XVIII, this would simply entail addition of one more column with all c_{ij}s equal to zero and demand equal to 33 MBbls.

This completes the description of how allocation of storage could be determined using a transportation model. For example, this model could easily be expanded in number of storage locations and number of locations requiring storage to include the total CONUS storage network. The remainder of the analysis is concerned with adjusting the initial conditions of the scenario to include previously identified improvements or changes in operations to determine their effect on storage cost.

Objective 5A/Predicting Daily Demand Rate (DDR) with More Accuracy

Table XII indicated that the forecast DDR, on the average, overestimated demand by 15%. In the next section it will be shown that tank bottoms and pipelines account for about 20% of POS. This amount is not a function of DDR. Also, deviations (line 9, POS computation), which are estimated to account for about 10% of POS, are not related to DDR. The remainder of POS, or about 70%, is solely determined by the projected demand rate. If DDR was adjusted downward to more accurately reflect actual conditions, this equates to a 10% reduction in POS (15% of 70%). This in turn provided more storage on base for PWRR. The conditions of the scenario were changed to reflect this condition. The resulting optimal allocation of storage and new minimum storage cost were determined using the transportation formulation in the same manner as for the original scenario. Because the primary purpose was to measure the overall effect of such a change, only the new total cost is reported:

$$Z_1 = \$314,560.$$

Objective 5B/Allowances for Tank Bottoms and Pipeline Fuel

The tank bottom, pipeline, and POS totals were calculated from the 15 July 1977 POS Computations and are summarized in Table XIX. Based on the survey results it appeared that a total allowance for pipeline and tank bottom fuel would not be feasible. In fact, the operational considerations against using pipeline fuel appeared overwhelming and certain obstacles limited the use of tank bottoms. However, a majority of Base Fuels Management Offices did report that portions of their tank bottom fuel may be usable. Therefore, it was felt further research would only be worthwhile as regards a partial allowance based on tank bottoms alone. That is, if for example 40% of the tank bottoms are considered usable, this equates to a 5% reduction in POS levels (40% X 12.3%). Based on such a change to the scenario, a new storage cost was determined that took into account this added storage now available for war reserve fuel. This new cost was:

$$Z_2 = \$321,455.$$

Objective 5C/Use of Expected Levels of POS to Reduce PWRR

A minimum expected level of POS was determined to be sufficient at each location to reduce PWRR by 25%. This in turn lessened the

Table XIX

Total Tank Bottom, Pipeline and POS Quantities
CONUS Air Force Bases, JP4 Only

	Amount-Bbls	As a Percentage of Total POS
Tank Bottoms	263,708	12.3
Pipeline	141,501	6.6
Total	305,209	18.9
POS	2,141,106	--

Source: POS Computations 15 July 1977.

requirement for storage. The resulting optimal allocation of storage with no other changes to the requirements determination process and new minimum storage cost were determined as before. The total cost was:

$$Z_3 = \$305,585.$$

Objective 5D/Replacement of JP4 and JP5 with JP8

If JP4 and JP5 are replaced by JP8 this makes available 75,000 bbls of government storage at location F to store PWRR fuel. The net effect of such a change was measured by the change in the storage cost. The new minimum cost was:

$$Z_4 = \$305,100.$$

Objective 5E/Construction of New Tanks

A Condition I, representing 125,000 bbls of new storage at location A, was added to the original scenario. The cost of this construction was estimated at $12 a barrel (Ref 14:125). In essence, this represents a fixed charge of $1,500,000 associated with this potential new storage location. The annual storage expenses of a new tank are estimated to be two thirds that of existing storage, thus making the yearly storage .20 per barrel. A time horizon of n equal 10 years was estimated over which capacity and requirements would remain stable. Using DoD's recommended discount rate for economic analysis of 10% (Ref 23:11), all the variables to analyze the economic effectiveness of this new construction were known.

All annual storage costs of the scenario were discounted using equation (3) with $n = 10$ years and $R = .10$. Once organized in a cost and requirements table format it was simple enough to compute the minimum cost solution in discounted dollars (z_5'). Applying equation (4), it was then possible to calculate total storage cost (Z_5') for the scenario with Condition I added. Table XX summarizes the solution and is followed by the calculation of z_5' and Z_5'.

To measure the net savings of adding this new storage it was necessary to examine the alternative; not to build any new tanks and absorb a slightly higher annual storage expense but forego the initial investment that the construction required. In other words, maintain the status quo of the original scenario. Using the original value of Z_o for the scenario this was discounted at $n = 10$ years and $R = .10$. From

Table XX

Discounted Costs and Requirements, New Tanks Scenario (MBbls)

Locations with Storage	A	B	C	D	E	F	Supply of Storage
A	1.84 25	1.90	1.90	M	M	1.90	25
B	1.90	1.84 215	1.90	1.90	1.90	1.90	215
C	1.90	1.90	1.84 50	1.90	1.90	1.90 5	55
D	M	1.90	1.90	1.84 10	1.90	1.90 8	18
E	M	1.90	1.90	1.90	1.84 5	1.90 5	10
G	1.66 65	1.66 25	1.66	1.66	1.66	1.66 70	160
H	3.75	3.75	3.75	3.75	3.75	3.75 62	220
I	1.23 125	1.29	1.29	1.29	1.29	1.29	125
Demand for Storage	215	240	50	10	5	150	

Discounted minimum storage cost excluding construction charges $= z_5'$

$= 305(\$1.84)+18(\$1.90)+160(\$1.66)+125(\$1.23)+62(\$3.75) + \text{POS}$

$= 1247.25+152(\$1.84)+40(\$1.60)+30(\$3.69)$

$= 1701.63 = \$1,701,630.$

Total Discounted Storage Costs including Construction Costs $= K_i + z_5' = Z_5'$

$= 1,500,000 + 1,701,630$

$= \$3,201,630.$

equation (5) the results were:

$$\text{Total Discounted Storage Cost without Construction} = Z_o' = 328.35(1 - (1.1)^{-10}/.1 = 2017.57 = \$2,017,570.$$

To justify this capital investment Z_o' should exceed Z_5'. In this case, although operating expenses are reduced by $316,000 over a 10 year period, this only partially recovers the $1,500,000 initial investment. Therefore, it could be concluded that using the particular values chosen by this report, economic analysis would indicate not investing in the new construction.

More precisely, this problem concerning a long term capital investment could be set up in a fixed charge mixed integer format. A conditional transportation model, which includes set up costs and selection of an optimal set of sources to meet demand, is appropriate in this respect (Ref 21:289). It is described here as applied to this particular situation of allocating storage using a transportation model when set up charges are a factor.

The total discounted cost for any storage location i can be represented by:

$$C_i' \left\{ \begin{array}{lll} = & K_i + \sum_{j=1}^{n} c_{ij}' x_{ij} & \text{if any } x_{ij} > 0 \\ & & \\ = & 0 & \text{if all } x_{ij} = 0 \end{array} \right\} \quad \text{for any } i = 1, 2, \ldots, m$$

where x_{ij} = number of barrels stored at location i for location j.

c_{ij}' = cost per barrel for n years stored at location i for location j discounted to present value using equation (3).

K_i = fixed cost associated with setting up at location i.

A zero-one variable, y_i, was introduced which assumed a value of one if location i was used (any x_{ij} greater than 0) and a value of zero if location i was not used (all x_{ij} equal to 0). The objective function then became:

$$\text{Minimize } Z = \sum_{i=1}^{m} K_i y_i + \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}' x_{ij}$$

To insure that the y_i would take on only values of zero or one, one set of constraints was:

$y_i \leq 1$

$y_i \geq 0$

y_i is an integer for $i = 1, 2, \ldots, m$

Plus, to insure that y_i equals zero if location i was not selected, the supply constraints became:

$$\sum_{j=1}^{n} x_{ij} = s_i y_i \qquad i = 1, 2, \ldots, m$$

The demand and non negativity constraints remained unchanged:

$$\sum_{i=1}^{m} x_{ij} = d_j \qquad j = 1, 2, \ldots, n$$

$$x_{ij} \geq 0 \text{ for all i and j}$$

The advantage of this approach was that now the set up charges were explicitly included in the linear programming formulation. Because of this, fixed large mixed integer programming is much more computationally efficient and better suited to large problems. Unfortunately, the solution procedure for this type of problem can be somewhat sophisticated. Therefore, while computationally exceeding the scope of this report, the analysis has succeeded in identifying a suitable approach for use with a transportation model to allocate storage when potential storage construction and/or modernization is a part of the allocation decision situation.

