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Petroleum Laboratory Operations

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Contents

		Page
	PREFACE	**iii**
	INTRODUCTION	**iv**
Chapter 1	**PETROLEUM OVERVIEW**	**1-1**
	Petroleum Supply Management	1-1
	Quality Surveillance and Assistance Programs	1-2
	Environmental Stewardship	1-4
	Organizational Relationships	1-4
	Roles And Responsibilities	1-7
Chapter 2	**PETROLEUM QUALITY MANAGEMENT**	**2-1**
	Quality Assurance	2-1
	Quality Surveillance	2-2
	Contaminants	2-8
Chapter 3	**PETROLEUM LABORATORY OPERATIONS**	**3-1**
	Manage Quality Surveillance Operations	3-1
	Standing Operating Procedures	3-1
	Laboratory Safety	3-2
	Chemical And Petroleum Storage	3-3
	Supplies	3-5
	Maintenance	3-5
	Laboratory Operations	3-6
Chapter 4	**DEPLOYMENT AND REDEPLOYMENT**	**4-1**
	Planning	4-1
	Establish Petroleum Laboratory	4-1
	Developed Theater	4-2
	Redeployment	4-3
Chapter 5	**PETROLEUM PRODUCTS**	**5-1**
	Fuel	5-1
	Fuel Oils	5-2

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Lubricating Oils 5-2
Lubricating Greases 5-2
Chapter 6 INTRODUCTION TO CHEMISTRY 6-1
Chemistry 6-1
Matter 6-1
Reagents And Solutions 6-2
Indicators 6-4
Balances And Weighing 6-4
GLOSSARY Glossary-1
REFERENCES References-1
INDEX Index-1

Figures

Figure 1-1. Organizational relationships 1-5
Figure 2-1. Fuel gravity range 2-4
Figure 2-2. Notional quality surveillance testing in the operational area 2-8
Figure 3-1. Fuel Samplers 3-8
Figure 4-1. Petroleum Quality Analysis System - Enhanced 4-2

Preface

TM 4-43.31 provides specific guidance for petroleum managers and for petroleum laboratory specialists in the operation of petroleum laboratories.

The principal audience for TM 4-43.31 is all members of the profession of arms. Commanders and staffs of Army headquarters serving as joint task force or multinational headquarters should also refer to applicable joint or multinational doctrine concerning the range of military operations and joint or multinational forces. Trainers and educators throughout the Army will also use this publication.

Commanders, staffs, and subordinates ensure that their decisions and actions comply with applicable United States, international, and in some cases host-nation laws and regulations. Commanders at all levels ensure that their Soldiers operate in accordance with the law of war and the rules of engagement. (See FM 27-10.)

TM 4-43.31 uses joint terms where applicable. Selected joint and Army terms and definitions appear in both the glossary and the text. Terms for which TM 4-43.31 is the proponent publication (the authority) are italicized in the text and are marked with an asterisk (*) in the glossary. Terms and definitions for which TM 4-43.31 is the proponent publication are boldfaced in the text. For other definitions shown in the text, the term is italicized and the number of the proponent publication follows the definition.

TM 4-43.31 applies to the Active Army, Army National Guard/Army National Guard of the United States, and United States Army Reserve unless otherwise stated.

The proponent of TM 4-43.31 is the United States Army Sustainment Center of Excellence. The preparing agency is the Combined Arms Support Command, Training Support and Doctrine. Send comments and recommendations on a DA Form 2028 (Recommended Changes to Publications and Blank Forms) to Commander, United States Army Combined Arms Support Command, ATTN: ATCL-TS (TM 4-43.31), 2221 Adams Ave, Bldg 5020, Fort Lee, VA, 23801-1809; or submit an electronic DA Form 2028 by e-mail to: usarmy.lee.tradoc.mbx.leee-cascom-doctrine@mail.mil.

Introduction

TM 4-43.31 highlights the petroleum laboratory's critical position in petroleum supply by providing an overview of the petroleum supply process as it relates to petroleum quality management. It is important for petroleum laboratory personnel to understand where they fit into the petroleum supply chain management process. The TM provides relevant information on the bulk fuels quality management process that begins with manufacture of the fuels to its point of sale or issue to the supported units.

This TM was written for commanders, staffs and Soldiers responsible for petroleum quality surveillance laboratories. It is oriented toward tactical field operations and deals with management and technical personnel responsibilities by providing relevant information to the petroleum supply support chain of command and to petroleum laboratory specialists. TM 4-43.31 adds information about the petroleum laboratory's organizational relationships from a command and a technical viewpoint.

Major changes to TM 4-43.31 include shortening the format from ten chapters to six chapters. Much of the information in the earlier version is obsolete due to changes in technology and philosophy. It now contains practical information for petroleum laboratory management ranging from chemical storage to establishing a laboratory in the deployed environment to sample sizes. The earlier version devotes much space to the filling out of manual forms, for example. The chapter on environment has been deleted because environmental laws are frequently revised thereby risking providing obsolete material at some point in the life cycle of TM 4-43.31. Environmental considerations are highlighted throughout the TM as it relates to specific laboratory operations. Another change resulted from the reduction in the number of makes and models of mobile laboratories; it has reduced its equipment to only the Petroleum Quality Analysis System-Enhanced for field operations. TM 4-43.31 describes the bulk fuels and other petroleum products that the petroleum laboratory may be called upon to test.

TM 4-43.31 contains descriptions of strategic organizations that enable and support petroleum supply operations. The TM also provides roles and responsibilities for Army personnel associated with petroleum supply support and quality surveillance.

TM 4-43.31 contains six chapters:

- **Chapter 1** Provides an overview of the petroleum supply system and where petroleum laboratories fit into the petroleum supply system. It describes the organizational command channel and technical channel that petroleum laboratories interface with on a daily basis.
- **Chapter 2** describes the quality assurance and quality surveillance process from the manufacturer to the government taking ownership of petroleum products until the product is issued to the supported unit. Chapter 2 also provides information on types of tests performed in petroleum laboratories along with common fuel contaminants.
- **Chapter 3** describes day-to-day procedures for petroleum laboratory operations. This chapter provides general information for the contents of laboratory standing operating procedures, customer assistance, safety, supply, storage, and laboratory maintenance.
- **Chapter 4** describes deployment and redeployment considerations. This chapter provides high level information on the petroleum supply chain planning process. Chapter 4 describes operational level information for establishing a petroleum laboratory site in its designated area. It also provides troop leading considerations as they relate to the petroleum laboratory.
- **Chapter 5** provides information about various petroleum products. The purpose of this chapter is to present a broad overview of packaged and bulk petroleum products used by the Army, but not necessarily tested by petroleum laboratories.
- **Chapter 6** provides a brief introduction to chemistry as it relates to petroleum. The purpose of this chapter is to provide a broad overview of chemistry. While petroleum laboratory specialists may not always need an in-depth background it is important that chemistry is understood at a rudimentary level because testing products are essentially chemical in nature.

Chapter 1
Petroleum Overview

This chapter provides an overview of the petroleum supply system and where petroleum laboratories fit into the petroleum supply process. It describes the organizational command channel and technical channel that petroleum laboratories interface with on a daily basis.

PETROLEUM SUPPLY MANAGEMENT

1-1. Petroleum laboratory specialists should have some knowledge of petroleum supply as it relates to their responsibility in petroleum management. All levels of Army petroleum management must have a quality surveillance program. Overall, the mission of laboratories is to verify the adequacy of quality surveillance measures taken by fuel handlers and to provide technical assistance for handling, storage, sampling and identification through quality surveillance testing. Tactical petroleum laboratories play an essential role in the receipt, storage and issue of petroleum products.

1-2. Class III is one of the Army's ten classes of supply. Class III also referred to as petroleum, oils, and lubricants (POL) consists of bulk fuels, lubricants, hydraulic and insulating oils, temporary protective's, liquid and compressed gasses, chemical products, liquid coolants, deicing and antifreeze compounds, and additives. POL products are divided into the bulk and packaged categories. Petroleum laboratory specialists are mainly concerned with class III, bulk fuel, which includes air and ground fuels.

PETROLEUM SUPPLY

1-3. The Army receives, stores, transports, and distributes fuel to supported units. Providing quality fuel requires checks at the point of purchase, during storage, and prior to issuing to the supported units. Petroleum laboratory specialists are primarily responsible for quality surveillance tests on POL in Army class III supply points. Daily quality surveillance of petroleum storage and distribution systems is essential to detect leaks, sabotage, damage, pilferage, deterioration during storage, and contamination. If POL products are found unsuitable, petroleum laboratory specialists make recommendations for product disposition.

1-4. The Defense Logistics Agency-Energy (DLA-Energy) manages the bulk petroleum supply chain, from the refinery to the supported unit. All Army supply points, as the Department of Defense's distribution centers, maintain accountability and inventories of supplies, required to maintain the readiness of supported units. The Army, in its role of providing land based distribution within a theater, operates sites that are capitalized and non-capitalized. Capitalization refers to ownership. Fuel owned by Defense Logistics Agency-Energy (DLA-Energy) is capitalized. Fuels purchased from DLA-Energy and owned by the Services is non-capitalized. A petroleum supply point can be a single tank or a pipeline system with a network of multiple terminals. Army petroleum personnel, to include the petroleum laboratory specialists, may be assigned to work with any of the following supply points.

- If a government-owned, government-operated facility is an Army class III supply point; the stock may be either Army-owned or DLA-Energy owned. Either way, an Army petroleum manager will supervise the receipt, storage, and issue of petroleum stocks. If a petroleum laboratory is assigned, the petroleum manager may also provide fuel testing for supported units and other petroleum supply points. Petroleum laboratories should be prepared to test and make recommendations on any of the fuels used by all types of supported units within its area of operations. Petroleum laboratory specialists consult the Army Petroleum Center, the Joint

Petroleum Office or DLA-Energy as the approving authorities for downgrading, blending, and dehydration. Samples may be brought to the petroleum laboratory or petroleum laboratory specialists may travel to the supported unit to draw samples for testing.

- Army petroleum managers with tactical laboratories may provide support to a government-owned, contractor-operated facility. Typically, stocks are DLA-Energy owned, so DLA-Energy runs the quality surveillance program for the supply point. There are instances, however, when tactical petroleum laboratory personnel may support a contractor operated supply point.
- Petroleum laboratory personnel will not be involved with quality surveillance of stock stored in a contractor-owned, contractor-operated petroleum supply point. Petroleum laboratory specialists may be assigned, however, to take samples and test product to ensure that the contractor is meeting the specifications of the contract.

1-5. Government-owned, government operated; government-owned, contractor-operated; and contractor-owned, contractor-operated class III supply points may be employed in developed and undeveloped theaters.

PETROLEUM LABORATORY TECHNICIAN

1-6. Petroleum laboratory specialists test stock upon receipt and during fuel storage for serviceability. The petroleum laboratory specialist provides laboratory testing to supported units by performing prescribed tests on petroleum samples. Samples are drawn for testing in accordance with the latest version of Military Standard 3004 (MIL-STD-3004), *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products* minimum sampling and testing requirements.

1-7. As the experts on fuel quality, petroleum laboratory personnel assist the bulk fuels accountable officer with logistics status reporting as it relates to the quality of bulk petroleum stocks. The logistics status report is an internal status report that informs commanders and staff about the current logistics position. Normally a status report is completed daily, but during periods of increased intensity the commander may require status updates more frequently. Information regarding the quality of fuels received, stored and issued alerts the chain of command to a variety of problems.

1-8. Petroleum laboratory specialists may be tasked to test fuels procured within an undeveloped theater. Laboratory technicians may travel to the refinery to work with or as a quality assurance representative. Quality assurance samples may be drawn and sent to a fuel testing laboratory outside of the theater. Under emergency conditions, the samples may be sent to a tactical petroleum laboratory within the theater.

1-9. Laboratory technicians may assist supported units with quality surveillance testing of captured fuels. Unless, approved by a petroleum laboratory supported units should not use captured fuels beyond the emergency needs of the battlefield.

QUALITY SURVEILLANCE AND ASSISTANCE PROGRAMS

1-10. The Petroleum Quality Surveillance and Technical Assistance Program, administered by the Army Petroleum Center, consists of multiple programs designed to assist commanders in the receipt, storage, and issue of petroleum. The total program consists of the elements listed below. While all of these are important to the overall fuels supply process, petroleum laboratory personnel are the most affected by the Quality Surveillance Program and by the Petroleum Laboratory Certification Program. Appendix C, AR 710-2, *Supply Policy Below the National Level,* provides in-depth detail on each of the technical assistance programs.

- Quality Surveillance Program.
- Petroleum Technical Assistance Program.
- Operational Surveillance Program.
- Air Pollution Abatement Program.
- Petroleum Laboratory Certification.
- Engineering Technical Review Program.

- Underground Storage Tank Program.

QUALITY SURVEILLANCE PROGRAM

1-11. Petroleum laboratory specialists perform and supervise quality surveillance throughout the Army petroleum supply chain. The Quality Surveillance Program is used to monitor the condition of fuel from point of origin at the refinery until it is issued to the supported unit. In addition to ensuring that all petroleum issued to supported units is suitable for its intended use, quality surveillance provides day-to-day information on how well equipment and products are maintained. MIL-STD 3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products* dictates the testing frequency and the testing methods for bulk products in transit and in storage.

TECHNICAL ASSISTANCE PROGRAM

1-12. The Petroleum Technical Assistance Program provides Army commanders, upon request, professional technical assistance to resolve problems on receiving, storage, handling, usage, quality surveillance, supply, and distribution of petroleum products. The Technical Assistance Program is conducted by the Army Petroleum Center upon request for all Army petroleum laboratories. AR 710-2, *Supply Policy Below the National Level* provides more information about this program.

PETROLEUM LABORATORY CERTIFICATION PROGRAM

1-13. All Army petroleum testing laboratories must be certified annually to perform quality surveillance. The Army Petroleum Center certifies petroleum laboratories (tactical and base) through the Petroleum Laboratory Certification Program. Certification includes a facilities, equipment, methods, and personnel qualifications review. Laboratory certification is a commander's overall responsibility. Commanders typically delegate this responsibility to petroleum laboratory noncommissioned officer in charge.

1-14. The Army Petroleum Center certifies Army laboratories to test Army-owned petroleum stocks and to make disposition on fuel that fails specification testing and also fails MIL-STD 3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products* use limits.

- Certification includes a review of:
  - Facilities – Shelter, hazardous materials storage containers, generator.
  - Equipment – Testing, power cable, placards.
  - Methods – Observation of testing procedures, standing operating procedures, and a correlation sample.
  - Personnel Qualifications – 92L school training.
- Steps in the Certification Process:
  - The unit contacts the Army Petroleum Center to request certification.
  - The Army Petroleum Center sends the unit a certification checklist. This checklist applies to mobile petroleum laboratories worldwide. Installation laboratories are handled case-by-case.
  - Units submit initial information required by the checklist to the Army Petroleum Center.
  - The Army Petroleum Center evaluates options for obtaining correlation sample and for scheduling an inspection.
  - Laboratories test one aviation fuel sample and one diesel fuel sample and report deficiencies to the Army Petroleum Center.
- After the correlation sample is completed, and all other items on the checklist are satisfied, an inspection is scheduled. The inspection may be done in conjunction with the correlation sample, depending on unit and mission.
- After all checklist items are satisfied, a certification letter and certificate, signed by the Army Petroleum Center Commander, are issued to the unit. The certification letter will outline information needed to maintain certification.
- A staff assistance visit team performs certification inspections on the Army Petroleum Center's behalf and makes certification recommendations for deployed petroleum laboratories.

- For overseas locations (Hawaii, Korea, Germany), the Army Petroleum Center designates a senior 92L noncommissioned officer in country to perform the certification inspections.

