DEPARTMENT OF DEFENSE PROJECT MANAGER MOBILE ELECTRIC POWER:

A CASE STUDY IN STANDARDIZATION

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EXECUTIVE SUMMARY

Electricity is essential for modern civilization. Civilization depends on electricity for communication, food preservation, manufacturing, entertainment, and various other functions necessary for modern civilizations to exist. Electricity is also essential for national defense. The Department of Defense (DoD) has designated the production of electricity on the battlefield as mission essential.

During the Vietnam Conflict, over 2000 different makes and models of generator sets were deployed. The logistics support for all of these configurations was extremely costly and the configurations became impossible to support. The Department of Defense decided to standardize all mobile electric power sources into a single DoD standard family. The DoD Project Manager – Mobile Electric Power (PM-MEP) was created to achieve this standardization and manage the acquisition and distribution of this standard family for all of DoD. This paper is a case study about why standardization is important and how standardization of electric power sources on the battlefield is being accomplished.

WHY STANDARDIZE?

> "You will not find it difficult to prove that battles, campaigns, and even wars have been won or lost primarily because of logistics."
>
> General Dwight D. Eisenhower

A military force has three major functions: shoot, move, and communicate. Warfare materiel is designed to accomplish these functions. Great military commanders throughout history realize that a military force must have basic provisions such as food, water, and shelter, along with the warfare materiel necessary to successfully engage the enemy. Logistics is the branch of the military operations that deals with the procurement, distribution, maintenance, and replacement of these basic supplies and warfare materiel.[1] To be effective, the logistics system must ensure the correct provisions are provided to the correct location at the correct time in order for the warfighter to accomplish the mission. Support personnel traveling with the maneuvering army typically carry these provisions. The number of support personnel limits the maneuverability, flexibility, and effectiveness of the maneuvering army. History has shown the effectiveness of a military campaign is linked to how well the logistics system is strategically used and managed in order to support the campaign.

Alexander the Great was considered one of history's greatest logisticians. His 35,000 man army could carry no more than a 10 day supply of food when far from sea transport. However, he was able to march his troops thousands of miles at a rate of 19.5 miles a day without any problems. He accomplished this by eliminating unnecessary servants, wagons, and spouses from the marching army. He developed alliances with locals to provide magazines of provisions. He also marched along rivers to provide easy access to sea transport, where tons of supplies could be delivered versus carried with them.[2] Essentially, Alexander the Great used logistics management to reduce his support personnel allowing his army to become more maneuverable and effective in battle.

As technology improved, weapons grew more complex and the logistic needs increased. With the invention of gunpowder, the weapons of choice became rifles, pistols, and cannons. In order to use these weapons, they must be mobile and logistically supportable by safely carrying the gunpowder, and projectiles. This logistics support was even more complicated due to the fact that different manufacturers built weapons of different projectile calibers. For example, if there are five different caliber rifles, the logistics support system would need to provide each rifle with the proper caliber projectile. Therefore, five different caliber projectiles would need to be procured and distributed. Each warfighter needs to have the correct projectile to match his rifle. To get the right projectile to the matching rifle, the logistics system must not only procure, store and ship each of the five projectiles, but also track the location of the warfighter with the matching weapon. As the military forces increase in size, tracking the weapons becomes more difficult. Hence, providing the correct ammunition and projectiles to the correct personnel was difficult at best.

During the Revolutionary War, weapons were a major concern. All weapons were acquired from local private contractors and foreign governments. Many were the militias' personal weapons. The wide variety of weapons greatly complicated the problems of maintenance and supply.[3] George Washington's great concern over the standardization of rifles for the Continental army spurred development of a national armory.[4]   Along with these standardization concerns, in 1794 President Washington was disturbed by the inadequate performance and corruption of the contract system to provide weapons for the Army Department. Therefore, he proposed and the Congress passed a bill to create up to four public arsenals and magazines to manufacture and supply arms to the Army Department. The bill authorized the President to decide on the locations and to select (and dismiss) the armory superintendents. A Government owned site at Springfield, Massachusetts, was selected for the first National Armory shortly after the bill was passed.[5]