Summary

This chapter began with a presentation of a data analysis effort to formally identify the most significant product and geographic elements of DoD bulk fuels operations. In this respect, Pareto's law was shown to be in evidence in both the retail and wholesale distribution systems. The importance of this was that it highlighted the different degrees to which managerial control might be applied to groups of products and locations. That is, a general knowledge of the significant elements was a logical way of establishing some order to the magnitude of DFSC operations.

Next, the results of investigating three aspects of the POS computation formula were presented. Certainly, the entire procedure for determining inventory requirements warrants research, this study only included these three specific aspects. Data from a number of sources was analyzed; actual consumption from the DEIS, projected consumption for the Air Force Form 761, daily inventory levels from the Air Force Form 1237, and survey results from several base fuels management officers. Based on this, it was possible to make some quantitatively based statements about certain aspects of the formula to compute POS.

Following this, a scenario was developed to demonstrate the applicability of a linear programming transportation model to the allocation of storage. This model was then useful in examining the relative cost impact of changes to POS computation procedures. With the exception of a different safety stock formula, the conditions of the scenario were adjusted to reflect each of the earlier discussed requirements issues bearing on bulk fuels storage. This provided a means of integrating many seemingly unrelated topics into a unified perspective. The results are summarized in Table XXI.

As regards interpretation of the results in Table XXI, it must be remembered that the initial condition storage cost was based on an

Table XXI

The Sensitivity of the Scenario to Various Changes in Parameters

Scenario	Minimum Storage Cost - Z_i $	Change from Initial Conditions ($)	Percent Change
Initial Conditions	328,350	--	--
More accurate Daily Demand Rate	314,560	↓ 13,790	4.2
An allowance for tank bottoms	321,455	↓ 6,895	2.1
An allowance for expected POS against PWRR	305,585	↓ 22,765	6.9
Using JP8	305,100	↓ 23,250	7.1
Initial Conditions (10 year costs)	2,017,570	--	--
Adding more storage (10 year costs)	3,201,630	↑ 1,184,060	58.6

optimal allocation of storage as calculated using a precise mathematical model. In actuality, storage is not allocated in quite such an orderly fashion. Therefore, no knowledge existed as to how the storage of JP4 would be organized if this scenario existed as a real world situation. However, due to the limited size of the scenario and limited constraints it would seem reasonable to assume that even without a formal procedure storage would have been distributed in about the same manner as calculated using the model.

Chapter IV discusses these results in more detail. It also includes some recommendations for further study and draws several conclusions from the research.

IV. SUMMARY AND CONCLUSIONS

The Objectives in Review

The five specific objectives of this study were described in Chapter I. Due to the ease of losing sight of the overall goals in a sometimes involved operational study of this nature, the writer has made a conscious effort to identify each aspect of the research with a particular objective. While at times this may have caused the report to appear overly structured, it was felt to have aided in the continuity of reporting the analysis. For one final time the objectives are reviewed and particular results emphasized.

It was necessary to be familiar with DoD bulk fuels operations to knowledgeably view the research effort. Objective One was formulated with this in mind. The concept of integrated material management as applied to DFSC was introduced. Standard pricing and stock fund organization were described so as to provide an insight into how costs are determined and distributed among the using agencies. An introduction to some of the procedures used in setting inventory levels and associated terminology was also presented.

Objective Two grew out of a need to objectively scope down the research variables. This led to an investigation of Pareto's law as it applied to the 27 products and almost 1200 locations comprising DoD's fuel distribution system. Tables VIII through XI and Figure 6 were

AD-A065 690 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCH--ETC F/G 21/4
DEPARTMENT OF DEFENSE BULK PETROLEUM: AN INVESTIGATION OF INVEN--ETC(U)
DEC 78 C M NORTHRUP
UNCLASSIFIED AFIT/GOR/SM/78D-12 NL

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helpful in showing that in both the wholesale and retail aspects of bulk fuels the significant elements do indeed represent a small percentage of the total. An important outcome of this was that it formalized a theory of managerial control intuitively practiced by DFSC; identify the critical elements and concentrate control efforts on these items. As regards the subsequent research, the results supplied credence to a consolidation of DoD fuels into a hypothetical scenario involving JP4 and Air Force installations.

Three aspects of the formula for computing POS levels were examined as part of Objective Three. The availability of actual Air Force Form 761s (POS computations) provided a unique opportunity to investigate data not commonly accessible. Combined with the DEIS, this information enabled a comparison of projected and actual consumption rates. Next, the validity of an economically defensible safety stock formula based on the normal distribution was tested. Actual safety stock levels were compared to values calculated using this formula. Finally, the issue of what adjustments should be made to POS for fuel in tank bottoms and the pipelines was discussed. In conjunction with this policy, the research reported on some limited results based on an informal survey of several Air Force base fuels management officers.

Accomplishment of Objective Four led to an investigation of the transportation model for the allocation of storage and a practical demonstration of this linear programming approach to this situation. The availability of the required inputs to such a model was researched. In some detail a scenario was developed that illustrated many of the conditions present in the DoD bulk fuels environment. A storage allocation solution based on these initial conditions of the scenario was derived using the transportation model formulation.

In conjunction with Objective Five, the initial solution of the scenario provided a base case against which the cost of several alternatives could be compared. These comparisons supplied the thread that tied together much of the analysis effort of this study. This emphasis on sensitivity analysis was based on a concern that, while DFSC and the military services are well aware that there are certain costs incurred in not considering tank bottoms usable or not using POS to offset PWRR or not applying some of the other alternate procedures that would reduce inventories, they are for the most part unaware of the overall effect of such decisions. Sensitivity analysis provided a means of measuring the effect of such changes in existing inventory determination methods or allocation of storage procedures against a predetermined standard. In this case, that measure was the storage cost of a hypothetical scenario as determined using a transportation model. Certainly, other linear programming models are equally appropriate and this is surely not the only measure available. For that matter, the specific value of the objective function as the parameters of the scenario were changed is not that important. What is important is that no matter how inflexible inventory policy might be, there are costs associated with these policies and it is rational to attempt to measure them.

The Research Questions

At the outset of this study effort, two research questions were posed. The analysis complete, a reexamination of these questions is now possible.

As stated in Chapter I, the first question was:

> Do present inventory determination methods provide justifiable requirements?

In an economic sense the results of this study indicate that it would be difficult to corroborate some aspects of the present procedures for setting inventory levels. Empirical data revealed projected daily demand rate, the determining factor in calculating POS, was overestimated by 15% during October 1977 to March 1978. While this equates to about only 250 barrels per each of the 104 locations in the sample, in total it represents almost 25,000 barrels of JP4 unnecessarily earmarked as POS for each day's supply on hand. Considering an average POS level as five days (line 7, POS computation, Appendix A), the ultimate effect of this 15% error is an overage of 125,000 barrels of JP4. This is not an indictment of the individual fuel manager's usage projections. On the contrary, the 15% figure appears to be a rather remarkable accomplishment in light of the subjective elements in a usage prediction. The point is, any calculation based on such an imprecise figure will not truly reflect needed inventories.

Other aspects of procedures for determining inventory levels are potentially suspect. The safety level calculation (line 5, POS computation, Appendix A) was previously identified. DFSC itself has expressed concern with the derivation of this amount. The study reported on two Air Force bases where the use of a precise safety stock formula provided somewhat lesser safety stock levels. In addition, adjusting POS for "unusable" quantities in the tankage system remains a questionable practice in the opinion of some investigators. In the survey of this study, a significant number of fuels officers said that some of these quantities were "usable." War reserve requirements account for a large percentage of the stock of bulk fuels. These levels, which are based on detailed war plans and usage projections, would support the first days of a war effort. Considering the complexity underlying their determination and in light of the results for POS, it would be reasonable to assume some inefficiencies in PWRR determination could be possible.

Many of the apparent shortcomings that surfaced in analyzing inventory levels can be traced to a single condition. As Leuba and Schneider observed in their report following interviews with hundreds of fuels operations managers and an extensive literature search (Ref 14:vi):

> The petroleum industry manages its inventories with an implicit/experience based practice rather than with a formal/analytic technique.

This statement is equally relevant to DoD petroleum management.