ENVIRONMENTAL STEWARDSHIP

1-15. Petroleum laboratory operations include the storage, use, and disposal of products that are harmful to the environment. A hazardous material is defined as any substance or material that could adversely affect the safety of the public, handlers or carriers. Protect the environment by properly disposing of chemicals and samples as hazardous waste. Some examples are: flammable liquids and gases, corrosives, oxidizers, explosives, and toxins.

1-16. Always consider the environment in making day-to-day decisions because petroleum units potentially have an adverse impact on the environment. Improper handling of petroleum presents a threat to Soldiers, the mission, and the environment. Closely monitor the impact of how hazardous materials are handled. Every petroleum laboratory should conduct an environmental assessment to ensure that it is in compliance with environmental standards. Refer to AR 200-1, *Environmental Protection and Enhancement,* for detailed information on environment stewardship.

ORGANIZATIONAL RELATIONSHIPS

1-17. Since quality fuel is paramount to a successful mission, petroleum laboratories communicate along command channels and technical channels. The command channel involves the petroleum units within the Army while the technical channel includes joint and Army organizations. The petroleum laboratory supports the mission of its higher headquarters making this organizational relationship that of supported unit and command channel. Command and technical channels include a two-way flow of information to ensure that the laboratories receive the most current guidance and to inform the command or suppliers of real or potential problems in the field. There is also two-way communication between the supported units and the petroleum laboratory that includes information about test results. This section provides a brief description of the organizations with which the petroleum laboratory personnel will interact. See Figure 1-1 on page 1-5 referencing organizational relationships.

ECHELONS ABOVE BRIGADE

1-18. Defense Logistics Agency-Energy procures bulk fuel, contracts for fuel production, and negotiates international fuel agreements. Strategically, DLA-Energy serves as a link between the Services and the petroleum industry. DLA-Energy operates and maintains laboratories in the Americas, Pacific, Europe, Africa, and the Middle East that monitor petroleum quality until it is purchased by the Army. DLA-Energy provides technical assistance to petroleum laboratories in the theater, particularly in recovering and downgrading products.

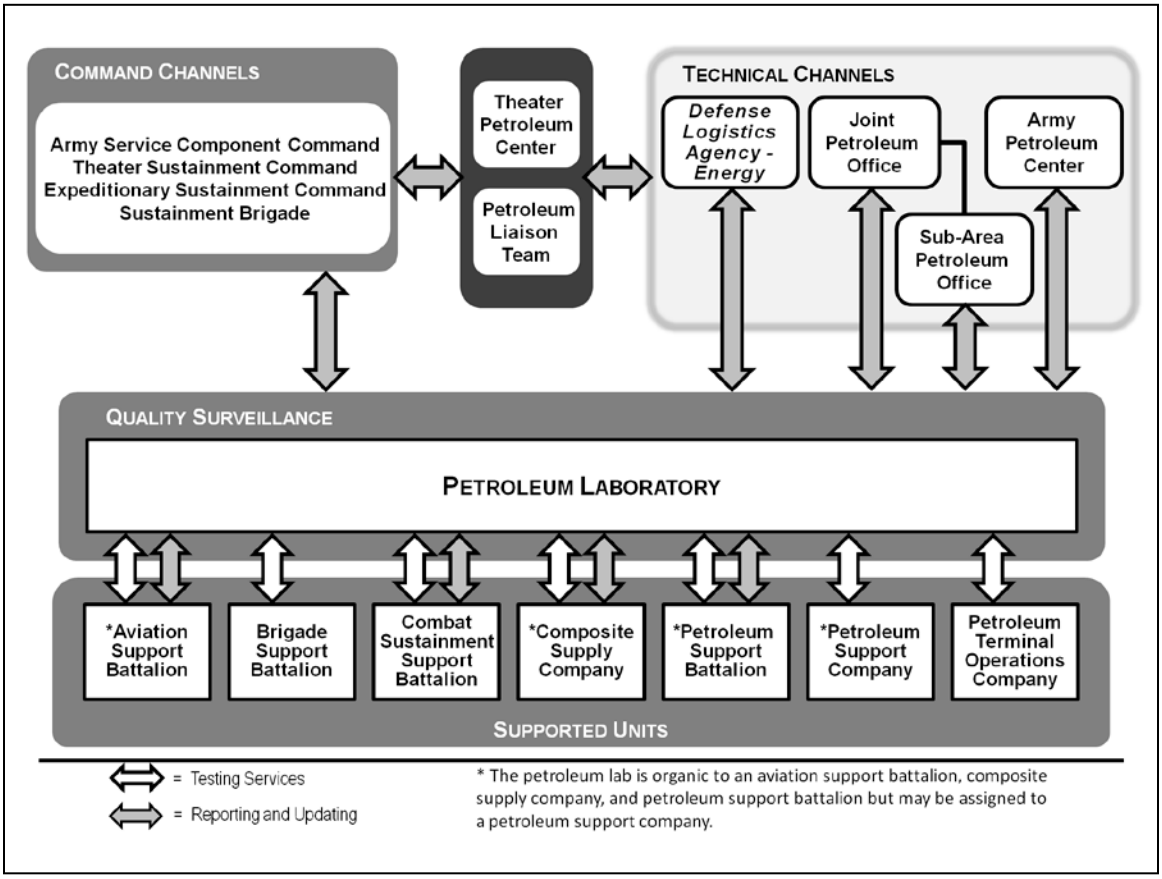

Figure 1-1. Organizational relationships

1-19. The Joint Petroleum Office works with Service components and DLA-Energy to plan for, coordinate, and oversee all phases of bulk petroleum support in the theater. The Joint Petroleum Office monitors the accuracy of theater petroleum laboratories through a correlation program. The actual management of the correlation program may be delegated to a Service or to DLA-Energy.

1-20. Subarea petroleum offices are subordinate to the Joint Petroleum Office. The Joint Petroleum Office establishes subarea petroleum offices to fulfill specific support requirements in an area of operations. Among other tasks, the subarea petroleum office coordinates the quality surveillance program for all petroleum supply points in its realm of responsibility.

1-21. The Army Petroleum Center is the lead Army agency that provides guidance for fuel quality and provides technical guidance on equipment, and infrastructure to assist units in managing fuels operations. It validates, consolidates, and coordinates bulk petroleum requirements with DLA-Energy and Army organizations.

1-22. The Theater Petroleum Center serves as the operational Army link to strategic petroleum partners. Theater petroleum centers provide liaison between DLA-Energy, host/partner nations, the Army service component command, Army Petroleum Center, combatant command, expeditionary sustainment command, and theater sustainment command as needed, and serves as the senior theater Army petroleum advisor to the combatant command. The Theater Petroleum Center works closely with the Joint Petroleum Office and subarea petroleum offices, and may serve as the subarea petroleum office, to ensure the seamless distribution of petroleum in theater.

1-23. Quartermaster detachment, petroleum liaison teams serve as the Army link to strategic petroleum partners. The petroleum liaison teams work closely with the Joint Petroleum Office and

subarea petroleum offices, or may serve as the subarea petroleum office, to ensure the seamless distribution of petroleum in theater.

1-24. The expeditionary sustainment command is a United States Army logistics headquarters. The sustainment command's primary mission is to command the sustainment brigades that provide combat support and combat service support in the areas of supply, maintenance, transportation, field services and the functional brigades or battalions that provide medical, general engineering and construction, smoke generation, biological detection and decontamination support. The command is designed to deploy into a theater of operations, assume command of the logistical units in place and provide oversight and materiel management. The command will report to a theater sustainment command while in theater.

1-25. The theater sustainment command plans, prepares, and rapidly deploys to execute operational logistics within an assigned area of operations. A theater sustainment command may support one or more expeditionary sustainment commands as required.

1-26. A petroleum supply and petroleum operating battalion were combined to form a unique multi-functional petroleum support battalion. The petroleum support battalion is comprised of three to five assigned or attached petroleum support companies, transportation medium truck companies (petroleum), and/or petroleum pipeline and terminal operating companies for the operation and maintenance of a military petroleum distribution. The petroleum support battalion operates as a central dispatching agency to schedule and direct the flow of bulk petroleum through the petroleum pipeline. Additionally, it supervises a program for quality surveillance of petroleum products and operates and maintains a mobile petroleum laboratory.

1-27. Petroleum support companies normally have three support platoons with each platoon having two each 800,000 gallon capacity fuel system supply points with the 210,000 gallon tanks to provide bulk general support. The area support section can provide retail direct support capacity using a 120,000 gallon fuel system supply point. Assault hose line augmentation teams establish linkage between tank farms and high volume users. The company headquarters platoon provides daily inventories and coordination of transportation support based on customer requirements. A laboratory is assigned to the petroleum support company to conduct quality surveillance testing. An 800,000 gallon fuel system supply point is allocated from the Army Prepositioned Stocks for the petroleum support company upon opening theater distribution missions.

1-28. The petroleum pipeline and terminal operating company controls petroleum pipeline and terminal facilities for receipt, storage, and distribution of bulk petroleum products in support of an independent corps or theater Army area of operations. It deploys up to 75 miles of pipeline for distribution of 720,000 gallons per day and two commercial-type tank farms (up to 250, 000 barrels each) or one tactical petroleum terminal of up to 3.8 million gallons. The company may establish, operate and maintain a laboratory for quality surveillance.

1-29. Petroleum transportation medium truck company consists of 60 POL tankers with either 7,500 or 5,000 capacity.

1-30. Quartermaster pipeline operating platoons attach to a petroleum support company to establish the early entry petroleum receipt capability at the beach termination unit of the Navy offshore petroleum discharge system, and establish the initial theater petroleum stock objectives in the theater petroleum terminal with the aid of the company storage sections. The platoon will be capable of operating 45 miles of Inland Petroleum Distribution System for expedient bulk petroleum distribution.

1-31. The sustainment brigade exercises mission command within assigned area of operations.

1-32. Base petroleum lab teams operate a petroleum laboratory providing quality surveillance testing using data to make recommendations for proper use, reclamation, and disposal of product. It also provides technical support and supervision to other laboratories for handling, storing, sampling, identifying, and performing quality evaluation of petroleum products and containers.

1-33. Composite supply companies provide general supply, class I perishable and semi-perishable supply, retrograde support, petroleum supply, and water supply support to supported units. A petroleum laboratory is organic to the composite supply company.

BRIGADE AND BELOW

1-34. The aviation support battalion mission is to provide command for all subordinate units and to synchronize logistics and health services support operations for the combat aviation brigade. Its distribution company provides liquid logistics support to the combat aviation brigade by operating two 120,000 gallon, fuel system supply point, with distribution capabilities of 25,000 gallons in a single lift. The unit also establishes forward area refueling points for refueling of aircraft. A petroleum laboratory is organic to the aviation support battalion.

1-35. The role of the distribution company is to plan, direct, and supervise supply distribution to the brigade. It conducts daily receipt, storage, and issue of supply classes I, II, III (bulk and packaged), IV, V and IX and transports cargo for the brigade. This unit is employed in the brigade support area and operates throughout the supported brigade area.

1-36. The forward support company provides class III direct support combat replenishment to supported units combat trains.

1-37. Quartermaster petroleum quality analysis team operates a petroleum laboratory used to perform quality surveillance testing of petroleum products. The petroleum quality analysis team provides technical assistance for handling, storing, sampling, identifying, and performing quality surveillance of petroleum products and petroleum containers on an area support basis.

ROLES AND RESPONSIBILITIES

1-38. The joint petroleum officer, responsible to the theater commander, ensures there is a quality surveillance program within the command.

1-39. Commanders execute supply support at the tactical level. Commanders at all levels provide information, equipment, and available manpower for the effective and efficient operation of the petroleum supply chain. Commanders direct the acquisition, storage, inspection, testing, issue and distribution of petroleum products.

1-40. The petroleum officer commands or exercises staff responsibility for units engaged in petroleum and water operations. Petroleum officers serve in staff positions requiring petroleum and water experience. The petroleum officer directs acquisition, storage, inspection, testing, issue and distribution of petroleum and water products. Petroleum officers determine bulk and packaged petroleum products and water requirements, storage space requirements, distribution system requirements, and quality surveillance requirements. The petroleum officer recommends locations for petroleum and water pipe-line and hose line routes, terminals supply points, and depots; advises on water and bulk petroleum distribution system.

1-41. The support operations officer is the principal staff officer for coordinating logistics support. The support operations officer provides the technical supervision for the external logistics support mission. The support operations officer plans and monitors support operations and makes necessary adjustments to ensure support requirements are met.

1-42. The Quartermaster petroleum liaison team provides liaison and coordination for bulk petroleum support between United States, Allied, and host nation forces.

1-43. The class III platoon leader should be familiar with a variety of petroleum supply management duties especially having a clear understanding of storage plans, policies and procedures. Platoon leaders are responsible for accountability of personnel and assigned equipment. Platoon leader responsibilities specific to quality surveillance include:

- Review lab analysis reports.
- Review gains and losses of product.

- Rotate product stocks.
- Inspect systems and storage tanks.
- Review standing operating procedure for sampling/testing scheduling.
- Review unit sample log and test schedule.

1-44. The bulk fuels accountable officer supervises the overall class III supply point operation, mobile filling station sites, bulk storage facilities and tank farms. Petroleum supply point accountable officers are responsible for the layout of the supply point as well as the operations involved in the receipt, storage, and issue of petroleum. The accountable officer directs the acquisition, storage, inspection, testing, issue and distribution of petroleum stocks. Accountable officers develop local policy guidance; periodically reviews all operating procedures; and executes corrective actions. Accountable officers direct the preparation of reports and maintenance of records pertaining to petroleum accounting and distribution operations. The accountable officer must ensure that petroleum operations adhere to applicable environmental policies, procedures, laws and regulations. Specific to mobile laboratory operations, the accountable officer ensures that the commander is advised of quality surveillance problem areas. Bulk fuels accountable officer responsibilities specific to petroleum laboratories include:

- Determine quality surveillance reporting requirements.
- Review lab analysis reports.
- Review gains and losses of product.
- Inspect systems and storage tanks.
- Review standard operating procedures for sampling/testing scheduling.
- Review unit sample log and test schedule.
- Establish tank card file.
- Supervise performance of standard physical and chemical tests.
- Evaluate test results to ensure products meet federal and military specifications.
- Recommend disposition of off-specification or captured petroleum products.

1-45. Petroleum system technicians are primarily responsible for supervising and managing the reception, storage and shipping of bulk or packaged petroleum products. The petroleum system technician serves in staff positions assisting with requirements determination for bulk fuel and packaged petroleum products, storage space and fuel systems. Petroleum system technicians monitor petroleum quality surveillance procedures. In addition, the petroleum system technician develops, supervises and coordinates unit procedures and programs for environmentally sound handling of petroleum products.

1-46. The laboratory noncommissioned officer in charge (NCOIC) is responsible for the day-to-day supervision, and coordination for ensuring mission accomplishment. The NCOIC implements laboratory policies, procedures, and priorities. As a manager, the laboratory NCOIC is responsible for assigning duties and for planning and managing the functioning of the laboratory. The NCOIC prepares and reviews laboratory reports and makes recommendations for the disposition of petroleum products. The laboratory NCOIC develops and implements training, to include cross training, for all personnel. Laboratory NCOICs prepare, review, and submit required reports for the accountable officer’s approval. The NCOIC also assists the platoon sergeant as needed.

1-47. The senior petroleum laboratory specialist reviews laboratory testing in progress and test results. The senior laboratory technician requisitions laboratory supplies, implements, standing operating procedures and assists the NCOIC with training laboratory personnel.

1-48. Petroleum laboratory specialists perform petroleum testing in strict accordance with federal, international and military standards and guidance.

1-49. The calibration coordinator is responsible for the calibration program. The calibration coordinator maintains the record of calibration program equipment and ensures that “A” and “C” level calibration is performed.

Chapter 2

Petroleum Quality Management

This chapter describes the quality assurance and quality surveillance process from the manufacturer to the government taking ownership of petroleum products until the product is issued to the supported unit. Chapter 2 also provides information on types of tests performed in petroleum laboratories along with common fuel contaminants.