Since the eighteenth century, U.S. military officers wanted increased uniformity in the manufacture of weapons and ammunition. Their goal was to simplify logistics and to make repairs of firearms in the field more feasible.[6] Honoré le Blanc was a French inventor who worked out a system for making gun parts to a standardized pattern. So if a part broke, it could be replaced immediately by another part that would fit the gun exactly. Thomas Jefferson, who was then the ambassador of the United States to France, knew about le Blanc's work and the possibility of interchangeable parts for arms manufacture. Jefferson quickly forwarded this discovery to the armories in the United States. In this way, the principles of interchangeable parts began to be used in manufacturing guns in the United States. The National Armory at Springfield, Massachusetts played the largest role in the development of interchangeable parts and mass production. At this armory, from 1794 to 1815, weapons manufacturing was transformed from a craft-based system into a factory product.[7]

Standardization and interchangeability have been promoted by the military to reduce the logistics burden since these concepts were developed. With the advent of the sewing machine, the clothing industry was changed. It was discovered that uniforms and shoes needed during the Civil War, could be made in a few basic sizes that would fit most men. This standardization made quantity production simpler and pushed ahead the ready-made clothing industry after the war.[8] During World War I, with the advent of trucks, the need for standardization became evident when support and maintenance were required. Maintenance requirements and parts support on these trucks were larger than any materiel up to that time. As technology further increased to allow warfighters to fly, maintenance requirements for aircraft surpassed the requirements for trucks. Every new weapons system, communications system, and support system adds to the logistics burden of the armed forces.

Standardization of the items above has greatly reduced the number of parts procured, stored, and delivered to the military. Interchangeability has allowed standardization goals to be fulfilled. The results of the standardization policies have improved operational capabilities by reducing the overall logistics burden to the military and reduced support costs through the economy of scale where discounts are usually given for higher order quantities.

STANDARDIZATION OF MOBILE ELECTRIC POWER SOURCES

Electricity has changed the modern world. The use of electricity changed the way people preserve food, illuminate the darkness, control indoor environments, communicate, disseminate information, move from one place to another, etc. Electricity also changed the way the military wages war. Numerous weapon and support systems depend on electricity to operate. These systems vary from weapons systems such as: antiaircraft missile and communication systems to support systems such as: water purification, food storage, and cooking systems. With the addition of new equipment on the battlefield, such as magnetic resonance imaging (MRI) systems used in the mobile field hospitals, the electrical needs of the DoD have greatly increased. Numerous other military systems require electricity to the point where modern warfare could not be accomplished without electricity.

The need for electricity on the battlefield became evident during World War II. The number of uses was limited, but as weapon systems such as mobile radar stations became necessary, the need for electricity increased. The DoD procured various generator sets from private vendors to meet various needs. Throughout the Korean conflict and into the Vietnam conflict the need for electricity on the battlefield increased exponentially. Numerous generator set models were procured in very large quantities to meet the electrical needs on the battlefield.

During the Vietnam conflict, the military fielded over 2000 different makes and models of generator sets. As with other materiel, these generator sets required maintenance to maintain operational availability. Each make and model required their own consumables such as fuels, oils, coolants, and filters, along with spare parts such as switches, wire, radiators, valves, etc. The wide variety of makes and models of the generator sets expanded the logistics burden to the point where the generator sets became unsupportable. The correct spare parts could not be delivered to the correct location at the correct time. The variety of makes and models prevented interoperability between adjacent units. Providing electric power on the battlefield became difficult at best.[9] The principles of standardization and interchangeable parts were not applied in the procurement of these generator sets.

The DoD recognized the need for power on the battlefield and the problems with producing power on the battlefield experienced in Vietnam. In 1967, the DoD established a Multi-Service Working Group to identify solutions to this intolerable situation. After a thorough study, the Working Group recognized how the principles of standardization and interchangeability solved logistics problems in the past and recommended that the DoD establish a standard family of military generator sets for use by all DoD component services. As a result, the DoD created DoD Directive 4120.11, SUBJECT: "Standardization of Mobile Electric Power (MEP) Generating Sources". This directive established the position of DoD Project Manager for Mobile Electric Power (PM-MEP) to establish and manage a DoD standard family of mobile electric power sources.[10]

The legal authority for DoD Directive 4120.11 started in 1947, when there were over 25 different supply systems throughout the DoD services. The National Security Act of 1947 prompted new efforts to eliminate duplication of supply systems. The Act created the Munitions Board, which began to reorganize these major supply categories into joint procurement agencies. Congress became disenchanted with the Munitions Board and passed the Defense Cataloging and Standardization Act of 1952.[11] The Defense Cataloging and Standardization Act, Public Law 82-436, as codified by United States Code, Title 10, Chapter 145 Cataloging and Standardization, sections 2451 and 2452, required the Secretary of Defense to develop a single catalog system and related program of standardizing supplies for the Department of Defense. As authorized by this act, DoD Directive 4120.11, "Standardization of Mobile Electric Power (MEP) Generating Sources" was created.