Prior to an awareness of analytic methods for setting inventory levels and before increased public scrutiny, a rule of thumb of five days supply prevailed in DoD fuels management. This same rule of thumb exists today, now incorporated into the formula for computing POS. Many other aspects of government fuels operations were observed to be founded on such intuitive ground. Based on years and years of practical experience, it is difficult and may appear presumptuous to find fault with these intuitive approaches. Unfortunately, rules of thumb become difficult to defend when considered alongside precise mathematical solutions.

The second research question asked was:

> Once inventory levels have been assigned, is there a concise analytical tool to enable evaluation of alternative storage options within the entire storage network?

The study developed a transportation model that was shown to be useful in this respect. Sensitivity analysis using this model made it possible to view individual changes for their overall effect. Within the confines of a hypothetical scenario, certain options, to include a more accurate daily demand rate forecast, allowances for tank bottoms, allowances for expected levels of POS against PWRR, storing JP8, and adding more storage, were evaluated using a storage cost criterion.

However, some limitations to this approach were previously identified as needing further investigation.

The first limitation concerned the lack of adequate cost data associated with maintaining petroleum inventory levels. The approach taken by this study relied on a rather specific interpretation of storage costs that included only civil engineering tank maintenance functions. While the appratus for collecting this cost information does exist, in the form of civil engineering cost accounting capabilities, fuel storage costs are not presently identified as a specific item. Thus, such costs had to be estimated for the report. Other identifiable holding costs need to be considered before an accurate account of what it costs to maintain DoD's fuel inventory can be determined.

Another limitation to the applicability of this approach is that under the existing arrangement there is no central manager who has the authority to direct allocation of storage. DFSC cannot even order a particular storage arrangement within its own GOGO terminals without prior service approval. It is these conditions that make it imperative that such a model be made available. This may even provide the necessary impetus to change the situation. Simply because it is not practical in the present environment should not be interpreted to mean that development of a better way of doing business should go unnoticed.

The third limitation cited in Chapter II was that the problem does not concern a homogeneous commodity, a usual assumption of transportation models. Recalling the earlier identification of the significant product and geographic elements, this would provide some basis for prioritizing those resources to be allocated. The allocation of storage then becomes an iterative process of solving the model for successive elements in the order of their priorities.

The last limitation addressed the computational difficulty and data considerations associated with modeling any sizeable subset of the entire population. While this is certainly true, it is not peculiar to this model. The number of possible interactions in a storage network of 1,200 locations is truly frightening. What is heartening to realize is that the number of feasible interactions is considerably less due to such constraints as distance, tank compatibility, etc. The sparseness of a transportation model matrix is an important factor in determining the computational difficulty or the amount of computer time necessary to handle such a problem. In conjunction with this, it may be conceivable to partition the entire system into several subsets and approach the problem in that respect.

In summary of the research questions, the research indicated that some inflation of inventory levels does exist. A total reevaluation of POS requirements might well result in a reduction of petroleum stocks. The model developed, despite some limitations, is a logical approach to evaluating the effect of any such reductions. However, there is a degree of uncertainty present in petroleum management that is difficult to quantify in any model. The continuing backlash of the oil embargo of 1973 and recurring threats of a similar nature can be very disconcerting to a fuels manager. A poorly defined national energy policy is also a factor. Less dramatic occurrences affecting the availability of fuel, such as rail or truck strikes or bad weather, which are totally unpredictable, seem to be increasingly devastating. The resulting tendency is to distrust any quantitative technique which may reduce requirements and insure that available inventories take such disturbances into account as much as possible. The author is unable to find fault with such a practice. The only qualm is that such uncertainty should be openly acknowledged and not subtly included as a tacit adjustment to operating inventory levels.

Recommendation for Further Study

As with any analysis, the research effort has raised more questions than it has answered and several of these are candidates for possible further research. Three potential areas for research concern: (i) exercising the methodology devised by this report concerning displacing tank bottoms fuel with POS, (ii) a critical evaluation of the POS formula, and (iii) a replication of this study in a classified form. Each of these is discussed in the following material.

The emotional concerns that seem to surround the tank bottom and pipeline issue were unexpected. The methodology and data exist to once and for all objectively address this issue. If it can be shown that it is a statistically common occurrence for operations to occur at inventory levels where POS would not be sufficient to displace tank bottom and pipeline amounts, then there is no rationale to change present operating procedures. Until such a precise response can be made, external agencies will continue to question such a policy.

A review of the total POS computation itself is worthy of consideration. There are pitfalls of straightjacketing all locations into this single formula that have only been alluded to by this report. For instance, is the same POS format applicable to Air National Guard bases where flying is primarily a Friday-Saturday-Sunday proposition or undergraduate pilot training bases where operations are planned only Monday through Friday or a DFSC terminal that may issue 200,000 barrels twice a month or a MAC base that experiences seven days per week of uniform activity? An abundance of empirical data consisting of the DEIS, Air Force Form 761s, DFSC POS computations, and base level inventory records is available for research that in turn may provide an insight into a more comprehensive formula that takes into account this location by location variability. One possible starting point is the safety stock calculation and the practicality of equation (1) of this report.

This report has purposely avoided many aspects of military fuels operations because of their security classification. Possible replication of this study under a classified cover has several possibilities. An investigation of the PWRR calculation appears to be a logical follow on. The same sort of questions addressed by this report as regards justifiable requirements and the net effect of different operating policies need to be answered. Another potential area of interest, also of a sensitive security nature, is Air Force fuel planning in Europe and the overlap with NATO. Once again, the same questions are relevant, only this time on a basis that transcends only Air Force operations to include other closely allied countries.

Conclusions

As stated in Chapter I, the primary objective of this study was to investigate the establishment of inventory requirements and the resulting storage of these levels to determine if there were possible areas for increased efficiency. The following brief statements summarize the general findings of this report in accomplishing this objective:

1. Utilization of existing storage could be improved if assignment of tankage was centrally determined.
2. Supplementing present inventory determination and storage procedures with more analytic techniques could improve the credibility of these calculations.
3. The cost implications of less stringent inventory requirements, while often overlooked, represent measurable savings of considerable magnitude.

In conclusion, this thesis has concerned itself with strictly operational problems. Many of these have defied solution since they were first recognized. There is no reason to expect any dramatic reversal. Yet, in many cases the mere acknowledgment of a problem is the most important step leading to its eventual solution. If this work effects only slightly the DoD fuels managers' knowledge of how, why, or where these problems exist and that they are not unsolvable, the effort will have been worthwhile.

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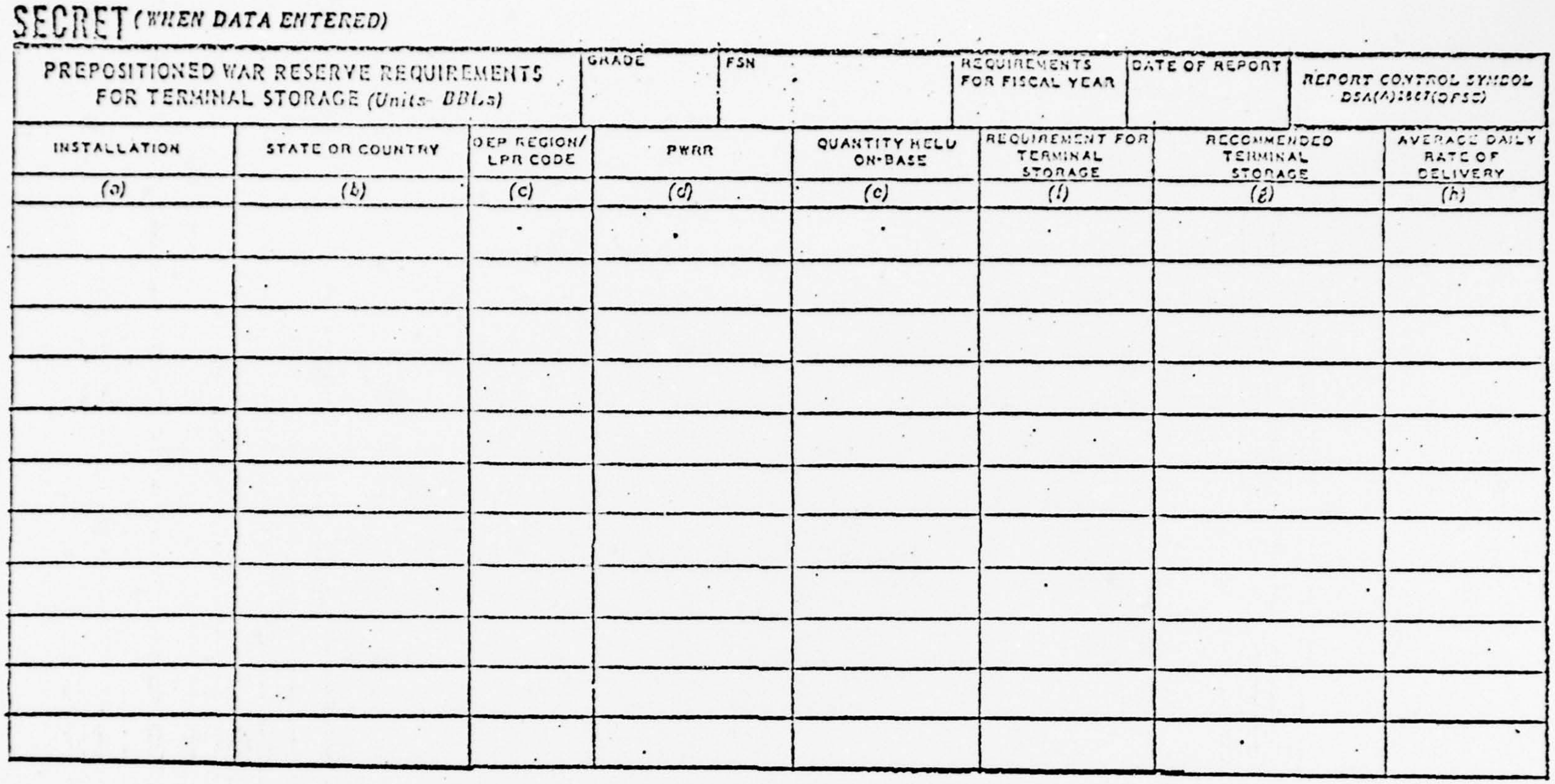
APPENDIX A