QUALITY ASSURANCE

2-1. Quality management is the responsibility of every element in the supply chain that manufactures, receives, stores, and issues bulk fuel. Laboratories routinely test fuel at the major unloading facilities, at intermediate filling points along pipelines, and at class III supply points. A series of testing procedures ensures that bulk fuel is of the highest quality, meet the required performance standards, and can be used for intended purpose.

2-2. DLA-Energy contracts refineries to produce fuel products in accordance with defense customers' specifications. Manufacturers use a series of quality control procedures during fuel production to ensure that the fuel meets or exceeds government specifications. Typically, the contractor is required to maintain an inspection system and a written quality control plan that is satisfactory to the government. Quality assurance, during the manufacturing, process seeks to prevent problems with the product. Manufacturers dedicate resources to improving procedures or systems that ensure quality merchandise is always produced. In manufacturing, quality control and quality assurance are interrelated because both serve the same purpose of producing quality products.

2-3. Quality assurance takes place at the strategic level. Quality assurance is a contract administration function performed by the Government to determine whether contractors fulfill contract requirements and specifications of petroleum products and related services. The DLA-Energy administers the contract quality assurance program thereby ensuring that fuel conforms to government specifications. This technical manual addresses DLA-Energy level quality assurance because it is possible that Army petroleum laboratory and petroleum management personnel may be assigned as quality assurance representatives at some point in their career.

2-4. Refineries control quality during the manufacture and storage process. Quality control is the inspection procedure performed by refinery personnel to monitor the production of a particular petroleum product. Quality control involves the manufacturer's inspection of the handling, step-by-step processing, and finishing of materials. It also involves the final inspection and testing of end products to ensure that contract materials are acceptable. Military petroleum products are usually procured under federal or military specifications.

2-5. Fuel purchased by the government must meet specifications at time of delivery. Requests for proposal often dictate that manufacturers/service providers detail quality control and quality assurance processes in the bid for the contract. As a result, refineries maintain an effective quality control program that covers testing, sampling, blending, packaging, sealing, marking and loading of bulk fuel.

2-6. Government personnel responsible for administering contract quality assurance at the contractor facility are known as quality assurance representatives. Quality assurance representatives monitor contractor performance and management systems to ensure that cost, product performance, and delivery schedules are in compliance with the terms and conditions of the contracts. Quality assurance inspections can be performed either at the refinery or at the point where the product is intended to pass into government hands.

2-7. If the product is in compliance with all of the terms of the contract and it is accepted by the quality assurance representative it then becomes government-owned through a financial transaction. The quality assurance representative's role in the financial transaction is the testing of the bulk fuel. If the quality assurance representative's tests result in the conclusion that the fuel meets contract specifications, the required documentation is completed for submission through designated channels. Eventually, according to the contract terms, the contractor will be paid. After the product becomes government-owned, petroleum managers turn their attention to quality surveillance inspections.

2-8. Quality assurance inspections may also lead to rejection of the product. If the product appears to be other than that ordered, or if samples fail to meet requirements, further testing may be performed. If the product does not meet specifications, the quality assurance representative coordinates the rejection according to the contract, contracting policy and DLA-Energy's standard processes. DLA-Energy does not accept products and services that do not fully conform to the contract requirements.

2-9. Quality assurance representatives inspect storage facilities used to store contractor-owned products. Refer to the latest MIL-STD 3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products* for testing criteria.

2-10. Quality assurance representatives verify that the products designated for shipment are moved through segregated lines.

2-11. Tank cars and tank vehicles are inspected for suitability to receive and transport product. Petroleum managers must not expedite movements at the expense of quality or quantity determinations. Any tank car or tank vehicle that is not acceptable for loading is rejected.

2-12. The quality assurance representative inspects tankers and barges to make sure these vessels are in an acceptable condition to receive product. All cargo tanks must be approved for loading for the tanker or barge to pass the inspection.

- A barge is any vessel with less than a 30,000 barrel capacity.
- A tanker is any vessel with over a 30,000 barrel capacity.

QUALITY SURVEILLANCE

2-13. Contaminated or dirty fuels can damage expensive engines and cause the failure of critical combat missions. Quality surveillance takes place at the strategic, operational and tactical levels. The purpose of quality surveillance is to ensure fuel used in military equipment is clean, bright and suitable for immediate use for its intended purpose. Contaminated or deteriorated fuel can cost lives, especially with aircraft. Quality surveillance applies to all petroleum products, and is the responsibility of all personnel who handle petroleum. Sediment, water, microbial growth, and commingled fuel damage aircraft, ground vehicles and fuel storage equipment. Quality surveillance tests performed depend on where the POL is in the supply chain. Quality surveillance tests must be performed in accordance with MIL-STD 3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related* Products, Table IX, Minimum Sampling and Testing Requirements for Petroleum Products.

2-14. Laboratory tests ensure fuels meet specifications, identify unknown products, detect contamination, verify field tests, and provide the basis for disposition of unacceptable fuel. Laboratory tests include, but are not limited to distillation, gravity, corrosion, water tolerance, particulate matter, freeze point, vapor pressure, gum content, tetraethyl lead, and sulfur. Fuel must be tested by a laboratory when:

- Requested by petroleum offices.
- Bulk fuel stored for six months or more. Refer to MIL-STD-3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products*, Table VIII.
- The quality of fuel is questioned or it cannot be classified.
- A filter/separator is first placed in service after the filter elements have been changed and within 30 days from the date last sampled from that conveyance or tank.
- It is determined that an aviation fuel may be contaminated or commingled.
- Commercial deliveries of bulk fuel. Refer to MIL-STD-3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products*, Tables XXVI through XXVIII.

2-15. The petroleum laboratory specialist decides which tests to perform based on the type of sample and the source of the sample. Due to the criticality of fuel quality, test all samples on the same day as submitted by the supported unit or drawn by laboratory personnel. Laboratory specialists verify test results through comparison to the specifications and deterioration limits for the sample product.

2-16. Report test results according to unit standing operating procedures. When tested products do not meet specifications, tactical laboratory personnel recommend, through channels, alternate use, reclamation, or disposal. Petroleum laboratory personnel annotate recommendations for product disposition on the petroleum products laboratory analysis report and in the sample log book and notify supported units that testing is completed.

TYPES OF TESTS

2-17. Petroleum supply technicians and laboratory specialists do visual checks for appearance, water, and sediment. Laboratory tests confirm suspected product contamination and deterioration. Petroleum laboratory specialists perform quality surveillance testing in accordance with American Society for Testing and Materials (ASTM) guidelines found on the ASTM International web site and in accordance with the MIL-STD-3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products*. For each product, the extent of testing is divided into levels:

- A level testing is a complete specification inspection test series used as procurement inspection test.
- B-1 level testing is a quality surveillance test used for checking product contamination after movement.
- B-2 level testing is a quality surveillance test used for checking product deterioration due to age.
- B-3 level testing is a quality surveillance test used to check for general contamination.
- C level testing is a quality surveillance test for specific gravity, visual color, appearance and any other test required by the specific petroleum product.

2-18. Quality surveillance testing is used to find common contamination and deterioration. Refer to MIL-STD-3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products* and the ASTM guidelines for testing criteria. Product temperature and gravity, visual checks, and color provide clues to product contamination. Some of the possible tests are: flash point; vapor pressure; sediment and water; viscosity; specific density, electric conductivity and distillation.

- If the product meets or exceeds all specification requirements the product is classified as on grade.
- If the product fails one or more of the specification limits, but falls within the use limit of MIL-STD-3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products* that product is classified as suitable for use.
- If the product fails one or more of the specification limit and does not fall within the use limit of MIL-STD-3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products* that product is classified as not suitable for use.

2-19. Correlation testing is performed to ensure that individual laboratories obtain similar results and as a means to certify laboratory personnel. Correlation testing may be done by sending identical samples to two or more laboratories. These laboratories use the same apparatus in performing the tests. Correlation testing may also be done by having two or more technicians within a given laboratory perform tests on identical samples using the same apparatus under controlled conditions.

Common Tests

2-20. The American Petroleum Institute (API) developed a measurement, referred to as API gravity, to compare density of petroleum products. Each type and grade of fuel has a particular API gravity range. The API gravity test compares the fuel to water to measure the petroleum product's density. API gravity tests are run on all petroleum products, except greases, to determine their densities. These tests are generally used as a quality control indicator, but some specifications have actual API gravity requirements. The scale was developed to eliminate the problem of working with decimals associated with specific gravity. An API

gravity of 10 is equal to 1.000 specific gravity. API gravity is needed in order to select volume reduction factors to be used in fuel accounting procedures. When the API gravity of a product rises more than 0.5 (for example, motor gasoline going from 59.5 to 60.1 API gravity), the cause is usually contamination by a lighter petroleum product. A drop in API gravity is generally caused by contamination with a heavier product. Results that vary more than 0.5 API indicate a problem, and further tests must be performed to determine the cause. Figure 2-1 illustrates specific gravity and API gravity ranges.

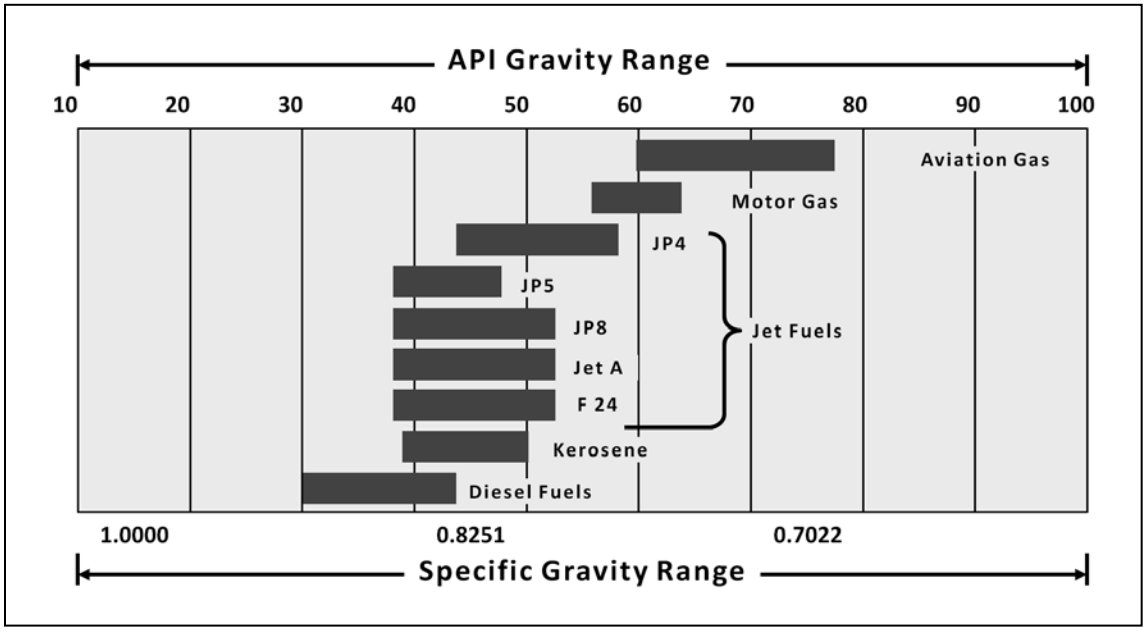

Figure 2-1. Fuel gravity range

2-21. As the API gravity goes up, its corresponding specific gravity goes down. Specific gravity is a means of comparing weights of substances. This is independent of the actual numerical value of the pull of gravity in any locality. Specific gravity is the ratio between the weight of a quantity or volume of a substance and the weight of an equal quantity of water. It is a relative measure of weight density compared with water. Solids and liquids are usually compared with water at its maximum density at 4° Celsius.

2-22. Appearance and workmanship is a visual test performed on a product to determine if it is homogeneous, clear, bright, separated, or otherwise different from what the product should look like. Depending on the product, it will be clear (free of suspended matter or particles), bright (sparkle in transmitted light), homogeneous uniformly mixed), separated (stratified or bleeding), or have visual sediment or water. To make these determinations, care should be taken that nothing is overlooked. Control of such contamination requires constant vigilance. Solid and liquid contamination can lead to restriction of fuel metering points, improper seating of inlet valves, corrosion, fuel line freezing, gel formation, filter plugging, or failure to lubricate. Product containing visual sediment and water should be allowed to settle and then filtered before use.

2-23. Color tests are made on many petroleum products to detect deterioration and contamination. In some cases color tests are performed to identify products. Jet fuels, kerosene, and solvents are usually color tested by the Saybolt chromometer method. Undyed motor and aviation gas can also be tested by this method. Equipment used in the test includes a Saybolt chromometer, color standards, and a daylight lamp. Diesel fuel, lubricating oils, and heating oils are color tested by the ASTM color scale method. Equipment used in the test includes a light source, glass color standards, a sample container, and a viewing piece. In refining, a color test is used to determine the uniformity of a product batch.

2-24. Once the product is in the distribution system, a color test is used as a quick check for deterioration and contamination. If a color test reveals a color darker than expected, the test may indicate contamination by a heavier product or deterioration due to age. If a test reveals a color lighter than expected, the test may indicate contamination by a clear or straw-colored product.

2-25. The cloud point test is performed on diesel fuels, fuel oils, and other petroleum oils that are transparent and have a cloud point below 12° Fahrenheit. The cloud point is an indication of the behavior of oil in certain lubricating devices. The formation of minute, waxy crystals may plug the wick through which oil flows in some lubricating devices. However, extreme low temperature operating conditions are rarely encountered with equipment lubricated in this manner. Fuels oils and diesel fuels with high cloud point could clog filter if a preheater is not used. Contamination with a heavier product can raise the cloud point.

2-26. The distillation test is performed on light distillates such as aviation turbine fuels, motor gas, aviation gas, distillate fuel oils, and kerosene. The distillation test is used to evaluate vaporization characteristics of a fuel. To obtain a fuel that has specific characteristics, controls must be established over the amount of evaporation that will take place at different boiling temperatures. As distillation progresses, the composition of the sample changes. Some liquid residue may remain after the maximum temperature is reached. This portion of the fuel may not vaporize in service; it will remove the lubricant from the cylinder walls and contribute to crankcase oil dilution.

2-27. The existent gum by jet evaporation test is performed on motor gas and aircraft fuels. High gum content indicates that the fuel might cause deposits in the induction system and sticking of intake valves. The existent gum test can tell the user the amount of oxidation that has taken place before the test was performed. Storage tanks that are vented to the atmosphere breathe when temperatures fluctuate. This causes the fuel to oxidize and form gum. Contaminated fuel will show an oily gum; deteriorated fuel will show a dry gum. High-gum product can be blended down to a usable level by adding a low-gum product of the same grade.

2-28. The freezing point test is run on aviation fuels to determine the temperature at which the fuel begins to freeze. Wax and excess aromatic components in fuel raise the freezing point. These components can be present as a result of contamination or poor refining. Modern aircraft fly at high altitudes where temperatures can be as low as -67° Fahrenheit. At these low temperatures, wax and aromatics can freeze and clog fuel line strainers, shutting off the engine. At the procurement level, a fuel failing the freezing point test usually indicates poor refinery blending. Such fuel is rejected and reblended before shipment. In quality surveillance work, a fuel failing the freezing point test usually indicates contamination with diesel fuel or fuel oil. This can be confirmed by high distillation end points, oily gum results, and water reaction interface test failures. Fuels failing the freezing point test can be upgraded by blending with on specification product.