DoD policy, as defined by DoD Directive 4120.11, is to establish, maintain, and provide a DoD standard family of MEP generating sources for maximum use by the DoD Components. The DoD directive also requires the establishment of common military operational requirements, design and development, procurement, logistic support, and operational use. These operational requirements are established through the planning and coordinating of the DoD development, engineering, and product improvement efforts. One of the goals of the directive is to reduce the diversification of MEP generating sources entering the DoD supply system, thus minimizing logistic support without compromising mission accomplishment of the DoD Components. Another goal of the directive is to standardize, to the maximum extent practicable, the electrical output characteristics of the MEP generating sources, consistent with military systems and equipment needs under Mil-Hdbk 633[12].

Since the US Army had the greatest requirement for electric power, DoD Directive 4120.11 assigned the DoD PM-MEP to the Army for implementation. Part of their responsibility includes the coordination among the other DoD Components.

PROJECT MANAGER – MOBILE ELECTRIC POWER

DoD Directive 4120.11 established the position of DoD Project Manager – Mobile Electric Power (PM-MEP). This Directive assigns PM-MEP the responsibility for the overall management of MEP generating sources. This responsibility includes: providing all technical and acquisition management of MEP generating sources; providing direction and control for MEP generating sources in the areas of engineering, acquisition, technical publications, standardization, and configuration management; and assisting in the guidance and coordination for MEP generating sources in the areas of supply management, training and maintenance management. PM-MEP is also responsible for the planning and coordination of the total DoD development, engineering, and product improvement efforts on MEP generating sources. The Directive also requires PM-MEP to maintain current military standardization documents Mil-Std 1332 "Definitions of Tactical, Prime, Precise, and Utility for Classification of the DoD Mobile Electric Power Engine Generator Set Family", and Mil-Std 633 "Mobile Electric Power Engine Generator Standard Family Characteristics Data Sheet", on standardized MEP generating sources and characteristics[13]. During the Acquisition Reform of the Clinton administration, Mil-Std 633 was mistakenly converted to a non-contractually binding Mil-Hdbk 633. Steps are currently being taken to convert it back to Mil-Std 633.

APPROACH TO STANDARDIZATION

DoD PM-MEP's approach to accomplish standardization was to: develop a standard for power quality, Mil-Std 1332; develop operational and performance requirements; produce a performance specification from the requirements; procure hardware; evaluate the hardware against the specification; and field the approved hardware. The approved hardware becomes the DoD Standard Family of MEP sources as defined in Mil-Std 633.

In order to ensure standardization through various procurements and spare parts support, technical data packages (TDPs) would be created to describe the approved hardware. TDPs are made up of drawings and specifications that allow any competent manufacturer to build the hardware. Contractors would be required to provide end items that meet the requirements of the TDPs. To ensure replacement parts from multiple vendors would be form, fit, and functionally identical, the principle of 100% interchangeability would be implemented in the development of the TDPs. Tolerances would be adjusted so that parts built by company A would mate properly with parts built by company B as long as both companies meet the requirements of the drawings.

A spiral type development process would be used to incorporate new requirements and technologies into the hardware. Through a configuration management process, drawing and requirement changes, due to performance requirements, field issues, obsolescence of parts, etc., would be evaluated and incorporated into the TDPs. For incorporation of major technical advances, the PM-MEP would essentially start over with the development of a new requirements document that would allow the development of new hardware.

IMPLEMENTATION

The first major task the Project Manager – Mobile Electric Power undertook was to standardize the fleet. DoD PM-MEP employees surveyed the generator fleet procured during the Vietnam Conflict to determine performance and asset densities. From this information, 69 generator set models were selected to define the standard fleet.[14] Mil-Std 633 “Mobile Electric Power Engine Generator Standard Family Characteristics Data Sheet” (see example in appendix) was created to describe these sets and define the DoD standard fleet.