Inventory and Storage Forms

1. Prepositioned War Reserve Requirements for Terminal Storage
2. Excess Base Storage
3. Emergency Distribution Plan
4. Bulk Fuels Peacetime Operating Stock (POS) Computation (AF)
5. DFSC PSO Format



SECRET (*WHEN DATA ENTERED*)

PREPOSITIONED WAR RESERVE REQUIREMENTS FOR TERMINAL STORAGE (*Units- BBLs*)			GRADE	FSN	REQUIREMENTS FOR FISCAL YEAR	DATE OF REPORT	REPORT CONTROL SYMBOL DSA(A)1887(DFSC)
INSTALLATION	STATE OR COUNTRY	DEP REGION/ LPR CODE	PWRR	QUANTITY HELD ON-BASE	REQUIREMENT FOR TERMINAL STORAGE	RECOMMENDED TERMINAL STORAGE	AVERAGE DAILY RATE OF DELIVERY
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)

DD Form 1887, Prepositioned War Reserve Requirements for Terminal Storage

This form is used by the military departments to report to DFSC that amount of fuel that they are unable to store on base (column f). After considering the service's recommendations as to where they would like the excess stored (column g), DFSC arranges for storage and assumes responsibility for transportation to base of intended usage (column a) in case of war (see Emergency Distribution Plan that follows).

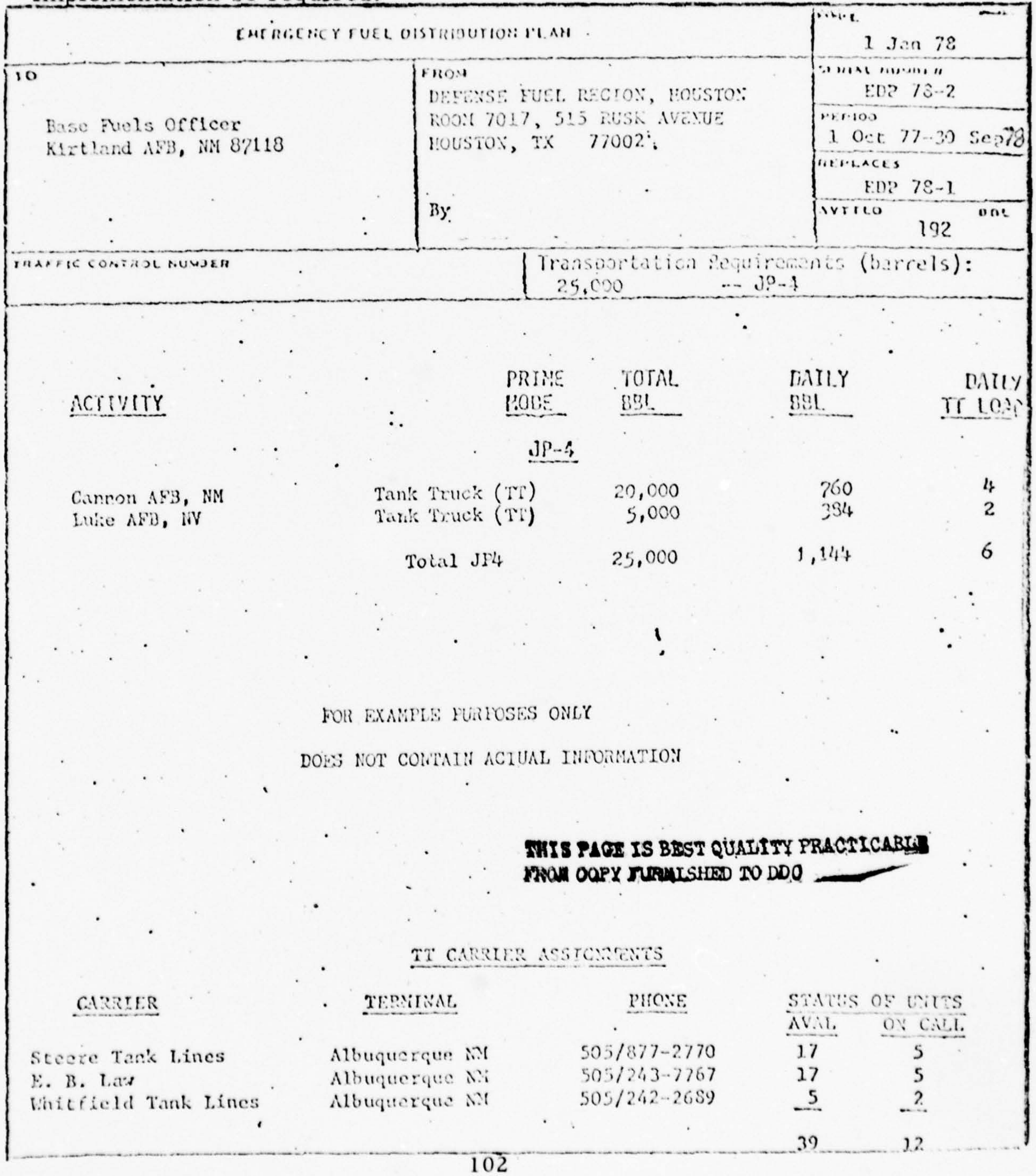
EXCESS BASE STORAGE - CONUS *(Units - BBLs)*				FISCAL YEAR OF AVAILABILITY	DATE OF REPORT	REPORT CONTROL SYMBOL DSA(AR)1888(DFSC)
INSTALLATION	STATE	GRADE	EXCESS STORAGE	MODES OF SHIPMENT	RATE OF DELIVERY	REMARKS
(a)	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*	*(g)*

DD Form 1888, Excess Base Storage

Should a military installation have storage that exceeds its requirements and that service is unable to utilize the tankage to store any excess requirements for its other bases, the amount of storage available is reported to DFSC on this form.

Emergency Distribution Plan (EDP)

This is the plan for distributing fuel during national emergency conditions. It originates with the DFR and is updated annually or as requirements change. DFSC is responsible for originating and monitoring the execution of any movement of fuel under this order. In this hypothetical example of an EDP, the Base Fuels Management Officer, Kirtland AFB, must supply four and two trucks daily to Cannon AFB and Luke AFB, respectively, of the amounts indicated should EDP implementation be required.