2-29. This fuel system icing inhibitor test is performed on jet turbine fuels that contain the inhibitor ethylene glycol monomethyl ether or diethylene glycol monomethylether. The B-2 test kit technique is not applicable to diesel fuel. Fuel system icing inhibitor is added to jet fuels to prevent dissolved water from freezing at high altitudes (above 8,500 feet). Fuel system icing inhibitor must be added at procurement indicated by JP8 specification limits. If the fuel system icing inhibitor level is not within the JP-8 specification limit refer to MIL-STD 3004 for use limits. Fuel system icing inhibitor will drop out of fuel easily when the fuel is in contact with water. Proper quality control of jet fuel requires that contact with water be strictly avoided. If test results show that the fuel system icing inhibitor level is low, fuel system icing inhibitor level could be increased by upgrading through blending or injecting additive. Storage procedures should be evaluated to find the source of the water contamination.

2-30. The kinematic viscosity test is performed on diesel fuels, fuel oils, hydraulic fluids, and lubricating oils to measure the internal resistance to flow. A viscosity range is established for fuel and is the prime test to separate various grades. The viscosity range is needed to maintain flow conditions in the heavier (4, 5, or 6) grades. In grades 1 and 2, the viscosity determines how well the fuel will be vaporized. Poor vaporization at the fuel nozzle can cause poor burning and carbon formation. Too low a viscosity can cause flashbacks in the burners. Viscosity test results may be high if the fuel is contaminated with a heavier fuel. The fuel should also show a darker color. When the result is lower than expected, contamination by a lighter product, such as gasoline or jet fuel, is indicated. A corresponding low initial boiling point in distillation and a low flashpoint will also occur. Either high- or low-viscosity problems can be corrected by blending.

2-31. The Pensky-Martens Flash Point test is run on fuel oils and diesel fuels and is used to verify that the fuel oil or diesel fuel meets minimum safety levels for combustible vapor formation. It is especially significant for testing fuel to be used by ships. If the fuel oil flashpoint drops by more than 6° Fahrenheit,

contamination with a lighter product (gasoline or jet fuel) should be suspected. This should also show up in a lower initial boiling point in the distillation. If the flash point goes up more than 6° Fahrenheit, contaminations with a heavier product (heavy fuel oil or lubricating oil) should be suspected. A higher distillation end point, higher viscosity, and possibly a color change will verify this. To a limited degree, off specification product can be upgraded by blending.

2-32. The pour point of petroleum oils test is performed on most petroleum products. It can also test the fluidity of a residual fuel oil at specified temperatures. The tests are important in determining the use of products in cold climates. The pour point of a petroleum specimen is an index of the lowest temperature of its utility for certain applications. If a product will not pour below a certain temperature, it will have restricted use. Products that have a pour point that does not meet specifications usually are contaminated by a heavier product.

2-33. The particulate contaminant in aviation fuel tests are run on aviation and ground fuels to test for the presence of excessive solid contaminants such as dirt, sand, and metal. From the time a fuel is refined until it is used, it comes in contact with iron, rust, sand, and other solid contaminants. Generally, fuel is allowed to settle and then filtered in order to remove these contaminants. The particulate contaminant test is performed at various distribution locations to determine the effectiveness of the cleaning process. If the test result is too high, an immediate resample should be taken as high results may be due to poor sampling technique. If are sample also fails, the entire system should be evaluated to detect the problem. The high result could be caused by inadequate settling times or unserviceable filter elements. Specification requirements for particular products may be found in their respective military specification.

2-34. The Reid Vapor Pressure test is run on jet propulsion, type 4 (JP4), aviation gasoline, and gasoline to ensure the product will vaporize when required. Vapor pressure must be at a level that will ensure the fuel vaporizes in the carburetor. If the pressure is too high, fuel will vaporize in the fuel line, causing vapor lock, and the engine will not run. Also, fuel in storage with too high a Reid Vapor Pressure will evaporate excessively. If the vapor pressure is too low, fuel will enter the carburetor as a liquid, causing oil dilution and incomplete combustion. Reid Vapor Pressure is directly related to temperature. For this reason, refiners adjust gasoline vapor pressures to fit the season. If the Reid Vapor Pressure of an aviation gas is too high, contamination with a higher Reid Vapor Pressure motor gas is suspected. If the Reid Vapor Pressure of a gasoline is too low, contamination with a heavier product or deterioration due to weathering is indicated. The distillation test IBP and 10 percent points will be high when the Reid Vapor Pressure is lower, and deterioration is indicated. If caused by contamination, the distillation end point will be high. If the Reid Vapor Pressure of JP4 is too high, gasoline contamination is indicated. Lead contamination should be suspected. If JP4 Reid Vapor Pressure is too low, the same problem indicated by a low gasoline Reid Vapor Pressure exits. Generally, Reid Vapor Pressure problems can be solved by blending with a specification product.

2-35. The thermal stability tests are run on aircraft turbine fuels to check for resistance to thermal breakdown. Thermal stability is the resistance of fuels to chemical and physical change upon exposure to high temperatures that tend to decompose them. Thermal stability of fuels under high temperatures has become increasingly important in the transition of jet aircraft from subsonic to supersonic speeds. Fuel is expected to perform a cooling function by providing a heat sink; that is, by absorbing the heat generated in high-speed flight. Fuel cannot do this unless it resists decomposition. A coke-like substance forms in thermally unstable fuels and plugs fuel jets and manifolds. Aircraft fuels are routinely exposed to test temperatures of -65° to 400° Fahrenheit. Presence of aromatics and olefin components are restricted in jet fuels because they are less heat resistant. Low thermal stability is usually caused by contamination with a motor gas or aviation that contains these undesirable components. This problem can usually be corrected by blending with better product.

2-36. Water and sediment tests are run to determine the amount of water in crude, fuel, and lubricating oils, the amount of water and sediment in crude and fuel oils, and the amount of water and sediment in diesel and other distillate fuels. Water and sediment that accumulate in ship cargo tanks and in shore tanks affect quality and quantity. Excessive sediment can plug burner tips and prevent fuel from vaporizing properly. This is also true for injectors in diesel engines. Water in fuel may freeze and clog fuel lines. Water in lubricating oils can corrode metal surfaces and cause a loss of additives. Water and sediment can

be removed by letting the product settle and filtering it. Drummed and canned stock contaminated by water or sediment or both must be disposed of as prescribed by regulations.

2-37. The water reaction test is performed on aviation fuels to determine the presence of excess alcohol or aromatic components and to evaluate the presence of surfactants on the fuel/water interface. The water layer in the test is initially set at 20 milliliters. If the level increases in the test, this indicates the presence of alcohol. If the water layer decreases from 20 milliliters, the presence of aromatics is indicated. Aromatics absorb water, and excess amounts of them will cause excess water to be held in fuel. This water will freeze at high altitudes, clogging fuel lines. For these reasons, a water level change value is set in aircraft fuel specifications. The interface ratings are set to measure the effect of surfactants in the fuel. These surfactants can cause excess sediment and water retention, which causes fuel filter clogging. There is a correlation between the water separation index, Modified rating or the microseparometer surfactant rating and the interface rating.

2-38. Conductivity tests are performed on JP4 and jet propulsion, type 8 (JP8) turbine fuels containing a static dissipater additive. The ability of a fuel to dissipate electrical charges that have been generated during pumping and filtering operations is controlled by its electrical conductivity, which depends upon its content of ion species. If the fuel conductivity is sufficiently high, charges dissipate fast enough to prevent their accumulation and dangerously high potentials at a fuel dispensing point. The use of static dissipater additive can increase fuel conductivity to safe levels. Static dissipater additive is added to JP4 or JP8 turbine fuels in very small proportions so that its effectiveness can be diminished by blending with other fuels that do not contain static dissipater additive. Moreover, conductivity can be affected by filtering and transferring operations and by temperature changes. For this reason, the fuel sample for the conductivity test is taken close to where the fuel enters the aircraft.

2-39. The purpose of the fuel additive injector is to inject corrosion inhibitor, static dissipater additive and fuel system icing inhibitor into Jet A1 or Jet A to create JP8 or North Atlantic Treaty Organization Code Number F34 (F34). The Hammonds is a fluid powered, multi-additive injection system. The injector provides proportionate to flow additive by borrowing just enough energy in the flowing jet fuel line to turn the fluid motor.

TESTING

2-40. Prior to the quality assurance representative's acceptance of the fuel, an upper, middle, and lower composite sample is taken from each of the refinery's stock locations for A level testing. This test series is done on all petroleum products prior to the manufacturer loading the product for shipment to the military and immediately before the military takes possession of the product. All tests listed in the specification for the product are performed. The quality assurance representative compares the sample results against the contract specifications to determine whether the fuel meets the requirements for the order.

2-41. Quality surveillance fuel samples are drawn and tested at the different nodes along the fuel supply chain. Each of these petroleum supply chain nodes is covered by a specified test series; refer to MIL-STD 3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products,* Table IX. The minimum sampling and testing frequency of the product is dependent on the type of product, location, type of storage, and when it was last tested. Petroleum product sampling and testing fall into five categories:

- Before acceptance of delivery from a manufacturer.
- When contamination or deterioration is suspected.
- After movement of bulk products.
- Before issue to supported units.
- Periodic checks on filter effectiveness.

2-42. The theater petroleum supply system begins with the receipt of bulk fuel. Bulk fuel is shipped from the refinery by truck, pipeline, barge, tanker, or rail and receipted into a bulk storage facility. Figure 2-2 on page 2-8 provides a broad overview of the bulk fuel supply chain to illustrate quality surveillance nodes in the operational area. This graphic is not depicted to scale and is not intended to show every petroleum situation because each deployment and each bulk fuel supply chain will be different. It is assumed, in this graphic, that all fuel is government-owned and has been tested for quality assurance at the refinery and accepted.

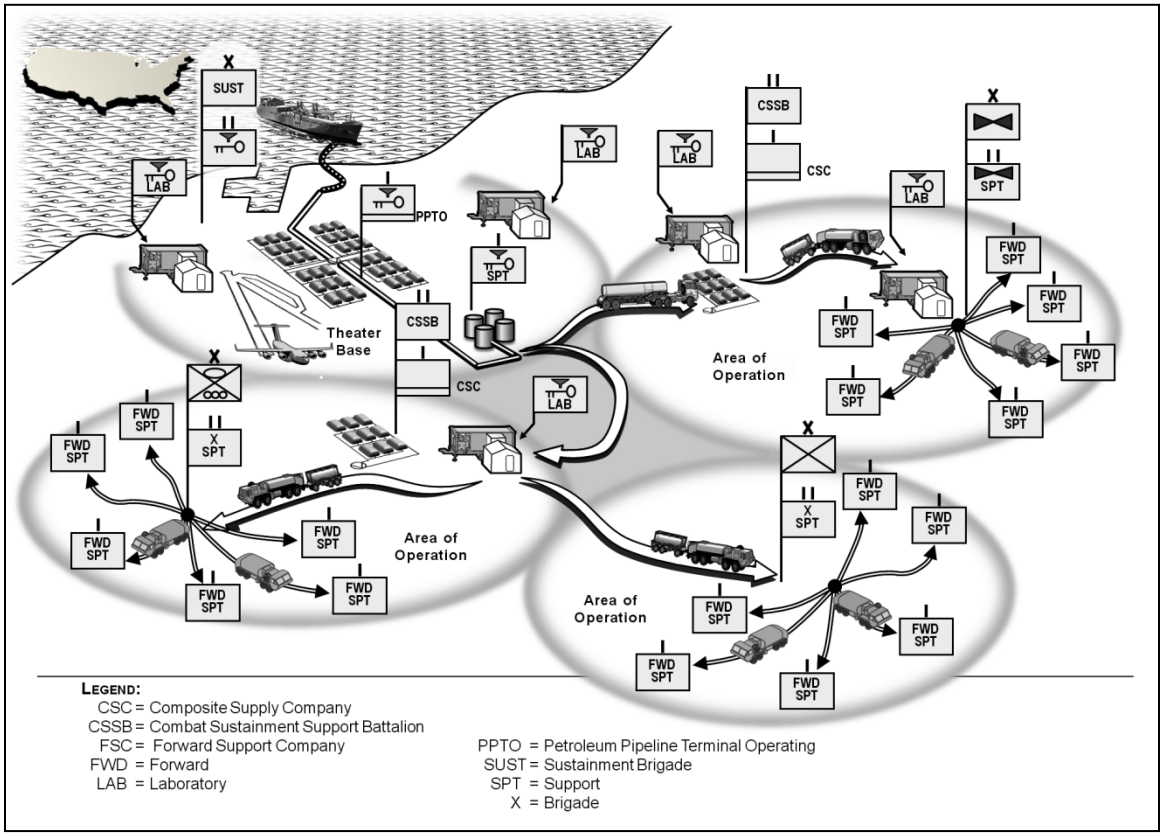

Figure 2-2. Notional quality surveillance testing in the operational area

2-43. The appearance of a petroleum product tells a lot about it. Petroleum specialists visually examine samples for identification, contaminants, and deterioration.

- Color is an indicator for freshness and uniformity, but not necessarily quality. Off color does not always mean that the fuel is off specification; however, it does mean to look for contamination signs.
- The fuel should be clean and bright. Cleanliness and brightness are distinct from fuel color. Clean means without visible sediment, cloud, haze, emulsion, or free water. Bright means having the characteristic sparkle of clean, dry fuel in transmitted light.
- Ordinarily, a cloud or haze in fuel shows the presence of water, but cloudiness can be caused by large amounts of fine sediment.
  - To be visible to the naked eye as specks, sediment particles must be larger than 40 microns.
  - Entrained water may appear as a cloud or haze and it may settle out. Entrained means that there are air bubbles, particles or water in the fuel.
- A quart sample of acceptable aviation fuel should not contain more than 10 fibers. The fibers can be detected visually, but a specific count can be determined only by laboratory testing.

2-44. The presence of water in a fuel is tested with the fuel water detector kit. If a reading is below the maximum allowable amount, the fuel is within the limits prescribed by military specification.

CONTAMINANTS

2-45. Quality surveillance testing and sampling are used to find contamination hazards. Contamination from sediment, water, commingling and microbial growth can occur anywhere in the petroleum supply chain. Laboratory personnel draw samples from each mode of fuel transport and from storage tanks to ensure that the fuel remains clean. Units draw and submit fuel samples to petroleum laboratories to ensure

that the fuel meets specifications for intended use. Contaminated fuel causes damage to all military equipment, but special care must be taken with aircraft fuels. See Table XXX, Contamination tables, MIL-STD-3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products* for specific effects of contamination on aircraft.

WATER

2-46. Free water may appear in the form of a cloud or haze. It may also appear as an emulsion. It may appear in the form of droplet clinging to the side of containers, or in larger quantities on the bottoms of containers. Free water is undesirable because it causes icing, corrosion, and malfunctioning of aircraft accessories. Free water in gasoline, diesel fuel, and turbine fuel can be removed easily by settling and by adequate filter/separators. Dissolved water cannot be detected visually, nor can it be removed by filter/separators. Small quantities of water do not harm the fuel if the water remains a solution. However, it separates readily when the fuel cools to a temperature lower than that at which the water went into the solution. Dissolved water becomes free water when it separates from the fuel.

2-47. Water is one of the most common contaminants. It can get into fuel through leaks and condensation. Dissolved water in fuel is like vaporized moisture in the air. Fresh or salt water may be present in small droplets and produce a cloud effect, in larger droplets that cling to the sides of containers, in very large amounts that settle to the bottom in a separate layer, or in emulsions. Emulsions usually occur when fuel droplets become suspended in water. This may happen when fuel is agitated in the presence of water, as when it passes through a pump. The heavier the fuel, the longer the emulsion may last.

- Free water can be seen in the fuel as a cloud, emulsion, droplets, or in large amounts at the bottom of a tank, sample container, or filter separator.
- Dissolved water is water that has been absorbed by the fuel. It cannot be seen and cannot be separated out of the fuel by filtration. The danger of dissolved water is that it settles out as free water when the fuel is cooled to a temperature lower than that at which the water is dissolved.