From these 69 sets, PM-MEP developed Mil-Std 1332, “Definitions of Tactical, Prime, Precise, and Utility for Classification of the DOD Mobile Electric Power Engine Generator Set Family”. Mil-Std 1332 standardizes the power quality that is expected from the DoD standard family. Power quality is defined in terms such as voltage and frequency transient response. Transient response will affect the equipment powered by the generator sets and may cause the equipment to fail. An example of a problem with transient response is when the lights dim when an air conditioner turns on. Mil-Std 1332 is essential for the system designers of the electronics, communication, and computer equipment, so the designers can understand the characteristics of their electrical supply. This Standard is the basis for the specifications used to procure the DoD Standard family of MEP sources.

Once Mil-Std 1332 was approved by all DoD Component Services, PM-MEP established a program in the late 1960s/early 1970s to create a DoD standard MEP sources family, commonly referred to as Military Standard program, based on these performance requirements. A purchase description was created and coordinated with the other services to ensure each service's needs were met. Hardware was developed, tested, and with agreement between all services, the first DoD Standard Family of MEP generating sets was created. The Military Standard generator sets were the first family that was built from performance requirements. This procedure was repeated in the late 1980s/early 1990s to create a more modern fleet with improved performance. This second generation standard family is called the Tactical Quiet Generator (TQG) sets. PM-MEP is currently working on the third generation family called Advanced Medium Mobile Power Sources (AMMPS).

REQUIREMENTS

Operational requirements originate in the US Army Training and Doctrine Command (TRADOC). TRADOC personnel poll the various Army users to determine their electrical requirements. This process results in a requirements document. The requirements document describes the many aspects of the program such as threats, supportability, needs, and basic operational requirements. This document has been called many names such as a Required Operational Capability (ROC) or an Operational Requirements Document (ORD). Currently this document is divided into three documents: the Initial Capabilities Document (ICD), the Capability Development Document (CDD), and the Capability Production Document (CPD)[15]. The requirements document for the current PM-MEP program is the Tactical Electric Power

(TEP) ORD, CARDS# 16125, approved by the Army on 18 August 2004. The TEP ORD was submitted to and approved by the Joint Requirements Oversight Council (JROC) for DoD concurrence. This paper will focus on the requirements in the TEP ORD since it is the most current.

The TEP ORD has four Key Performance Parameters (KPP) and twenty-five non-Key Performance Parameters. Designation of KPP is only a programmatic designation for parameters that are vital (important) enough that if these parameters are not met, the program will have to be re-evaluated. In the end, all twenty-nine parameters from the TEP ORD, along with many other performance requirements, are included as requirements in the performance specification. The primary requirement is the electrical performance as derived from Mil-Std 1332. All other requirements define the operational conditions, transportability, logistics support, reliability, compatibility, and interfaces with other equipment. Specific specifications and standards are required to meet the various requirements in the TEP ORD. Some examples of these requirements are provided in the following paragraphs.

Operational requirements documents describe the environment where the generator set is expected to operate. The TEP ORD requires the generator sets to "operate at rated load in tropical, temperate, arid and cold climates and in the additional environmental elements according to AR 70-38." Army Regulation (AR) 70-38 defines the climate zones for all Army materiel. For instance, AR-38 defines "basic" climatic condition as an environment where temperatures range from -25°F to 120°F. Another climatic condition, "cold", is defined as an environment where temperatures range from -50°F to -25°F. So the TEP ORD requires the generator set to be capable of meeting rated load requirements of Mil-Std 1332 at all temperatures ranging from -50°F to 120°F.

Since the generator sets are deployed with the military, they need to be transportable to anyplace in the world. The TEP ORD requires the generator sets to be capable of being moved on various modes of transportation. In the performance parameters section, the sets are required to be mounted on trailers and towed by various prime movers. Since these configurations will be towed on the highway, military trailers are used. These military trailers are already in the inventory and meet Department of Transportation regulations. The TEP ORD also requires the generator sets to be transported both internally by fixed wing aircraft and externally by rotary wing aircraft. Both Mil-Std 913, which defines the requirements for external air transport, and Mil-Std 209, which defines the requirements for lifting and tiedown provisions, are required to meet these air transportability requirements.