EMERGENCY FUEL DISTRIBUTION PLAN

		DATE 1 Jan 78
TO Base Fuels Officer Kirtland AFB, NM 87118	FROM DEFENSE FUEL REGION, HOUSTON ROOM 7017, 515 RUSK AVENUE HOUSTON, TX 77002 By	SERIAL NUMBER EDP 78-2 PERIOD 1 Oct 77-30 Sep78 REPLACES EDP 78-1 AVTFLO BBL 192
TRAFFIC CONTROL NUMBER	Transportation Requirements (barrels): 25,000 -- JP-4	

ACTIVITY	PRIME MODE	TOTAL BBL	DAILY BBL	DAILY TT LOAD
	JP-4			
Cannon AFB, NM	Tank Truck (TT)	20,000	760	4
Luke AFB, NV	Tank Truck (TT)	5,000	384	2
	Total JP4	25,000	1,144	6

FOR EXAMPLE PURPOSES ONLY

DOES NOT CONTAIN ACTUAL INFORMATION

THIS PAGE IS BEST QUALITY PRACTICABLE FROM COPY FURNISHED TO DDC

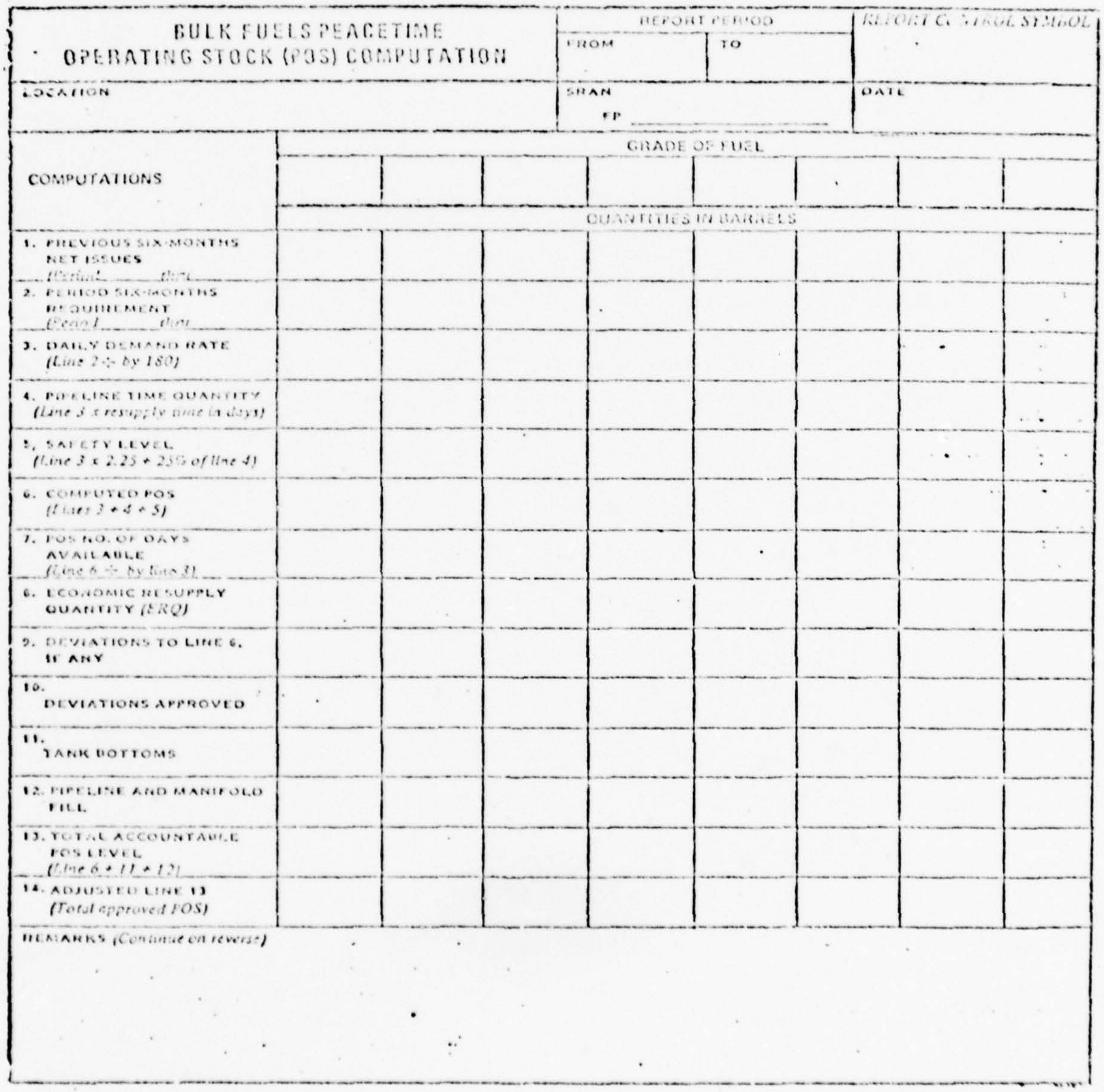
TT CARRIER ASSIGNMENTS

CARRIER	TERMINAL	PHONE	STATUS OF UNITS	
			AVAL	ON CALL
Steere Tank Lines	Albuquerque NM	505/877-2770	17	5
E. B. Law	Albuquerque NM	505/243-7767	17	5
Whitfield Tank Lines	Albuquerque NM	505/242-2689	5	2
			39	12

Air Force Form 761, Bulk Fuels Peacetime Operating Stock (POS) Computation

This is the form completed biannually by the base fuels officer in which he computes his operating stock. Some terms that might not be self explanatory are:

> Economic Reorder Quantity (line 8)--Minimum tender acceptable by delivery vehicle (rail car, tank truck, pipeline).
>
> Deviations (line 9)--Individual peculiarities requiring adjustments to POS. A common example concerns floating roof tanks and the added fuel that must remain in the tank to prevent the roof from resting on the tank bottom resulting in damage to the roof seal.



BULK FUELS PEACETIME OPERATING STOCK (POS) COMPUTATION			REPORT PERIOD FROM	TO		REPORT C[illegible] SYMBOL		
LOCATION			SRAN FP			DATE		
COMPUTATIONS	GRADE OF FUEL							
	QUANTITIES IN BARRELS							
1. PREVIOUS SIX-MONTHS NET ISSUES (Period ______ thru ______)								
2. PERIOD SIX-MONTHS REQUIREMENT (Period ______ thru ______)								
3. DAILY DEMAND RATE (Line 2 ÷ by 180)								
4. PIPELINE TIME QUANTITY (Line 3 x resupply time in days)								
5. SAFETY LEVEL (Line 3 x 2.25 + 25% of line 4)								
6. COMPUTED POS (Lines 3 + 4 + 5)								
7. POS NO. OF DAYS AVAILABLE (Line 6 ÷ by line 3)								
8. ECONOMIC RESUPPLY QUANTITY (ERQ)								
9. DEVIATIONS TO LINE 6, IF ANY								
10. DEVIATIONS APPROVED								
11. TANK BOTTOMS								
12. PIPELINE AND MANIFOLD FILL								
13. TOTAL ACCOUNTABLE POS LEVEL (Line 6 + 11 + 12)								
14. ADJUSTED LINE 13 (Total approved POS)								
REMARKS (Continue on reverse)								

Extracted from DoD 4140.25-M, the following is a sample format of the calculation DFSC accomplishes in arriving at PSO (equivalent to POS) for its terminals.