SEDIMENTS

2-48. Sediment is classified by particle size. Particulate contamination may be determined using the color method in a field environment. Samples are checked against a color standard to determine if a product is suitable for use. If sediment and/or fibers are detected during a visual inspection obtain a representative sample from the source and perform further laboratory tests as required. The most accurate method of determine particulate contamination is submitting a fuel sample for lab analysis. Sediment from tanks, pipes, hoses, pumps, people, and the air contaminate fuel. The most common sediments are pieces of rust, paint, metal, rubber, dust, and sand.

- Coarse sediment is particles 10 microns in size or larger (25,400 microns equal 1 inch). Particles of coarse sediment clog nozzle screens, other fine screens throughout the fuel system, and most dangerously, the fuel orifices of engines. Particles of this size also become wedged in sliding valve clearances and valve shoulders where they cause excessive wear in the fuel controls and fuel injection equipment.
- Fine sediment is particles smaller than 10 microns in size and is not visible to the naked eye. Fine sediment accumulates in fuel controls and forms a dark, shellac-like surface on the sliding valves. It can also form sludge like material that causes fuel injection equipment to operate sluggishly.

COMMINGLED FUEL

2-49. Mixed fuels or grades of fuels can be as serious as any other form of contamination. Different fuels must be stored in separate tanks and pumped one at a time so that fuels will not mix in lines, filters, separators, pumps, and refuelers. Mixed fuels or grades are hard to detect without testing.

MICROBIOLOGICAL GROWTH

2-50. Microbes grow in fuel containing water. Microbiological growth consists of living organisms that grow at the fuel water interface. These organisms include yeast, fungus and bacteria, all of which can cause

problems associated with microbiological contamination of aviation turbine fuels. Products of microbiological organisms and fungus hold rust and water in suspension and are effective stabilizing agents for fuel/water emulsions. These suspensions cling to glass and metal surfaces and may cause erroneous readings in fuel quantity systems, sluggish fuel control operations and sticking of flow dividers.

Chapter 3

Petroleum Laboratory Operations

Chapter 3 describes day-to-day procedures for petroleum laboratory operations. This chapter provides general information for the contents of laboratory standing operating procedures, customer assistance, safety, supply, storage, and laboratory maintenance.

MANAGE QUALITY SURVEILLANCE OPERATIONS

3-1. All chemicals are potentially dangerous if not handled and stored correctly. AR 710-2, *Supply Policy Below the National Level*, dictates that commanders establish a petroleum quality surveillance program in accordance with the testing standards directed in MIL-STD-3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products*.

3-2. Quality surveillance is integral to class III materiel management during the storage portion of the supply support mission. Laboratory personnel identify sources and types of contamination and deterioration. All petroleum managers responsible for petroleum laboratories must familiarize themselves with laboratory operations because sampling techniques, petroleum equipment inspections, and test results affect Soldiers, vehicles and aircraft. Since the petroleum manager is responsible for providing logistics status reports to units, knowledge of reclamation and disposition of fuel products is essential. The following are areas petroleum managers should be checking in regards to quality surveillance:

- Are products circulated?
- Are fuels handling systems inspected?
- Are filter separator elements inspected and replaced?
- Is sampling referenced in unit standing operating procedure?
- Are samples submitted for testing?
- Is a sample log book maintained by the laboratory?
- Are laboratory reports reviewed and on-hand?
- Are all tests evaluated with specification requirements?
- Are product disposition recommendations in accordance with federal, international and military standards and guidance?
- Is the environment being protected?

STANDING OPERATING PROCEDURES

3-3. Standing operating procedures should be published and updated as necessary to meet changing conditions or to modify existing practices. Standing operating procedures cover responsibilities, policies, product storage, administrative and work controls, protective clothing and equipment, accident reporting, first aid procedures, waste disposal, general lab safety, and housekeeping procedures. The standing operating procedures should be amended as the situation dictates.

3-4. Every petroleum laboratory should have standing operating procedures that spell out the procedures for protecting the health and welfare of laboratory personnel. Standing operating procedures help petroleum laboratory specialists in minimizing exposures to hazardous materials. Petroleum laboratory standing operating procedures should cover the following general safety precautions:

- The amount of chemicals at the lab bench shall be as small as practical, but sufficient to sustain the operation.
- Assume that any chemical mixture is as toxic as its most toxic component.

- Assume that substances of unknown toxicity are toxic.
- Do not fill container with material other than that indicated on the label.
- Procedures for when spills of hazardous chemicals occur:
  - Provide first aid.
  - Notify chain of command of all spills.
  - Evacuate area.
  - Refer to safety data sheets for special precautions or spill cleanup requirements.
  - Remove ignition sources, such as hot plates or Bunsen burners around spilled flammable material.
  - Confine spill to as small an area as practical.
  - Notify fire department as needed.
- Use all laboratory equipment only for its intended purpose.
- Handle glassware with care to minimize breakage. Immediately dispose of broken glassware in a broken glass container.
- Check seals, tags and hoses of firefighting equipment periodically to make sure they are properly serviced and ready for use.
- Inspect all apparatus before operating.
- Dispose of hazardous chemical and material according to the waste disposal plan.
- Avoid skin contact with hazardous chemicals.
- Wash all areas of exposed skin prior to leaving the laboratory.
- Never wear contaminated gloves outside of the laboratory.
- Prohibit eating, drinking, smoking, chewing gum, or application of cosmetics in the laboratory.
- Prohibit storage of food or beverages in storage areas or refrigerators used for laboratory operations.
- Keep the work area clean and uncluttered. Thoroughly clean the work area at the completion of each workday or operation.
- Keep an inspection log documenting eyewash/shower testing and flushing. Post date of inspection on shower and eyewash stations.
- Document fire extinguisher inspection dates and procedures. Post date of inspection on each fire extinguisher.
- Storage tank safety:
  - Before climbing the tank ladder to draw a sample the laboratory technician will be grounded.
  - Use caution when going up or down the ladder, especially with sampling equipment.
  - Stand upwind and face away from the tank hatch when venting prior to drawing a sample.

LABORATORY SAFETY

3-5. All petroleum managers assigned a laboratory are responsible for implementing laboratory safety procedures. Commanders, platoon leaders, and bulk petroleum accountable officers with assigned petroleum laboratories should become proficient at identification of safety and health hazards. Laboratory NCOICs are responsible for promoting safety during day-to-day operations. Petroleum managers responsible for a laboratory should:

- Ensure that standing operating procedures are implemented during laboratory operations.
- Ensure that personnel working with hazardous chemicals receive health and safety training.
- Ensure that laboratory personnel receive first aid training in accordance with medical guidelines and standing operating procedures.
- Ensure that personnel are provided and have received training in the use of protective clothing and equipment.

- Perform daily inspections of laboratory operations to ensure compliance health and safety procedures.

3-6. The right health protection measures allow petroleum laboratory personnel to work with petroleum products with no ill effects. Develop work habits that minimize exposure to chemicals because every quality surveillance test involves its own specific hazards. Laboratory personnel must recognize chemical exposure symptoms and take the precautions necessary to prevent exposure. All personnel should be familiar with safety data sheets to quickly locate toxic levels, first aid measures, and safety dangers.

3-7. Good laboratory housekeeping serves to minimize exposure to petroleum testing hazards. The following housekeeping tasks can either prevent or mitigate exposure to hazardous materials:

- Clean floors and counters throughout the work day.
- Routinely perform chemical hygiene inspections.
- Inspect the eye wash station weekly.
- Never block access to exits, emergency equipment and utility controls.
- Remove waste chemicals and slop fuels from the laboratory as needed, but not less than once a day.
- Follow approved international procedures for prescribed test.

3-8. Since laboratory personnel come into contact with corrosive, flammable, and toxic materials, safety is paramount to an effective operation. Use personal protective equipment during day-to-day testing tasks. Protective equipment includes safety glasses, goggles or face shields to protect the eyes:

- Wear eye protection in the laboratory whenever hazardous chemicals are in use.
- Wear chemical gloves to protect the skin from chemical and physical exposures.
- Wear flame-resistant, knee-length laboratory coats to protect from chemicals that easily soak through normal outerwear.

3-9. Maintain safety data sheets for each fuel, chemical, or hazardous material on hand. Chemical manufacturers, distributors and importers are required to provide safety data sheets describing the dangers of hazardous chemicals. Laboratory personnel need easy access to safety data sheets for all chemicals that are used during day-to-day operations. Each safety data sheet lists:

- The compound properties.
- Stability.
- Health hazards.
- Safe handling precautions.
- Control measures.
- Recommended exposure limits.
- Signs and symptoms associated with exposure to that chemical.

3-10. Be especially careful with mercury. Mercury is a poisonous material that enters the body by ingestion, inhalation, or skin absorption. Mercury has such density, high surface tension, and low viscosity that pouring without splashing and spilling is almost impossible. When mercury is poured, always use a funnel and dispense over spill trays. If a mercury spill occurs, make sure there is adequate ventilation. Do not vacuum or sweep the area as this will disperse mercury throughout the laboratory. Cover the spill with sulfur. Clean up the mercury and sulfur together and discard them in a suitable container.

3-11. Place toxic, flammable or corrosive chemicals in unbreakable containers for moving between rooms or through the laboratory corridors. Use carts designed for uneven surfaces for moving larger quantities of chemicals to avoid tipping over. If the cart has open shelves, the cart should have restraining straps to prevent containers from tipping over or falling off.

CHEMICAL AND PETROLEUM STORAGE

3-12. Secure storage areas when not in use to prevent unauthorized personnel from entering. Keep walkways free from obstruction and clearly mark two or more exits. Due to the volatility of many chemicals, ensure chemicals are stored in accordance with the safety data sheets. Ensure that the storage

area is well lit, with storage maintained at or below eye level. Never use the storage area as a preparation or repackaging area.

3-13. Storage of laboratory chemicals presents an ongoing safety hazard for petroleum laboratory personnel. Many chemicals are incompatible with each other. Common methods of storage, such as by ordering alphabetically, could result in incompatible items stored next to each other. One storage option is to separate chemicals by organic and inorganic families and then further divide into related and compatible categories.

3-14. Proper storage reduces the hazards associated with chemical storage. Store chemicals by hazard class, not alphabetically, and post storage areas to show the exact location of the chemical groups. Labeling of containers is crucial to an effective and efficient laboratory operation as well as for personnel safety. Label each container with the appropriate warnings for its contents to include the date of receipt and projected date of disposal.

3-15. Maintain an inventory spreadsheet of the chemicals stored in the laboratory. The inventory spreadsheet should indicate the date chemicals are received; date of manufacture, batch/lot number, shelf life expiration date, quantity authorized, and quantity on-hand. Designate a storage location for each chemical, and return it to that location after use. Always use chemicals with the oldest shelf-life first.

3-16. Shelving should be level and stable as well as firmly fastened to the floor. Do not exceed shelving weight limits. Do not store large bottles and containers on shelves higher than two feet from the floor. Never allow reagent bottles or containers to extend over the shelf edges. Use spill trays to reduce commingling in the event of spills or leaks.

3-17. Keep shelves clean and remove empty bottles. Overpack and turn-in corroded or leaking containers and outdated or excess chemicals. Overpack refers to adding an extra layer of protection. Promptly dispose of damaged containers as appropriate for the contents.

3-18. Seal containers of toxic, volatile, malodorous, carcinogenic or reactive chemicals to prevent leakage, odors, or reaction with air. Ensure that caps and other closures are tight on hazardous chemicals containers. Periodically inspect storage containers for rust, corrosion and leakage. Vent volatile liquids containers on a time schedule appropriate for the product.

3-19. Store incompatible chemicals such as acids and alkalis separately to prevent mixing in the event of an accidental spill. Limited storage space sometimes prevents such prudent practice of chemical segregation and storage. If space is limited, store incompatible chemicals in the same storage cabinet, but segregate the chemicals according to hazard class and store in tubs, trays, or buckets while in the cabinet. These secondary containers reduce the chance that incompatible chemicals will inadvertently contact each other.

3-20. Segregate water reactive chemicals from other chemicals while in storage. Never store water reactive chemicals with flammable or combustible liquids. These chemicals shall be labeled “CAUTION - WATER REACTIVE CHEMICAL. DO NOT USE WATER TO EXTINGUISH FIRE.”

3-21. Shock sensitive refers to the susceptibility of the chemical to rapidly decompose or explode when struck, vibrated or otherwise agitated. Some chemicals become increasingly shock sensitive with age. Write the date received and date opened on all containers of shock sensitive chemicals. Discard closed containers of shock sensitive materials after one year unless an inhibitor was added by the manufacturer. Discard open containers of shock sensitive materials within six months of opening.

3-22. Segregate toxic chemicals from other chemicals and store in a closed cabinet. The cabinet shall be posted “TOXIC CHEMICAL.” The storage of unopened containers presents no unusual hazards. Store toxic chemicals or other chemical containers that have been compromised in unbreakable secondary containers.

3-23. Always handle gas cylinders with caution. Store gas cylinders in an upright position secured to a wall or a counter with a tank clamp. Ensure that protective caps are kept in place while cylinders are stored between uses. If a gas cylinder is empty, store with the valve open and the cap off and secure an “EMPTY” tag to the top of the cylinder. Always store empty gas cylinders separately from full gas cylinders within a secured outside storage area. Separate cylinders of incompatible gases while in storage.

3-24. Store flammable liquids that require storage at lower temperatures in refrigerators or freezers designed for storage of flammable liquids. Because refrigerators and freezers have no interior space venting, all chemicals should have tightly sealed caps. Apply signage to the doors of chemical refrigerators stating: NO FOOD, BEVERAGE, OR ICE FOR HUMAN CONSUMPTION."

3-25. Wash testing apparatus with solvent, soapy water, cleaning solution, tap water or distilled water and then allow it to drain until it is dry.

3-26. Prepare laboratory glassware with plug valves for storage by cleaning the plugs also referred to as stopcocks.

3-27. Mercury containers must be tightly stoppered at all times.

3-28. Do not exceed the pressure of the temperature designated as the safe upper limit for equipment used in a test or other operation. Do not use equipment for other than the intended purpose.

SUPPLIES

3-29. Request supplies through the unit supply sergeant. Petroleum managers and petroleum laboratory personnel must maintain a stock of testing chemicals and equipment to test a variety of bulk fuels. Petroleum laboratory personnel must know the units they will support in order to stock the correct testing materials. Prior to deployment or as soon as is practical, laboratory personnel should conduct mission analysis on the supported units. All testing equipment should be on hand or on order. All required chemicals and related support equipment should also be on hand or on order.

3-30. Safe quantities of flammable and combustible products must be considered along with the requirement to keep enough chemicals to operate the petroleum laboratory for an extended period in an undeveloped theater. Check information and follow recommendations on safety data sheets for each laboratory chemical to ensure that safety limits are not violated. Flammable and combustible liquids must be shipped and stored in metal containers and in accordance with hazardous materials shipment practices. Firmly attach readable labels clearly showing the appropriate warning (for example, corrosive, poison) to cargo carrying laboratory chemicals.

3-31. Petroleum laboratory managers should carry about 90 days testing supplies for effective 24 hour operations in an undeveloped theater. Storage and transport of 90 days of testing supplies may be challenging because of space and because chemical manufacturers recommend a maximum amount to keep on hand. Do not store quantities above those recommended by safety data sheets. If it is not possible to carry a 90-day supply, prior to deployment learn which supply support activity will be providing the laboratory supplies. If possible, coordinate with the supply support activity prior to deploying to avoid scrambling to purchase testing supplies from non-supply system sources. If the supply support activity knows the laboratory’s supply history it can have required stocks on-hand or in the supply pipeline. The petroleum laboratory may be assigned to an element that also has a multi-class supply support activity. If it is not possible to coordinate with the supply support activity prior to deployment go out and meet them personally soon after arriving in the undeveloped or the developed theater.

3-32. When chemical supplies are received, laboratory specialists should inventory and inspect each container for rust, corrosion, or leakage. If receipted chemical containers are not labeled or damaged take appropriate safety measures for the chemical type. In some instances, such as a direct vendor delivery, laboratory personnel should refuse to accept the shipment.