Along with air transport, there is a military specific air delivery system called a Low Velocity Air Drop (LVAD). LVAD is used when the aircraft cannot land where the generator set needs to be. So to delivery it, the generator set is pulled out of the back of an aircraft by a parachute. Then a second parachute, along with the proper packaging, allows the set to safely land on the ground. The requirements to accomplish the LVAD are described in Mil-Std 814, "Requirements For Tiedown, Suspension, and Extraction Provisions On Military Materiel For Airdrop".

The final set of requirements for transportability center around commercial shipping. Some of the generator sets will be shipped in International Organization for Standardization (ISO) containers, while others will be shipped on flatbed trucks. Mil-Std 209 also dictates the tiedown requirements to accomplish this shipping. A more harsh commercial shipping method is by rail. Along with Mil-Std 209 tiedowns provisions, tiedown methods must be developed according to the American Association of Railroads standards - General Rules Governing the Loading of DoD

Material on Open Top Car. The Military Transportation Management Command (MTMC) reviews all transportability requirements, final design, and test results in order to receive transportability approval. Without approval from MTMC, the generator sets cannot be fielded.

Another important requirement of the TEP ORD is the Electromagnetic Interference (EMI) requirement. The TEP ORD requires "Any EMI radiated by TEP systems should not adversely affect other systems and TEP systems shall not be susceptible to EMI." The requirements are described in Mil-Std 461, "Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference". With all of the electronics, communications equipment, computers, etc. on the battlefield, the generator sets must be capable of operating in an EMI environment. The objective of Mil-Std 461 is to ensure all materiel can operate properly together without affecting other materiel in the EMI environment of the battlefield. The military does not want the generator set to shutdown when someone operates a radio nor do they want the generator to produce interference on the radio.

As a North Atlantic Treaty Organization (NATO) member, the US Military has NATO Standardization Agreement (STANDAG) obligations. The key NATO obligation is STANAG 4135, "Electrical Characteristics Of Rotating Alternating Current Generating Sets". The members of NATO, including the PM-MEP office and TRADOC, negotiated this standard through meetings of the Electrical Power Working Group. The purpose of the Standard is to ensure the generator sets procured and fielded by individual NATO members can be used by all other NATO members. Some of the requirements that enable this usage by all NATO members are: the requirements in Mil-Std-1332; the ability to operate at both 60 and 50 Hz; and the ability to adjust the voltage to encompass both US and European standard voltages. Other subtle requirements include a NATO standard slave receptacle to enable the generator set to interface with any NATO vehicle in order to “jump start” the generator set when the batteries are low.

Since the generator sets are a made up of commercial components, the performance specifications also use commercial specifications and standards. The generator is required to meet National Electrical Manufacturers Associate (NEMA) codes: MG1 “Definite Purpose Synchronous Generators for Generating Set Applications”; and MG2-2001 “Safety Standard and Guide for Selection, Installation, and Use of Electric Motors and Generators”. The generator sets are required to meet Underwriters Laboratory (UL) requirements of UL-94HF-1 “Tests for Flammability of Plastic Materials for parts in Devices and Appliances”, UL-1053-1999 “Ground-Fault Sensing and Relaying Equipment”, and UL-1950 “Safety of Information Technology Equipment”. And of course, the generator sets must meet the National Fire Protection Association (NFPA) NFPA 70, the “National Electric Code”.

As discussed above, standardization is paramount in reducing the logistics burden. The TEP ORD recognizes this fact and sets the goals and logistics requirements. The following is an excerpt directly from the TEP ORD:

> “The TEP program goal is to minimize life cycle costs using ILS (Integrated Logistics Support) principles in Army Regulation 700-127. These ILS principles address standard fuels, readily available test, measurement and diagnostic equipment (TMDE), either commercial or in the military inventory; minimal special tools and minimal spare assemblies or modules. TEP systems will be maintained using standard tools and test equipment with minimal new special tools and TMDE. TEP systems must attain a fully mission capable (FMC) readiness status while being maintained by standard tools and test equipment. The system component and major item standardization must limit or eliminate special tools, support equipment, and spare assemblies.”

These principles and requirements are elaborated in the performance specification for the AMMPS program, where the control system of 10 generator set models will be in common, along with other components to the greatest extent possible. The principle of 100% interchangeability of components was also added to the performance specification.