Terminal____________________ Product_______________ Date ____________

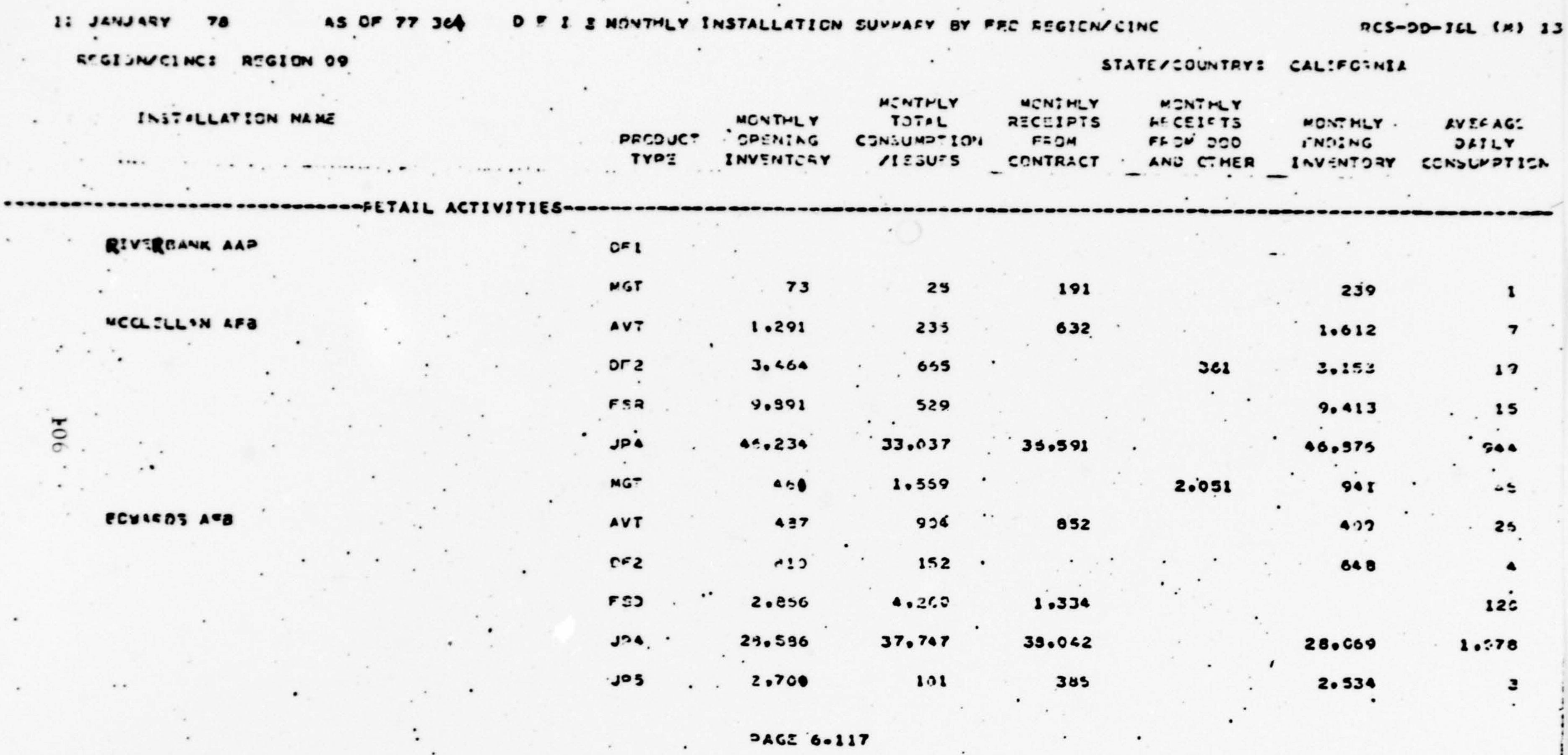
1. Most recent 6 month net issue __________________
2. Computed 6 month requirement __________________
3. Daily Demand Rate (DDR) (line 2 180) __________________
4. Pipeline Time Quantity (PTQ) (DDR X Resupply Time in Days) __________________
5. Safety Level (2.25 X DDR + 25% of PTQ) __________________
6. Additional Safety Level Requirement __________________
7. Augmented Safety Level (Line 5 + line 6) __________________
8. Number of Days in Safety Level (line 7 line 3) __________________
9. Deviation Quantity __________________
10. Method of Resupply __________________
11. Economic Reorder Quantity (ERQ) __________________
12. Number of days Supply in ERQ (line 11 line 3) __________________
13. PSO (line 4 + line 7 + line 9 or line 7 + line 11, whichever is greater) __________________

Note: The meaning of Deviation Quantity (line 9) and Economic Reorder Quantity (line 11) is basically the same as for the Air Force Form 761.

APPENDIX B

DFSC Reports

1. Defense Energy Information System
2. Report of Bulk Petroleum Storage Facilities



```
11 JANUARY   78        AS OF 77 364    D E I S MONTHLY INSTALLATION SUMMARY BY FRC REGION/CINC                    RCS-DD-I&L (M) 13
  REGION/CINC:  REGION 09                                                                    STATE/COUNTRY:  CALIFORNIA

                                                             MONTHLY     MONTHLY      MONTHLY
        INSTALLATION NAME                        MONTHLY      TOTAL      RECEIPTS     RECEIPTS      MONTHLY      AVERAGE
                                       PRODUCT   OPENING   CONSUMPTION     FROM      FROM DOD       ENDING        DAILY
                                        TYPE    INVENTORY    /ISSUES     CONTRACT    AND OTHER     INVENTORY   CONSUMPTION
-----------------------------RETAIL ACTIVITIES--------------------------------------------------------------------------------

      RIVERBANK AAP                     DF1

                                        MGT          73          25          191                      239            1
      MCCLELLAN AFB                     AVT       1,291         235          632                    1,612            7
                                        DF2       3,464         665                        361        3,153           17
                                        FSR       9,991         529                                   9,413           15
                                        JP4      46,234      33,037       35,591                     46,575          944
                                        MGT         460       1,559                      2,051          941           45
      EDWARDS AFB                       AVT         437         906          852                        407           25
                                        DF2         810         152                                     648            4
                                        FSD       2,856       4,260        1,334                                   120
                                        JP4      29,596      37,747       39,042                     28,069        1,278
                                        JP5       2,700         101          385                      2,534            3

                              PAGE 6-117
```

Defense Energy Information System (DEIS)

This is a management information tool compiled from field reports received the last Friday of every month from each wholesale and retail operation. The latest information is then distributed in hard copy, a sample of which is attached, to DFSC agencies requiring its use. The data itself is stored on computer magnetic tape and remains accessible for the next 18 to 24 months. For the specific purposes of this report, DEIS information had to be aggregated for various time periods, products, and locations.

LEGEND

TANK DATA

PROTECTION (Surface Tanks Only)

N - None
D - Diked
B - Surrounded by Blast Wall

DESIGN

C - Fixed Roof
F - Floating Roof
H - Horizontal Cylinder
M - Manifolded Battery of Small Tanks each of which has an individual capacity of less than 500 Bbls

INSTALLATION

S - Surface
C - Cut and Cover
U - Underground

FABRICATION

B - Bolted Steel
W - Welded Steel
R - Riveted Steel
L - Concrete W/Steel Liner
C - Concrete
O - Other

STATUS

S - Fully Serviceable - In Use
G - In Use - Repairs Needed
N - Serviceable - Not in Use
D - Unserviceable - Repaired by: Date
C - Under Construction - Completed by: Date
U - Unserviceable - Use Abandoned
R - Unserviceable - Economically Feasible to Repair; however, no project underway to repair

RECEIPT AND ISSUE METHODS

T - Tanker/Barge
O - Other
P - Pipeline (Other than On-Base)
C - Tank Car
R - Truck

TANK OWNER

A - Army
N - Navy
M - Marine Corps
F - Air Force
V - Air Nation Guard
U - Other - U.S. Government
C - U.S. Company
T - NATO
O - Other

PRODUCT OWNER

A - Army
N - Navy
M - Marine Corps
F - Air Force
V - Air National Guard
D - DFSC
U - Other - U.S. Government
T - Non U.S.
O - Other

PRODUCT STORED		PRODUCT STORED	
DF1, DF2, DFA, DFM, DFS	Diesel Fuel	FOG	Fog Oil
MG1, MG2, MGR. MGP, MGX, MGU, MLL, MLR, MLP, MUS	Mogas	OPX, OP1, OP2	Other POL
130, 131, 145	Avgas	NDF	Navy Distillate
JP-4, JP-5, JP-6, JP-7, JP-8, JR-1, JR-2, JA-1, JTS, RJ-4	Jet Fuel	LA2, LA3	Lube Oils Aircraft
NSF	Navy Special	REC	Deballast/Reclamation
KSN	Kerosene	OP3	Missile Propellants
FS1, FS2, FS4, FS5, FSL	Fuel Oil	OPO	Products Not Otherwise Coded
LO1, LO2, LO3, LO4, LO5, LO6, LO7, LO8, LO9, LO0, LOT, LOA, LOB, LOG, LOC, LOD	Lube Oils		

IV

DFSC 506 Report, Report of Bulk Petroleum Storage Facilities

This document contains a detailed listing of all DoD owned and leased tankage. As discussed in the development of an allocation model, such information would be needed if storage of fuel was to be centrally managed. A sample page from the FY 1979 report is included along with this legend to aid in its interpretation.