MAINTENANCE

3-33. Petroleum managers, this includes petroleum accountable officers, platoon leaders and commanders at all levels, with an assigned laboratory must establish command emphasis to ensure laboratory equipment and shelter is maintained to standards. Refer to AR 750–1, *Army Materiel Maintenance Policy* for more information on individual responsibilities for the maintenance of Army materiel. Petroleum laboratory specialists must perform operator level preventive maintenance checks and services using the appropriate equipment technical manual. The petroleum laboratory NCOIC ensures that operator maintenance is being performed by laboratory specialists by spot checking and follow-up inspections of all equipment.

Preventive maintenance checks and services on equipment ensure equipment is functional or identifies any issue with equipment to prevent damage to equipment or personnel. If equipment does not function, troubleshoot according to the technical manual, promptly report deficiencies, malfunctions or failures for evacuation according to the local maintenance guidelines. Petroleum laboratory specialists, as the operators of the laboratory and laboratory equipment, must perform the following preventive maintenance checks and services intervals:

- Before Operation: Perform prior to operating the equipment.
- During Operation: Perform while the equipment is in operation.
- After Operation: Perform after the equipment has been turned off.

3-34. Maintenance of laboratory equipment must be given the highest priority because of the importance of quality surveillance to the petroleum supply support mission. Petroleum laboratories are low density equipment and may not be considered a high priority within the local maintenance program. Petroleum laboratory equipment may also be considered low usage because the equipment typically accumulates less than a specific mileage, kilometers or hours. Under a low usage program the services schedule may be extended. Actively coordinate with the supporting maintenance activity to ensure that the equipment receives services according to the technical manual requirements.

3-35. Accurate quality surveillance test results depend on calibrated equipment. Calibration is the comparison of petroleum testing equipment of unverified accuracy to a measurement system or device of known accuracy to detect and correct any deviations from required specifications. See AR 750-43, *Army Test, Measurement, and Diagnostic Equipment* for more information on calibration. Typically, the supporting maintenance company has a testing, measuring and diagnostic equipment section. This section provides calibration and repair support for its customers:

- A-level calibration is done by sources external to the laboratory. Equipment is taken to maintenance where testing, measuring and diagnostic equipment is used to calibrate according to equipment specifications.
- C-level calibration is operator procedures performed by laboratory personnel. This level of calibration refers to manufacturer recommended operator level calibration procedures.

3-36. A calibration coordinator at the company or battalion level is responsible for the overall calibration program. The petroleum laboratory's supporting maintenance activity shares responsibility for calibration of equipment within its area of operations. However, every petroleum laboratory should have a designated calibration coordinator as the central point of contact for equipment calibration and to coordinate calibration requirements through the company level coordinator. Calibration coordinators maintain a current database of the equipment requiring calibration. Petroleum laboratory personnel assist the company level calibration coordinator by:

- Establishing, updating and/or verifying a calibration schedule for each piece of equipment.
- Identifying external sources for A-level calibration.
- Following local maintenance support's procedures for calibration.
- Identifying test equipment requiring calibration.
- Establishing and enforcing operator level procedures for C-level calibration.
- Identifying safety and environmental considerations for operator calibration procedures.

3-37. Periodically inspect all metal, rubber, or plastic tubing used in operations involving pressure or vacuum, to insure that the tubing has not become faulty. Replace defective tubing.

LABORATORY OPERATIONS

3-38. The purpose of quality surveillance is to ensure that products meet quality standards after acceptance from the refinery and still meet quality standards after transfer between government elements. Each petroleum laboratory should maintain an up-to-date file of government fuel and lubricant specifications. Accurate test results depend upon having the most current specification and testing standards on hand. Every laboratory should have a current library of specifications (military and federal), military standards and other standardization documents. The following references should be on the desktop for easy access:

- AR 710-2, *Supply Policy below the National Level*.

- AR 200-1, *Environmental Protection and Enhancement*
- DA PAM 710-2-1, *Using Unit Supply System (Manual Procedures)*.
- TM 10-6640-264-10, *Operator's Manual for Petroleum Quality Analysis System – Enhanced (PQAS-E)*.
- DOD 4140.25-M, *Management of Bulk Petroleum Products, Natural Gas and Coal Volumes I – IV*.
- MIL-STD-3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products*.

LABORATORY TEMPERATURE AND HUMIDITY

3-39. Testing, results in recommendations for recovering, upgrading, downgrading, or disposing of bulk petroleum. Accurate test results depend on petroleum laboratories maintaining a steady temperature and humidity. The petroleum laboratory should be kept at 73.4º Fahrenheit. Laboratory personnel should monitor the temperature throughout the day to ensure that it does not vary more than plus or minus 3.6º. If the temperature rises above 77.2º or falls below 69.8º it could affect test outcomes, which could cause problems when the fuel is used. Humidity causes condensation in fuel samples, which could contaminate the sample. Laboratory humidity readings should remain at 50. Monitor the laboratory humidity to ensure that it does not rise above 55 or below 45.

SAMPLING

3-40. A sample is a small amount of petroleum product that is representative of the whole tank product. Sampling and testing of petroleum products must be done by trained personnel. Never allow anyone to draw fuel samples unless that individual is thoroughly familiar with and can satisfactorily perform all required sampling. The importance of good sampling techniques cannot be overemphasized. If a sample submitted for testing does not truly represent the sampled product, the value of the test is lost. In order to draw clean and representative samples:

- Make sure all sampling equipment and containers are clean, dry, and free of lint and fibrous material.
- Rinse samplers and containers with a portion of the product being sampled. This is to make sure the product is not contaminated with a previous material.
- Clean samplers immediately after use and store in a clean dry space.
- Before taking a continuous sample, draw enough fuel through the sample connection to displace the entire product in the sample lines and fittings.
- Do not take samples through storage tank cleanout lines, water draw-offs, bleeder valves, or hoses. These samples are not representative of the product in the tank.
- If a tank does not have a manhole or sampling hatch, take the sample from the service hose after discharging a volume of product about two times the capacity of the hose.
- Do not fill any sample container above 80 percent of its capacity. If the container is filled to capacity, it may leak because of thermal expansion of the product.
- Tightly close all sample containers immediately after filled.
- Do not use sealing wax, paraffin, rubber gaskets, pressure-sensitive tape, or similar material to seal containers.
- Put gasoline, jet fuel, and kerosene samples in clean, dry cans or brown bottles to protect them from direct sunlight. Clear glass bottle permit visual examination of the sample. Brown glass bottles protect light sensitive samples.
- Carefully handle all samples of gasoline and jet fuel that require vapor pressure tests. Cool these samples, if possible, to prevent the loss of light ends and volatile materials.
- Maintain all liquid fuel samples between 32 degrees Fahrenheit and 42 degrees Fahrenheit to help preserve product characteristics.

3-41. There are different types of samplers used to obtain liquid petroleum samples. See figure 3-1.

- The weighted beaker sampler is used to draw samples from tank cars, tank trucks, shore tanks, ship tanks and barge tanks. A drop cord or brass-coated chain is connected to the stopper so that

the sampler can be opened anywhere beneath the surface of the product. This sampler is used to take upper, middle, lower, running samples and outlet samples.

- The sample thief also known as a bacon bomb thief is used to take bottom samples from storage tanks, tank cars and drums. When the thief hits the bottom of the storage tank, tank car or drums an assembly opens to draw in the fuel. As the thief is pulled up the opening closes sealing in the sampled fuel. The sample thief can also be used to draw samples from other depths of the storage by using a secondary trip line.
- The weighted bottle plug sampler is used to take samples from tank cars, tank vehicles, barges, tank ships, and shore storage tanks. This sampler is used to retrieve the top, middle, bottom, or all level samples of petroleum products that do not exceed the Reid vapor pressure of 16 per square inch.

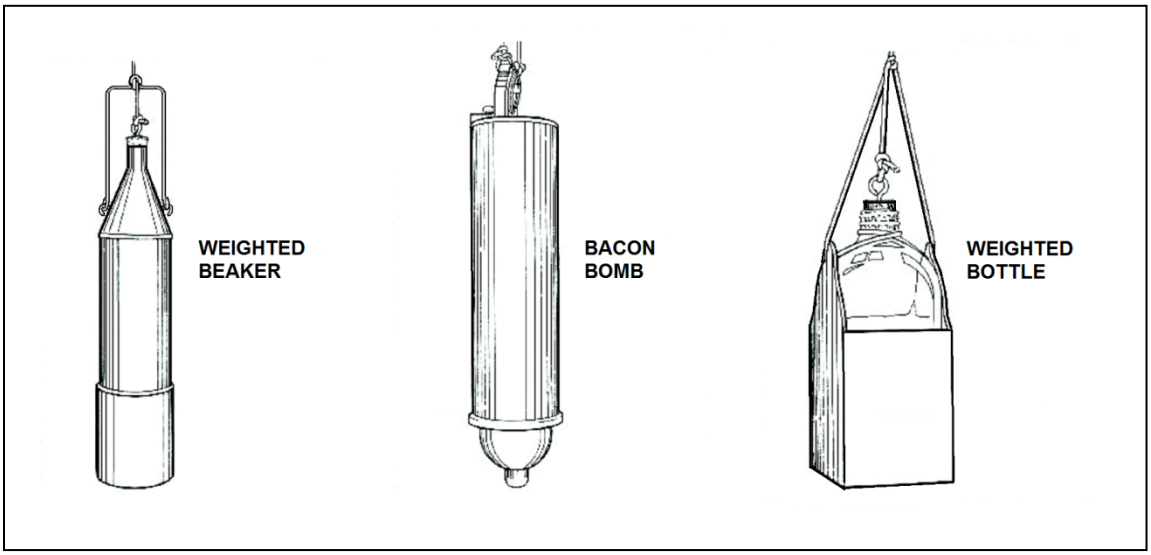

Figure 3-1. Fuel Samplers

3-42. Accurate test results depend on representative samples of the product being tested. Sampling procedures vary by the product, the tank, the carrier or the containers being sampled. Each sampling procedure is suitable for a specific product under definite storage, transportation, and container conditions. Since a sample is used for determining physical and chemical characteristics of a product, the basic principle of each procedure is to take a sample in such a manner and from such a location in the tank or container that the sample will be truly representative of the product.

- A top sample is taken with a bottle or beaker sampler about six inches below the product surface.
- An upper sample is taken with a bottle or beaker sampler from the middle of the top third of the product.
- A middle sample is taken with a bottle or beaker sampler from the middle of the product.
- A lower sample is taken with a bottle or beaker sampler from the middle of the bottom third of the product.
- A bottom sample is taken with a bacon bomb thief sampler from material or product on the bottom of the tank.
- An all-levels sample is taken by submerging a closed bottle or beaker sampler as close as possible to the bottom of a tank or container. The sampler is then opened and raised at a uniform rate so that it is 75 to 85 percent full when it comes out of the liquid.
- A spot sample is taken from a specific place in the tank.
- A composite sample combines individual samples that represent the bulk from which they were taken. The samples can be a single-tank or a multiple-tank composite sample.
- A single-tank composite sample is a blend of the upper, middle, and lower samples of the contents of a tank. The blend has equal parts of the three samples from a tank with uniform cross

sections. An upright cylindrical tank has uniform cross sections. The blend from a horizontal cylindrical tank consists of proportions of the three samples.

- A multiple-tank composite sample is a blend of single, all-levels samples taken from tanker or barge compartments that contain the same product. The sample consists of parts in proportion to the volume of product in each compartment sampled.
- An outlet sample is taken with a bottle or beaker sampler at the level of a tank outlet, whether fixed or swing line.
- A drain sample is taken from the draw-off or discharge valve.
- A continuous sample is one taken from a pipeline when the product is allowed to collect slowly in a sampler during the entire flow time. It represents the stream of product during the period of sampling.

RECEIVING

3-43. Establish a control point for processing supported unit samples. The laboratory technician receiving the samples will ensure that supported unit sample tags contain all pertinent information for each sample. Laboratory specialists receiving samples from supported units will determine the priority for testing each sample and annotate the sample log book with the priority along with the other required information.

3-44. The variety of customers may require varied responses from the petroleum laboratory. Petroleum managers must consider such factors as the mission command capability of supported units; accountability of the petroleum stock; fuel quality; the locations of units and class III facilities; the capabilities of the class III facilities and the transportation net in the area of operations; area transportation resources; the effects of weather on the transportation net and on petroleum products; safety; communications requirements; and the tactical situation.

3-45. Supported units should be submitting samples with sample tags correctly filled out and affixed to the container. Comprehensive information about each sample is crucial for accurate quality surveillance. Laboratory technicians must transfer all sample information to a laboratory sample log book.

3-46. No testing should ever occur without a correctly filled out sample tag. In the interest of customer support, the laboratory should be prepared to assist the supported unit in completing the sample tags rather than sending the customer away. Sometimes, even when the tags are correctly filled out, it may be necessary to ask for additional information about the history of the fuel, the storage facility or the equipment.

3-47. Laboratory personnel will inspect the sample to insure the container is free of dents, rust leaks, or over filling and it is of the proper size. Sample size varies with product type and the type of test required. Sample sizes are important for accurate test results. Instruct supported units on sample size to avoid having to reject samples that are not large enough to conduct the test requested. Test sample sizes depend upon the fuel being tested.

- Diesel samples require a minimum of one quart.
- Filter effectiveness samples require a minimum of one gallon, or matched weight monitor.
- Gasoline samples require a minimum of one gallon.
- Unknown fuels require a minimum of two gallons.
- Matched weight monitors require one gallon.
- C-series testing requires a sample of size of two gallons.

SAMPLES RECORDS KEEPING

3-48. Maintain a record of samples submitted by supported units. Normally, laboratory personnel should not allow the submitting unit to leave the area until the sample information has been added to the laboratory sample log book. During the receipt of customer unit submitted samples assign a priority to each sample. Assign the series of tests required for each sample and enter that series in the log book. Enter the following information in the laboratory log book for each sample:

- Laboratory number.

- Product.
- Submitting unit.
- Contact information (Unit, point of contact name, unit address/location, phone number)
- Sample number (example, 14-001, 14-002).
- Priority for testing.
- Source of sample (example, tank, tanker, railcar).
- Type of sample (example, all-level).
- Quantity sample represents.
- Sampler's name.
- Date sampled.
- Date submitted to laboratory.
- Test results and disposition.

3-49. Keep the sample in the laboratory until all testing has been completed. Maintain correlation samples until the correlation process is complete and test results have been received. Physically separate different products or grades of the same product. Segregate petroleum products determined to be off-specification until test results verify fuel is suitable for use.

3-50. Accurate records keeping makes it easier to submit any required daily, weekly, or monthly work reports that reflect the number of tests, number of samples, and the tests performed on the samples. Work reports provide valuable information for petroleum supply planning.

Chapter 4

Deployment and Redeployment

Chapter 4 describes deployment and redeployment considerations. This chapter provides high level information on the petroleum supply chain planning process. Chapter 4 describes operational level information for establishing a petroleum laboratory site in its designated area. It also provides troop leading considerations as it relates to the petroleum laboratory.

PLANNING

4-1. Theater combatant commanders develop strategy to organize the theater. Theater logistics planners develop the theater distribution plan based on the commander's operation plan, concept plan, functional plan, and operation orders. Distribution planning is the basis for the design, construction, and operation of the theater petroleum distribution system.

4-2. The Joint Petroleum Office considers mission, fuel requirements, fuel quality surveillance, infrastructure, equipment, supported units, interoperability of fuel transfer systems, sustainability and survivability, theater-specific factors, and the threat environment to plan bulk petroleum operations.

4-3. The Army develops its operations plans for specific missions and identifies units needed to fulfill the mission. Execution of supply support operations is then carried out at the tactical level by sustainment brigades, combat sustainment support battalions, aviation support battalions and brigade support battalions. The senior petroleum unit commander is responsible for all aspects of theater-level petroleum operations. Subordinate petroleum managers move, set-up, and operate fuel distribution systems to receive, blend, store, issue, and distribute bulk fuel.