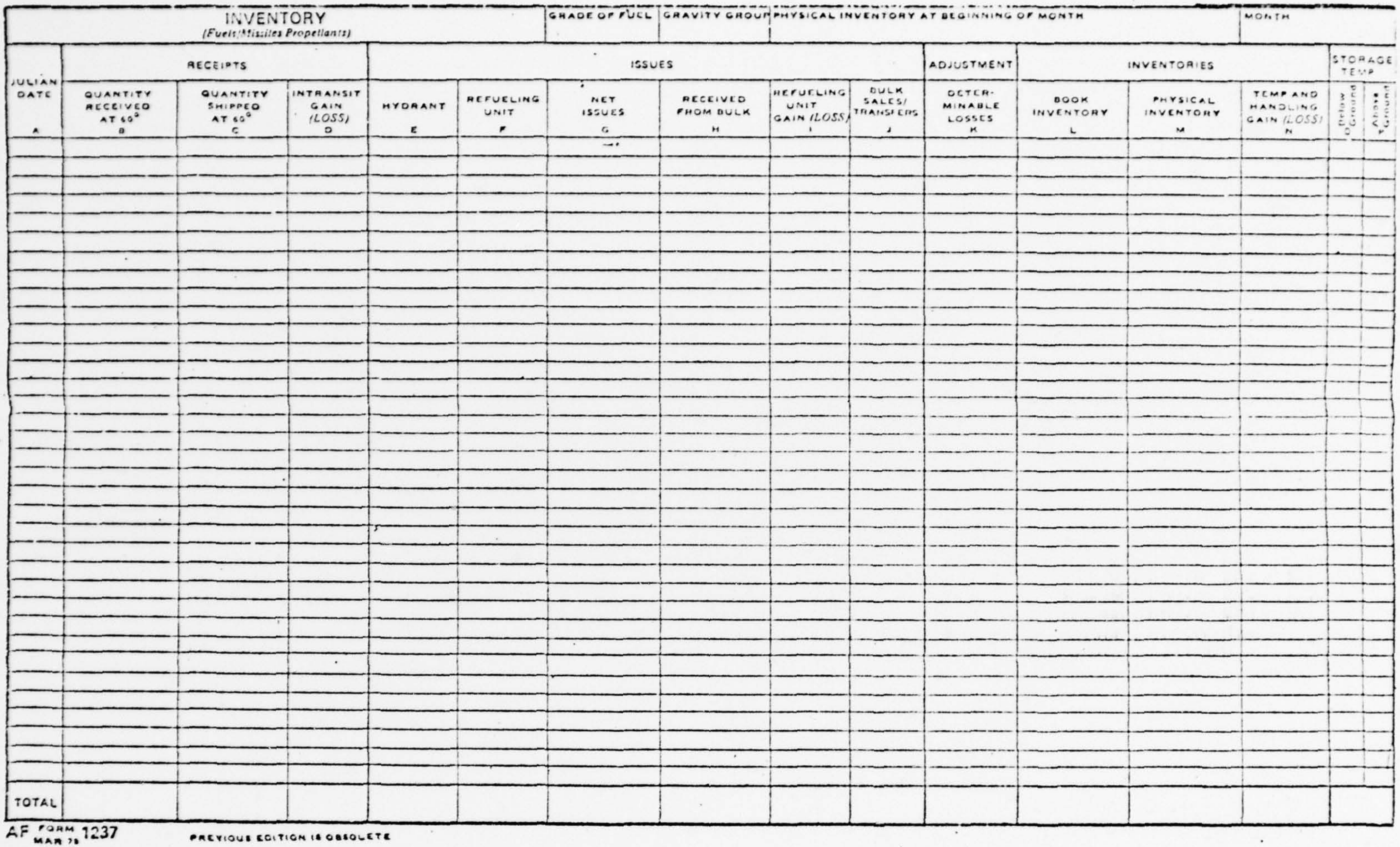
TANK DATA AS OF 1 JULY 1978 AREA OEP REGION 5

NAME OF ACTIVITY - CITY TANK IDENTIFICATION NUMBER	NO OF TANKS	PROD CODE	SHELL CAPACITY	RECEIPT METHODS	ISSUE METHODS	DRAFT FT IN	SHIP SIZE LOA BEAM	CHARACTERISTICS				TANK STATUS CD YR/MO/DY	OWNERSHIP	
								FAB	INS	DES	PRO		PROD	TANK
********************														
OHIO														
********************														
WRIGHT-PATTERSON FAIRBORN														
272		FS2	5,000	R	R			W	S	C	D	S	F	F
TOTAL TANKAGE PER PRODUCT	1		5,000											
208		JP4	600	CR	O			W	C	H		S	F	F
209		JP4	600	CR	O			W	C	H		S	F	F
273		JP4	1,200	O	O			W	C	H		S	F	F
274		JP4	1,200	O	O			W	C	H		S	F	F
275		JP4	1,200	O	O			W	C	H		S	F	F
276		JP4	1,200	O	O			W	C	H		S	F	F
283		JP4	1,200	O	O			W	C	H		S	F	F
284		JP4	1,200	O	O			W	C	H		S	F	F
285		JP4	1,200	O	O			W	C	H		S	F	F
286		JP4	1,200	O	O			W	C	H		S	F	F
249		JP4	10,000	PCR	R			W	S	F	D	S	F	F
250		JP4	10,000	PCR	R			W	S	F	D	S	F	F
251		JP4	10,000	PCR	R			W	S	F	D	S	F	F
252		JP4	10,000	PCR	R			W	S	F	D	S	F	F
254		JP4	10,000	PCR	R			W	S	F	D	S	F	F
255		JP4	10,000	PCR	R			W	S	F	D	S	F	F
256		JP4	10,000	PCR	R			W	S	F	D	S	F	F
257		JP4	10,000	PCR	R			W	S	F	D	S	F	F
258		JP4	10,000	PCR	R			W	S	F	D	S	F	F
271		JP4	20,000	PCR	R			W	S	F	D	S	F	F
TOTAL TANKAGE PER PRODUCT	20		120,000											
216THRU217		LA2	600	CR	R			W	C	M		S	F	F
TOTAL TANKAGE PER PRODUCT	1		600											
253		130	10,000	CR	R			W	S	F	D	S	F	F
TOTAL TANKAGE PER PRODUCT	1		10,000											
TOTAL TANKAGE PER ACTIVITY	23		136,400											
RICKENBACKER AFB LOCKBOURNE 43217														
TOTAL TANKAGE PER PRODUCT														
C-7-595		JP4	4,165	O	O			W	U	H		S	F	F
C-44-1190		JP4	52,360	O	O			W	U	H		S	F	F
C-5-25000		JP4	125,000	PCR	R			W	S	F	D	S	F	F
TOTAL TANKAGE PER PRODUCT	3		181,525											
C-2-286		LA2	572	CR	R			W	U	M		S	F	F
TOTAL TANKAGE PER PRODUCT	1		572											
DEFUEL STA 3		MGR	595	R	R			W	U	H		S	F	F
C-5-1190		MGR	5,950	R	R			W	U	H		S	F	F
TOTAL TANKAGE PER PRODUCT	2		6,545											
C-3-1190		MLR	3,570	R	R			W	U	H		S	F	F
TOTAL TANKAGE PER PRODUCT	1		3,570											
C-2-595		OPO	1,190	CR	R			W	U	M		S	F	F
TOTAL TANKAGE PER PRODUCT	1		1,190											
B-1		131	25,000	CR	R			W	S	F	D	S	F	F
TOTAL TANKAGE PER PRODUCT	1		25,000											
TOTAL TANKAGE PER ACTIVITY	9		218,402											
SPRINGFIELD ANG SPRINGFIELD														
TOTAL TANKAGE PER PRODUCT														

APPENDIX C

Daily Consumption and Inventory Levels at Air Force Bases

1. Inventory (Fuels/Missiles Propellants)
2. Consumption at Air Force Base Alpha
3. Consumption at Air Force Bravo



INVENTORY
(Fuels/Missiles Propellants)
GRADE OF FUEL
GRAVITY GROUP
PHYSICAL INVENTORY AT BEGINNING OF MONTH
MONTH

JULIAN DATE A	RECEIPTS			ISSUES						ADJUSTMENT	INVENTORIES			STORAGE TEMP	
	QUANTITY RECEIVED AT 60° B	QUANTITY SHIPPED AT 60° C	INTRANSIT GAIN (LOSS) D	HYDRANT E	REFUELING UNIT F	NET ISSUES G	RECEIVED FROM BULK H	REFUELING UNIT GAIN (LOSS) I	BULK SALES/ TRANSFERS J	DETERMINABLE LOSSES K	BOOK INVENTORY L	PHYSICAL INVENTORY M	TEMP AND HANDLING GAIN (LOSS) N	Below Ground O	Above Ground P
TOTAL															

AF FORM MAR 73 1237 PREVIOUS EDITION IS OBSOLETE

Air Force Form 1237, Inventory (Fuels/Missiles Propellants).