ESTABLISH PETROLEUM LABORATORY

4-1. The operational site of the petroleum unit will depend upon the theater distribution plan for petroleum. Operational-level petroleum units will set up petroleum supply support for receiving, storing, and moving fuels to the class III supply points. The petroleum unit coordinates with the transportation assets and with the theater distribution planners.

4-2. Mobile petroleum laboratory personnel must adapt to changing locations. It is important to note that every deployment is different and every site is different. When deployed, the petroleum laboratory will test fuel samples for supported units from either a developed or an undeveloped location. A developed location will have an infrastructure (roads, buildings) and undeveloped location will lack that infrastructure.

UNDEVELOPED THEATER

4-3. Consider safety, security and natural terrain while planning the petroleum laboratory field layout. If possible, send a laboratory representative with the advance party to conduct a site survey and assess the potential of the selected space to establish the petroleum laboratory. Identify hazards that can result in injury, illness, or death of personnel. A hazard can lead to damage, loss, or destruction of equipment and other assets. Hazards can also result in degradation of capabilities or mission failure. Hazards can be associated with enemy activity, accident potential, weather or environmental conditions, health, sanitation, and equipment. Hazards exist in combat operations, stability operations, base support operations, training, garrison activities, and off-duty activities. Consider hazard impacts on mission and non-mission related aspects of the petroleum laboratory.

4-4. The Army uses specialized mobile equipment for testing fuel stock received through normal supply channels, locally procured from commercial sources, and captured from enemy sources. The Petroleum Quality Analysis System-Enhanced is a lightweight transportable system that provides the capability to quickly and easily perform quality surveillance testing of military bulk fuels on the battlefield. The Petroleum Quality Analysis System-Enhanced performs B-2 level testing with the exception of existent gum and copper corrosion. The Petroleum Quality Analysis System-Enhanced shelter, see figure 4-1, can be transported by rail, ship, air, and road while either vehicle-mounted or dismounted. During deployments, laboratory personnel can begin testing samples within 120 minutes of arrival at its assigned location and

can redeploy after 60 minutes of completing sample testing.

Figure 4-1. Petroleum Quality Analysis System - Enhanced

4-5. If a site survey is not possible, conduct a map reconnaissance of the selected site. Once on the site, use the map during the terrain analysis and use the information gained to communicate relevant information to higher command. If the site will be used for an extended period of time, it may be necessary to coordinate with engineers to assist with terrain analysis. Seldom will logistics base locations contain the ideal mixture of desired characteristics. Site selection tasks include assessment of:

- The suitability of the terrain:
  - Avoid sloped ground.
  - Select firm, well-drained terrain, free of surface rocks and large stones.
  - Avoid site that is adjacent to low areas where vapors can collect.
  - Avoid being uphill or upstream from other facilities.
- The site should be located near existing road systems capable of carrying the traffic involved.

DEVELOPED THEATER

4-6. The terrain of the theater affects the mobility of laboratories. Base laboratories are not normally moved once established in the theater. When falling in on an established class III supply point in a mature and developed theater the first priority is to review available information about supported units. If necessary, compile a list of supported units by type in order to gain a clear picture of the petroleum laboratory's customers. Go out and meet supported units whenever possible because face-to-face contact promotes customer service by establishing relationships. Always do a wall-to-wall inventory of petroleum laboratory chemicals and supplies with the departing petroleum laboratory personnel. Ask questions about scheduled reporting times and types for this petroleum laboratory. It is of utmost importance that work schedules are maintained during the transition.

4-7. In a well-developed, mature theater base laboratories may be established and may be staffed with contractors. As the theater begins to mature, the petroleum laboratory personnel may be tasked to identify specific support requirements or to determine which services may be performed by contractors. If it is determined that the petroleum laboratory will be staffed with contractors, then the requiring class III supply point will work with the contracting support brigade to develop requirements. The contracting support brigade provides contract advice, assistance and contract management. Prior to deploying, the commander needs to nominate technically proficient personnel to perform duties as contracting officer representatives.

REDEPLOYMENT

4-8. A petroleum laboratory may be required to relocate from one position to another within the theater in order to support the maneuver commander's logistics requirements or redeploy to its home station. When the order is received to redeploy, the petroleum laboratory initiates redeployment activities. Actions taken will depend on where the petroleum laboratory is redeploying.

4-9. To meet contingency support requirements, units develop movement plans and standing operating procedures. An effective movement plan contains sufficient detail to prepare the unit to execute deployments while the standing operating procedures outlines functions that should occur upon notification of a unit movement. Maintain deployment binders containing:

- Unit movement plan.
- Unit movement standing operating procedures.
- Appointment orders.
- Training certificates.
- Recall rosters.
- Copies of load cards and container packing lists.
- Special handling permits.
- Blocking, bracing, packing, crating, and tie-down requirements.

4-10. The deployment binder also serves as a continuity bridge from one NCOIC to the next. The petroleum laboratory standing operating procedures should cover pre-movement checks, pre-movement inspections, who to report to, and who executes which tasks. Standing operating procedures should address standard locations, location of mission essential equipment, and vehicle load plans. Local procedures should address all roles and responsibilities for the deployment. During training exercises the petroleum laboratory should review, rehearse, revise and validate standing operating procedures so that every Soldier understands the deployment process.

4-11. Having the movement plans and standing operating procedures is not enough. Rehearse the plan and track the plan's results during the execution of the plan. Every Soldier should know their part of every mission. Every leader should practice troop leading procedures. Rehearsal, pre-combat checks and pre-combat inspections cannot be emphasized enough. Rehearsals ensure greater success in the redeployment. Develop a key task list for the petroleum laboratory and ensure that all Soldiers are trained on the key task list. During training exercises and rehearsals ask questions about commander's intent and end state. Learning to ask these questions during rehearsals ensure that the petroleum laboratory will be stood up and ready when the commander needs it during a real world mission. Petroleum laboratories should rehearse the basics and add specifics to the rehearsals as details emerge. Each petroleum laboratory is responsible for developing specific battle-oriented pre-movement checks focused on specific petroleum laboratory requirements. As a minimum, each Soldier should understand the nature of the operation:

- Who is participating?
- Time of the operation.
- Assigned tasks.
- The route should be briefed to all drivers.
- Call signs, password, number combinations.
- Location of objective.
- Individual's job and job of immediate leader.
- Location of leaders.

- Location of other friendly units (situational awareness).

4-12. Conduct pre-combat inspections to determine full preparation for tactical operations. Pre-combat inspections are conducted in the assembly area prior to movements. Pre-combat checks and inspections are integral to every mission. The platoon leader designates the time for pre-combat inspections as part of the platoon operations order.

4-13. Load planning is a critical part of deployment planning. Leaders prepare a detailed loading plan and ensure that all petroleum laboratory personnel are familiar with the plan. The load plan details the storage locations by container or bumper number. Petroleum laboratories must maximize vehicle and container load capacities. The packing list will change from mission to mission, but the majority of the items on the list are necessary for the completion of every mission. Prior to the move perform a 100% inventory because laboratory personnel must know what is being moved and where every item is packed. When the petroleum laboratory arrives at its destination, it should perform a 100% inventory to ensure that nothing was lost in transit.

Chapter 5

Petroleum Products

Chapter 5 provides information about various petroleum products. The purpose of this chapter is to present a broad overview of packaged and bulk petroleum products used by the Army, but not necessarily tested by petroleum laboratories.

FUEL

5-1. Fuel can be solid, liquid or gaseous. Since Army petroleum laboratories test only liquid petroleum this chapter will not address solid or gaseous products. Petroleum fuel is a complex hydrocarbon refined from crude oil. Hydrocarbons are organic substances consisting of carbon and hydrogen. Distillation of crude oil separates the various hydrocarbons into groups of similar hydrocarbons known as fractions or cuts. The percentage of each cut, per barrel, varies according to the geographic origin of the crude oil.

5-2. After the initial separation process into fractions or cuts, there are additional refining processes necessary to produce finished petroleum products. The fuels used by the military are refined to specific characteristics for the type of equipment engine. Military fuel specifications require additives. An additive is a product added to another product to change the second product's characteristics. Additives are packaged products used to convert commercial petroleum products for military use. Fuel additives and purpose for use of each are listed below:

- Viscosity improver prevents oil from becoming too thin.
- Pour-point depressant prevents oil from getting too thick at low temperatures.
- Inhibitors prevent corrosion and rust, oxidation, and foaming.
- Fuel system icing inhibitors prevents the water in fuel from freezing.
- Detergents prevent particles in the system from clotting together and forming clumps.
- Static dissipater is an additive that reduces the electrical charge of fuel.

5-3. Fuels can be primary, which is the natural state or can be secondary also referred to as artificial. Petroleum is the primary state for liquid fuel. Diesel, gasoline, kerosene, coal tar, liquefied petroleum gas, naptha, and ethanol products distilled from petroleum are the secondary or artificial form. Petroleum-base liquid propellants and fuels include automotive gasoline, aviation gasoline, jet or turbine fuels, and diesel fuel. These propellants and fuels are described below:

- Automotive gasoline is a translucent, straw-colored or light yellow liquid with a strong aromatic odor. Automotive gasoline is procured in regular, midgrade and premium grades. Gasoline grades are determined by the octane rating.
- Gasohol is classified as an alternative fuel source because it is gasoline with 10 percent, by volume, ethanol. It is procured in the same grades as commercial gasoline.
- Aviation gasoline is similar to unleaded automotive gasoline, but has a higher octane. Grades of aviation gasoline are decided by lead concentration. Aviation gasoline color ranges from colorless to red, green, purple, and blue. Aviation gasoline is used for internal-combustion engines in aircrafts.
- Jet fuel required for jet aircraft engines are obtained from special kerosene and gasoline fractions of crude oil. Jet propulsion (JP) comes in several different types. Typically, the military uses JP, type 5 (JP5) and JP, type 8 (JP8) or F 24. These jet propulsion fuels are referred to JP5 and JP8 by commercial sources as well. The military also uses commercial grade Jet A and Jet A-1 aviation jet fuels. JP8 is used in aircraft turbines and the majority of ground equipment throughout the Army making it the single fuel in the battlefield. F 24 is a NATO fuel product identification code referring to jet fuel utilized in the continental United States.

- Jet A is commercial grade jet fuel available in the continental United States, while Jet A-1 is used outside the continental United States.
- JP5 was originally developed for aircraft carrier planes because a safer fuel was needed for on-board storage. JP5 is a high flash point low vapor kerosene jet fuel. JP5 contains diethylene glycol monomethyl ether, a fuel system icing inhibitor.
- JP8 is complex combination of hydrocarbons including naphthenes, paraffins, and aromatics. JP8 is a pale yellow to water-white liquid with characteristic petroleum distillate odor. Similar to Jet A with the exception that it contains static dissipater additive, fuel system icing inhibitor, and corrosion inhibitor.
- F 24 consists of commercial Jet A fuel with three additives: fuel system icing inhibitor, static dissipater additive, and corrosion inhibitor/lubricity improver.

- Diesel fuel is a petroleum-based fuel that is used to power many types of vehicles and boats. It is made of a blend of crude oil components called hydrocarbons. Diesel fuel is graded according to its use. There are various categories of diesel fuel available: winter and summer grade, low and ultra-low sulfur, and marine diesel.
- Biodiesel is classified as an alternative fuel source because it is plant-based oil. Biodiesel burns cleaner that diesel. Biodiesel can be mixed with diesel and used in diesel engines.

FUEL OILS

5-4. Fuel oils are liquid petroleum products used to generate heat and power. These liquid fuels have several advantages over solid fuels. These advantages are:

- Greater heating value on a weight or volume basis so that less storage is required.
- More efficient combustion and an almost complete absence of ash.
- Greater ease of handling and firing.

5-5. Military burner fuels are procured under military specification for use in steam-powered vessels. Specifications for these fuels are not exacting, but compatibility is sometimes of concern because some burner fuels are stable when stored separately, but may not be stable in combination.

5-6. Commercial burner fuels are procured for general heating purposes. These fuels differ in viscosity, gravity and some require preheating before combustion can take place.

LUBRICATING OILS

5-7. Many lubricating oils are produced from the light and heavy lubricant fractions of crude oil. Some are made from steam or vacuum distillates, some from residual stock, and some from blends of distillates and residuals. The nature of these oils varies from spindle oils, which are only a little more viscous than kerosene, to highly viscous and heat-resistant aircraft engine oils.

5-8. Lubricating oils provide a film that permits surfaces to glide over each other with less friction. Oils are also used to clean, seal, and cool the equipment. The selection of the correct lubricating oil for a given application depends upon the design of the equipment and the conditions under which the equipment is to be operated.

5-9. Refining removes most of the undesirable components such as wax, asphalt and oxidizable impurities. After, refining, stocks are blended and compounded with fatty materials, as necessary to achieve desired results. Additives delay oxidation and the formation of acids and suppress crystallization of wax. This blending process also lowers the pour point, promotes oiliness, strengthens the lubricating film, reduces foaming, improves the viscosity index, and supplies a detergent and dispersant quality to the lubricant. Increased use of synthetic base oils will lessen the demand for petroleum base lubricants.

LUBRICATING GREASES

5-10. Grease is used in bearings, which because of their nature, are unable to retain oil. Grease is also used in inaccessible bearings where the grease is applied by grease cups. Under dirty, atmospheric conditions,

the use of grease is advisable as it seals the ends of bearings and thus prevents dust and dirt from entering the bearings.

5-11. Some of the large volume greases used by the Army include industrial, general-purpose grease, automotive and artillery grease; and ball and roller bearing grease. Essential properties include appearance, penetration, stability, corrosion, resistance to aqueous solutions, dropping point, fuel resistance, odor, free acidity, oxidation, and oil separation. Greases are classified according to amount of soap base or thickener. Soaps used are derived from fatty animal or vegetables oils such as tallow or cottonseed. General classes of grease are as follows:

- Calcium base greases containing low viscosity oils are cup greases. Those containing slightly more viscous oils are pressure gun greases. These are used in relatively slow moving bearings. The greases are water resistant, but they do not retain consistency well at high temperatures.
- Sodium base greases, containing the more viscous oils, will hold up in situations where high temperatures can be expected. Sodium base greases are water soluble. These greases are used in gears and in faster moving bearings.
- Lithium base greases are water resistant and possess low temperature characteristics. Lithium base greases are more costly than calcium and sodium base greases and are limited to low volume applications.
- Aluminum base greases combine the characteristics of calcium and sodium base greases and are water resistant and retain consistency at moderate temperatures. Aluminum base greases are used for gears, for reciprocating parts, and for lubrication of equipment.
- Barium base greases are water resistant and can be used at high temperatures.
- Mixed base greases are used where calcium or sodium base greases cannot be used. Mixed base greases are used on high-speed, anti-friction bearings under wet conditions.

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Chapter 6

Introduction to Chemistry

Chapter 6 offers a brief introduction to chemistry as it relates to petroleum. The purpose of this chapter is to provide a broad overview of chemistry. While petroleum laboratory specialists may not always need an in-depth background it is important that chemistry is understood at a rudimentary level because testing products are essentially chemical in nature.

CHEMISTRY

6-1. Chemistry deals with the composition and properties of substances or matter, of which everything is composed. In the petroleum laboratory, the laboratory technician will be responsible to identify chemical substances and estimate quantities present in their examination of fuel samples.

MATTER

6-2. Matter is anything that has mass and occupies space. The smallest unit or component of matter is an atom. There are over 100 different kinds of atoms in the world and all matter is made from one or more of these atoms. Matter can be broken down into its components, in addition to classifying it by its current state it can also be classified according to its composition or components.