This is the daily fuels inventory log kept by all Air Force fuels management officers. Two columns from this form can be found referenced in the report. The information in Column M, Physical Inventory, was used to establish a highest and lowest inventory in conjunction with amounts of fuel that might be available to displace tank bottoms and pipeline. Net Issues, Column G, became important in fitting demand for fuel to a particular probability distribution. Observed demand, as taken from Column G for two unnamed Air Force bases, is included on the next two pages.

Air Force Base Alpha
JP4 Consumption (Gallons)
Column G, Form 1237
28 April 1978 to 24 August 1978

Date	April	May	June	July	August
1		42116	28349	30056	41895
2		36489	45061	13142	23331
3		22797	22205	30058	25202
4		29972	22937	19145	36414
5		28624	40861	38930	43658
6		27120	37634	33674	30698
7		14286	24434	43737	38006
8		32205	49373	42122	34513
9		61905	42415	15359	24430
10		33611	32733	37313	53567
11		24919	23534	37424	56395
12		42954	38628	33755	24739
13		18316	36101	53224	22245
14		22753	31183	48279	42050
15		44523	32092	21178	41974
16		45896	39958	31802	25298
17		38867	20531	39599	29883
18		44786	21448	48791	38799
19		49075	48137	39820	23553
20		28545	31550	27701	30031
21		26412	31500	57885	34539
22		39236	36017	21657	37284
23		51063	22558	19646	59464
24		42489	8163	35725	31685
25		35278	17102	48722	
26		49104	44976	24963	
27		25229	38080	62692	
28	45182	12939	40036	41864	
29	12030	21696	26303	24952	
30	42782	47029	26493	28844	
31		46501		42994	

$$\overline{X} = \frac{\sum_{i=1}^{119} X_i}{119} = 34390 = \text{an estimate for } \mu_x$$

$$S_X = \left[\frac{\sum_{i=1}^{119} (X_i - \overline{X})^2}{n}\right]^{1/2} = 11308 = \text{an estimate for } \delta_x$$

Air Force Base Bravo
JP4 Consumption (Gallons)
Column G, Form 1237
1 March 1978 to 30 June 1978

Date	March	April	May	June
1	55483	10172	36581	54139
2	56219	15992	49908	92186
3	28988	64344	50893	39583
4	17956	69903	70267	24621
5	20259	73510	64495	77463
6	48546	47960	20092	56906
7	63358	84107	37785	51814
8	32978	27236	37001	51712
9	46899	18317	71308	100335
10	78652	56533	44473	54250
11	15438	28879	60901	29565
12	20853	52508	86348	49749
13	75266	65051	28936	44958
14	33226	93045	32144	60634
15	48560	14667	42517	47583
16	79825	49691	28080	82705
17	47780	55939	50350	41746
18	20525	53870	84802	19170
19	25478	54019	70816	46652
20	43399	72408	23166	76664
21	39072	64023	44483	69216
22	64403	48462	70169	64397
23	50909	11941	62698	76201
24	78255	42699	51649	44979
25	23590	82551	57537	16406
26	14341	31651	70758	48869
27	35264	55681	73904	50684
28	51073	84918	28413	98820
29	61801	56424	16943	85062
30	44806	27986	31667	81389
31	119261		66152	

$$\overline{X} = \frac{\sum_{i=1}^{122} X_i}{122} = 51,323 = \text{an estimate for } \mu_x$$

$$S_X = \left[\frac{\sum_{i=1}^{122} (X_i - \overline{X})^2}{n} \right]^{1/2} = 22,306 = \text{an estimate for } \delta_x$$

APPENDIX D

Tank Bottom and Pipeline Survey

1. Cover Letter
2. Answer Form

SUBJECT: Thesis Data Collection

FROM: Captain Craig M. Northrup, AFIT/EN, Wright-Patterson AFB, Ohio 45433

TO:

Your assistance is requested in conjunction with a thesis investigation of the Defense Fuel Supply Center's storage of bulk petroleum. The study is being performed by Captain Craig Northrup, a full time student in Operations Research at the Air Force Institute of Technology.

One area of concern is the issue of including tank bottoms and pipelines as usable fuel in Peacetime Operating Stock (POS) computations when POS and Prepositioned War Reserve are stored in the same system (as the General Accounting Office discussed in a 1975 report entitled *Bulk Fuels Need to Be Better Managed*). To form a sample data base from which to analytically examine this concept, it is requested that you review your Forms 1237 for the period 1 October 1977 to 31 March 1978 for JP4 only and note on the enclosed form your highest and lowest observed physical inventory (column M). In addition, any comments you wish to make regarding such a change in policy would provide added insight to the research.

Your responses will become part of a random sample and within the report no references to specific Air Force bases will be made. Your participation is entirely voluntary and no action of any kind will be taken if you choose not to respond.

Please use the answer sheet provided and forward in the enclosed envelope.

1. During the period 1 October 1977 to 31 March 1978 do you recall any significant changes in your authorized inventory levels? Note: Examples of significant changes in inventory might be (1) tanks closed for cleaning caused a readjustment of inventory, (2) reserve level changes, (3) similar actions causing fluctuations in inventory. YES/NO/UNKNOWN

   If answer YES, please explain.

2. Highest observed physical inventory for the period 1 October 1977 to 31 March 1978.

   Gallons JP4 __________

   Date __________

3. Lowest observed physical inventory for the period 1 October 1977 to 31 March 1978.

   Gallons JP4 __________

   Date __________

4. Using available equipment and if absolutely necessary, what percentage of the fuel in your tank bottoms could be pumped out?

5. In cases of absolute necessity do you consider it operationally feasible to recover fuel being used as pipeline fill?

Comments, if any

Thanks for your help!

VITA

Craig M. Northrup was born in Winona, Minnesota on 20 November 1947. He attended the United States Air Force Academy from June 1966 to June 1970 and graduated with a Bachelor of Science Degree in Engineering Management as well as a commission in the United States Air Force. After graduation, he attended Undergraduate Pilot Training at Webb Air Force Base, Texas. After receiving his wings in 1971, he served as a C-141 copilot, aircraft commander, and instructor pilot in the 86th Military Airlift Squadron at Travis Air Force Base, California. For the last year of his tour at Travis Air Force Base, he performed duties as 60th Military Airlift Wing flight simulator instructor and examiner. Subsequent to this assignment, Captain Northrup entered the Air Force Institute of Technology in June, 1977 as a graduate student in Operations Research.

Permanent Address:

1172 Benton Way
St Paul, Minn 55901

This thesis was typed by Joyce Clark.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFIT/GOR/SM/78D-12 | 2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DEPARTMENT OF DEFENSE BULK PETROLEUM: AN INVESTIGATION OF INVENTORY LEVEL DETERMINATION AND ALLOCATION OF STORAGE	5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Craig M. Northrup Captain USAF	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Institute of Technology (AFIT/EN) Wright-Patterson AFB OH 45433	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Institute of Technology (AFIT/EN) Wright-Patterson AFB OH 45433	12. REPORT DATE December 1978 13. NUMBER OF PAGES 130
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

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

18. SUPPLEMENTARY NOTES

Approved for public release; IAW AFR 190-17

JOSEPH P. HIPPS, Major, USAF
Director of Information 19 Jan 79

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

Petroleum
Storage
Strategic Resources
Inventory Management

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

This study analyzes the procedures for establishing authorized fuel levels at DoD facilities to determine if present petroleum inventories represent actual needs. Three aspects of the formula that is used by both the Defense Fuel Supply Center and the Air Force in computing peacetime operating stocks were studied.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

To estimate the effect on costs to the government of various inventory policies, the storage of petroleum was modeled in a linear programming fashion using a transportation model that minimized storage costs. A hypothetical scenario consisting of locations using/storing bulk petroleum was described and subsequently modeled as a transportation problem. The conditions delineating this scenario were then changed to reflect several alternate methods of calculating required inventory levels. The value of the objective function for each of these scenarios was measured against the minimum cost solution of the original conditions to determine the net effect on storage costs.

The study concludes that (1) utilization of existing storage could be improved if assignment of tankage was centrally determined, (2) supplementing present inventory determination and storage procedures with more analytic techniques could improve the credibility of these calculations, and (3) the cost implications of less stringent inventory requirements, while often overlooked, represent measurable savings of considerable magnitude.