- Matter classified by state exists as a solid, having a definite shape and volume. It may exist as a liquid, having a definite volume but no definite shape. It may exist as a gas, having no definite shape or volume. It may also exist as plasma, which is a gas that is energized usually by heat; it too has no definite shape or volume. The state in which matter exists depends on the prevailing temperature and pressure conditions.
- Matter classified according to its composition will fall into the following categories:
  - An element is matter that contains only one type of atom. Therefore, each kind of atom is called an element. Gold is an element since it is only made of gold atoms. The names of each of these known elements have been abbreviated with an approved symbol.
  - A compound is matter that is made up of two or more elements that are chemically combined in a very definite proportion. Compounds can be broken apart. The abbreviation for a compound is called a formula. The formula shows the proportion in which the elements are combined in the compound. Rust is a compound. It is made from the elements iron and oxygen.
- A mixture is matter that consists of either two or more elements or compounds (or both) blended together in any proportion. Unlike a compound, it usually absorbs all the properties of the ingredients that went into it. The constituents of a mixture can be separated and recovered by physical or mechanical methods. This is in contrast to compounds, whose constituents must be separated by a chemical process. The following are some types of mixtures:
  - In a homogeneous mixture the composition and properties are the same.
  - In a heterogeneous mixture the various components are visible.
  - An emulsion is a mixture of very small droplets of a liquid in another liquid.
  - A suspension contains very small, solid particles dispersed within a liquid which does not dissolve them. The solid particles tend to settle upon standing.
  - In a solution, the dispersed particles are single atoms, molecules, or ions and are too small to be seen with even high magnification.

QUANTITY OF MATTER

6-3. The following paragraphs contain the name, chemical symbol, atomic number and relative atomic mass of substances that are found in the periodic table of elements. Laboratory personnel use the metric system to measure matter. Also, there are unique terms that chemists and laboratory personnel use to describe matter discussed in the following paragraphs.

- The mole is a term used to describe a quantity of matter. The symbol for mole is mol.
- The atomic mass (weight) of an element represents the mass of an atom in atomic mass units and the weight, in grams, of one mole of atoms of an element.
- The equivalent weight is the weight of a substance, in grams, that would react with or displace one gram of hydrogen ions in a compound. The equivalent weight of a substance is found by dividing its molecular or formula weight by the total number of electrons its metallic component has lost in forming the compound (its total positive valence). For example, the equivalent weight of magnesium chloride (MgCl2) is found by dividing its formula weight, 95 grams by 2, since the magnesium atoms have each lost two electrons in forming the ionic bonds with chlorine. The equivalent weight of MgCl2 is 47.5 grams.
- Molar volume is a term associated with the measurement of gases. Gas volume varies with temperature and pressure. The molar volume of a gas is the volume occupied by one mole of its molecules under certain stated pressure and temperature conditions. For example, one mole of ideal gas will occupy a volume of 22.4 liters in a closed container at a temperature of 0º Celsius (273º kelvin) and a pressure of one atmosphere (760 millimeters of mercury).

6-4. The molecular or formula weight of a compound is the weight, in grams, of one mole of molecules of the compound. It is found by adding the atomic weights of all the constituent elements. For example, to determine the formula weight of magnesium chloride, (MgCl2), do the following:

- Step 1. Refer to the periodic table of elements, for the atomic weight of magnesium. It is 24. There is one mole of these ions in one mole of MgCl2.
- Step 2. Refer to the periodic table of elements for the atomic weight of chlorine. It is 35.5. MgCl2 contains two moles of chlorine ions, so the atomic weight must be doubled.
- Step 3. To the weight of one mole of magnesium ions (24 grams), add the weight of two moles of chloride ions (71 grams) to arrive at the weight of one mole of MgCl2 (95 grams).

REAGENTS AND SOLUTIONS

6-5. The use of solutions is important in the daily analytical work performed in the petroleum laboratory. The laboratory technician must prepare solutions in very accurately measured concentrations.

6-6. A chemical equation is used to represent the changes that occur when chemicals react or combine to form new compounds. An equation gives the qualitative nature of a reaction (what compounds or elements combine and what compounds are produced) and also describes the quantitative nature of a reaction (how much of each reactant is needed and how much of the products will be formed.) An equation shows the formulas of the starting materials and products, the proportions in which the starting material combine, and the proportions in which the products are formed. An equation is shorthand for a reaction. Although it does not tell everything, it is extremely useful for the solution of many chemicals.

6-7. A reagent is a chemical substance that is used for analyses because of its known reaction with other chemical substances. Such analyses are performed through observations of the effect of reagents on unknown substances. A qualitative analysis can identify an unknown when certain results are produced by a certain reagent. A quantitative analysis can then determine the amount of the substance present gravimetrically (by weighing) or volumetrically (by measuring volume).

6-8. A solution is a homogeneous mixture of two or more substances in which the mixed substances' particles are molecular in size and are uniformly distributed. The dissolved particles cannot be seen, do not settle out upon standing, and are easily removed by filtration. In the petroleum laboratory, the primary concern is in creating solutions in three ways. These three types of solutions involve dissolving gas in a liquid, dissolving solid in a liquid, and dissolving liquid in a liquid. Common terms used in the preparation of solutions are defined below.

- A solvent is the substance that does the dissolving.
- A solute is the substance that is dissolved or dispersed among the solvent particles.
- Solubility is a description of the degree to which a substance will dissolve in a particular solvent.

6-9. Petroleum laboratory specialists must create solutions for many of the chemical tests that they do. It is important that they understand the factors that affect solubility, so they perform their job efficiently. The solubility of a solute and solvent depends on the following factors:

- The nature of the substances mixed is very significant. In general, the rule "dissolves like" is true. This means that if the molecular structure of the solute and solvent particles is similar, they will probably exhibit an appreciable degree of solubility. For example, an aromatic compound is generally more soluble in benzene (another aromatic compound) than in water or ethanol.
- Temperature is another important consideration. The solubility of a solid solute in a liquid solvent generally increases when the temperature of the solvent is increased. However, the solubility of a gas in a liquid decreases with increased temperature.
- Pressure is significant only in a gas-liquid type of solution. The solubility of a gas increases when the pressure increases.
- The speed with which a solid solute may be dissolved in a liquid solvent is increased by granulating or powdering the solid and by agitating or stirring the mixture.

6-10. The concentration of a solution is a quantitative expression of the amount of solute that is dissolved in a certain amount of solvent. Technicians choose the particular expression for concentration depending on their intended use for the solution.

- Normality neutralizes acids and bases. A one normal solution contains one gram-equivalent weight of the solute per liter (1,000 milliliter) of solution. Normality equals the number of equivalent weights of solute divided by the liters of solution.
- Percent by weigh describes grams of solute per 100 grams of solution. The percent by weight equals weight of solute multiplied by 100% and divided by the weight of the solution
- Percent by volume describes the volume of solute per 100 volume units of solution. The percent by volume equals the volume of the solute multiplied by 100% and divided by the volume of solution.

6-11. Calculations dealing with neutralization of acids and bases generally use normality. Acid/base neutralization chemical reactions are important in petroleum laboratory work, and are described later. For now, it is important to know that using the concept of normality makes it easy to determine the progress of these reactions, and to determine how much acid and base is needed to complete the reaction. Solutions of the same normality contain the same number of equivalent weight per unit volume. Equal volumes of solutions of equal normality are equivalent. Therefore, 10 milliliters of one normal is not oxygen hydrogen (KOH), a base would neutralize 10 milliliters of any one normal acid solution, whether the acid is hydrogen chloride (HC1) or sulfuric acid (H2SO4).

6-12. A primary standard is a known substance, with properties that make it useful, as a reference in standardization. The properties of a primary standard should include a high equivalent weight, usually greater than 50. It should be chemically stable and should not absorb atmospheric moisture readily. It should react completely when neutralized. Primary standards are also rather weak acids and bases, which makes them safer to handle than secondary standards. Common primary standards are discussed below.

- Potassium hydrogen phosphorus (KHP). This primary standard is used to standardize bases because it is acidic. It has an equivalent weight equal to its molecular weight. Titration of KHP requires the use of phenolphthalein indicator. Other primary standards that can be used to standardize bases are: oxalic acid (H2C2O4), oxalic acid dehydrate (H2C2O4.2H2O), benzoic acid (C6H5COOH), and sulfamic acid (NH2SO3H).

6-13. Although secondary standards (substances commonly found in laboratories) can function just as well as a primary standard, they are called secondary standards because of certain characteristics that make them less desirable than primary standards. Foremost among these is the fact that the substances typically used as secondary standards are strong acids and bases, making them extremely hazardous to handle. They also have low equivalent weight which means relatively high concentrations must be used to neutralize

substances. The secondary standard should be of about the same normality as the solution to be standardized. Some examples are discussed below.

- Most strong acids, such as HC1 and H2SO4, can be used satisfactorily as secondary standards.
- The strong bases usually used as secondary standards are KOH and sodium hydroxide (NaOH).

6-14. Standardization is the process of obtaining a standard solution. A standard solution is one whose concentration is known to the fourth decimal place. In general, standard solutions are either acidic or basic. An acidic solution is standardized with a base and a basic solution is standardized with an acid. When a solution is standardized, comparison is made of volumes of solution of known and unknown concentration which will undergo neutralization.

6-15. Titration is the process of determining the volume of reagent solution required to react with a solution of another substance. Titration measures the volumes of the unknown and standard solutions. Since the concentration of the standard is unknown, the concentration of the unknown may be calculated by applying these fundamental relationships.

PH SCALE

6-16. The potential of hydrogen (pH) scale measures whether a solution is acidic or basic. The scale has a range from one to fourteen, with seven being neutral. Acids have a pH of 1-6.999; bases have a pH of 7.001-14; and neutral is 7.000. When acids and bases are mixed together, the pH is altered. When an acid and base is mixed in equal proportions based on their normality, they will combine to become a salt based liquid or neutral substance. Characteristics of acids and bases are stated below.

- Acid characteristics include: turn blue litmus paper red, and have a pH of less than 7.00.
- Base characteristics include: turn red litmus paper blue, and have a pH greater than 7.00.

INDICATORS

6-17. Indicators are dyes that change color or shade of color when the pH (degree of acidity or alkalinity) of a solution changes. Therefore, they can be used to indicate the concentration of hydrogen ions in solutions of acids and bases. They are also used in volumetric analysis to mark the end point of titration. Indicators used in the petroleum laboratory are as follows:

- Methyl Orange. This indicator has a pH range of 3.1 (red) to 4.4 (yellow-orange). It is also used in the presence of carbonate radicals (anything containing the CO3 atom group such as TL2CO3). The solution is made by dissolving 0.1 grams in 100 milliliters of distilled water. The end point is an orange-brown.
- Methyl Purple. This indicator has a pH range of 4.8 (purple) to 5.4 (green). The change from purple to green is fast and is preceded by a change from purple to light gray. This indicator is also used in the lamp sulfur test and is prepared according to the test method.
- Paranitrophenol. This indicator has a pH range of 5.0 (colorless) to 7.0 (yellow-green). It is also used only when called for in ASTM test procedures. The solution is made by dissolving 0.5 grams of p-nitro phenol in 100 milliliters of distilled water and filtering when necessary. The end point is pale yellow.
- Phenolphthalein. This indicator has a pH range of 8.0 (colorless) to 9.8 (red). It is also used in the absence of carbonate radicals. The solution is made by dissolving 1.0 grams in milliliters of 90 percent ethyl alcohol. The end point is faint black.
- P-Naphtholbenzein. This indicator has a pH range of 8.2 (amber) to 10.5 (blue). It will go from amber to olive green to clear green to bluish green to blue. This indicator is also used in the neutralization number test and is prepared according to the test method.

BALANCES AND WEIGHING

6-18. Weighing is a necessary part of preparing solutions and is used in many tests in the laboratory. The petroleum laboratory has several types of balances for specific reasons.

6-19. The analytical balance is used for precision weighing (0.0001 gram) of small quantities. Features include: easy-to-read display, separate sealed keys and automatic calibration.

6-20. The Harvard trip balance, is a precision balance used for weighing substances in the petroleum laboratory. It should be used on a reasonably flat and level surface. In this setting a very near balance should be attained with the beam and the tare poises all the way to the left.

- When the balance is not in use, be sure to remove the load from the weighing pan and to replace the rubber washers to lift the pivots off the bearings. Avoid storing the balance in a place where vibrations will be transmitted to it. Keep the balance clean at all times, being particularly careful not to let dirt accumulate in the vicinity of the bearings. Never lubricate the scale bearings. The bearings in these balances are high grade polished agate V-blocks and the knife edges are hardened, precision-ground steel. This type of bearing works best when clean and dry. Should the bearings become dirty, attempt to clean by blowing out with air blast. If this is unsuccessful, the bearing covers will have to be removed. In replacing the bearing covers, it is necessary that the hardened blue steel friction plate is replaced in the recess provided.
- From time to time, it is necessary to clean accumulated debris from the magnet faces. This is best done by inserting a piece of adhesive tape into the magnet slot and pressing it against the magnet face. This will pick up attracted material and prevent it from interfering with movement of the damper vane.

6-21. The triple beam balance is used when precise weighing is not required. For instance, it would be used when determining the approximate weight of tubes to be centrifuged.

- Keep the balance clean at all times; do not let dirt accumulate in the vicinity of the bearings. Do not apply oil or any lubricant to the knives or bearings. Blowing the bearings out with a dry air blast is a very effective way of cleaning them and it is recommended that this be done periodically to maintain the utmost of sensitivity in the balance.
- From time to time, it is necessary to clean accumulated debris from the magnet face. This is best done by inserting a piece of adhesive tape into the magnet slot and pressing it against the magnet face. This will pick up attracted material and prevent it from interfering with movement of the damper vane.
- When transporting the balance, take care that it does not receive any sharp blows and is not subjected to unnecessary rough treatment. When the balance is not in use, be sure to remove the pad from the weighing pan.

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Glossary

SECTION I – ACRONYMS AND ABBREVIATIONS

API	American Petroleum Institute
AR	Army regulation
DA	Department of the Army
DA PAM	Department of the Army Pamphlet
DOD	Department of Defense
DLA-Energy	Defense Logistics Agency-Energy
JP5	jet propulsion – type 5
JP8	jet propulsion – type 8
MIL-STD	military standard
NCOIC	noncommissioned officer in charge
pH	potential of hydrogen
POL	petroleum, oils, and lubricants
TM	technical manual

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Index

A

all-levels sample, 3-9

Army-owned petroleum product, 1-1

B

bacon bomb thief, 3-8

beaker sampler, 3-8

bottom sample, 3-9

C

capitalized, 1-1

calibration, 3-6

coarse sediment, 2-9

common sediments, 2-9

composite sample, 3-9

continuous sample, 3-9

contractor-owned, contractor-operated, 1-2

D

dissolved water, 2-9

DLA-Energy owned petroleum product, 1-1

drain sample, 3-9

F

fine sediment, 2-9

free water, 2-9

fuel storage, 1-2

G

general safety precautions, 3-1

government-owned, contractor-operated facility, 1-2

government-owned, government-operated, 1-1

H

hazardous material, 1-4

humidity, 3-7

L

logistics status reporting, 1-2

lower sample, 3-9

M

middle sample, 3-9

multiple-tank composite sample, 3-9

N

non-capitalized, 1-1

O

outlet sample, 3-9

P

personal protective equipment, 3-3

Petroleum Laboratory Certification Program, 1-3

Petroleum Quality Surveillance and Technical Assistance Program, 1-2

Petroleum Technical Assistance Program, 1-3

petroleum, oils, and lubricants, 1-1

Q

quality assurance program, 2-1

quality assurance representative, 2-1

Quality Surveillance Program, 1-3

S

Safety Data Sheet, 3-3

single-tank composite sample, 3-9

spot sample, 3-9

T

temperature, 3-7

top sample, 3-8

U

upper sample, 3-8

W

weighted bottle plug sampler, 3-8

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