QUALITY ASSURANCE

Once the contracts are awarded and the hardware is built, the Government must ensure the hardware meets the performance requirements. PM-MEP accomplishes this through various methods that include supplier's declarations, inspections, and testing. When a manufacturer has produced items that are ready to be presented to the Government, a team of engineers performs what is usually called a First Article Examination. This team is made up of different engineering fields such as safety, human factors, mechanical, and electrical. The team reviews the hardware against the First Article Examination checklist. This checklist addresses the elements that can be evaluated by examination such as size, wiring locations, proper operational instrumentation, safety, human factors, and basic maintenance actions. The team also examines suppliers' declarations for components to ensure proper requirements prior to testing, such as the horsepower of the engine. This examination allows the hardware to proceed into the testing phase of quality assurance.

The contractor, the Government, or a combination of both performs the testing. The US Army has an independent Operational Evaluation Command (OEC) whose personnel perform both technical testing and operational testing. OEC provides an evaluation report as to the suitability of the hardware for military use.

The performance specification calls out the test methods to be used to ensure the hardware meets the performance requirements. Most of the test methods are from Mil-Std 705, "Generator Sets, Engine-Driven, Methods of Tests and Instructions". These tests have been standardized to enable anyone to perform test methods on the same item and get comparable results. The standardized testing prevents manufacturers from falsely “meeting” requirements by changing the test method. There are other Military Standards that also describe test methods. Mil-Std 810, “Environmental Test Methods & Engineering Guidelines”, is used to ensure the generator sets will operate in the environments required such as High and Low temperatures, or high altitude operation. Along with the requirements for electromagnetic interference, Mil-Std 461 provides test methods required to ensure compliance. Other military standards, such as Mil-Std 209 and Mil-Std 913 also have their own test methods to ensure compliance.

Once the Government has approved the design, and production release has been given to the contractor, various individual and samples tests are conducted on the items as they come off of the production line. Some of these test methods are the same ones used during First Article testing. Others are modified to reduce test time and cost without losing quality assurance. Defense Contract Management Agency (DCMA) personnel are located on-site to ensure the tests are performed properly and the generators sets comply with the terms of the contract.

ACCOMPLISHMENTS

The DoD Project Manager – Mobile Electric Power has been working to meet the DoD standardization of MEP sources goal. The initial attempt at a standardized fleet reduced the generator set configurations from over 2000 down to a standardized 69 configurations. With this reduction in configurations, the logistics support required was reduced immensely. Assume one generator set configuration has approximately 700 components. Approximately 10 to 20 of those components are replaced on a regular basis during preventive maintenance, checks and services (PMCS), while the majority of components are replaced when they fail. Stockage of the PMCS components is vital on the battlefield. With 2000 different models and 20 regularly replaced components per model, the logistics system must procure, stock, and deliver approximately

40,000 different components to the battlefield. By reducing the configurations down to 69, the required components are down to 1380. This is a huge reduction of the logistics burden just by limiting the configurations on the battlefield. When you consider the total number of the set components, the reduction of the logistics burden is even greater.

When PM-MEP decided to write a performance specification for the first generation Military Standard generator sets in order to replace the original configurations, the reduction of configurations and the standardization of parts was a big part of the specification. The required configurations went from 69 to 37 with the new specification. Common parts such as voltmeters, current meters, switches, indicators, filters, terminal lugs, and hardware, were required to be used to the greatest extent possible. Also, considerations were made to use the skid mounted configurations on trailers to create the trailer mounted configurations. This commonalty again reduced the logistics burden where the same filter or switch is used on numerous sets. For example, using the 700 parts assumption discussed above and three different configurations, a total of 2100 parts are needed to the support the sets. Through the application of standardization of parts principle, you might be able to have 10 % common parts. From the example, the logistics burden could be reduced from 2100 down to 1890 parts.

In the late 1980s, when the second generation DoD Standard Family, commonly known as Tactical Quiet Generator program was implemented, the number of configurations was reduced to 16 configurations. The standardization of parts was again encouraged, prompting the contractor to select various engines of the same family. This meant common engine parts were used across the TQG family, which further reduced the logistics burden. During a re-engine program for the 30 and 60 kW TQG sizes, a requirement for common control systems with plug and play components was implemented. The result was a control system that could be used on four different configurations. Also numerous individual relays and control components were consolidated into five plug and play modules, which mounted into a common backplane.

The TQG set family made significant improvements in logistics supportability over the Military Standard generator set family. The TQGs reduced the Scheduled Maintenance requirements by 26%[16]. This reduction means 26% less coolant, oil, filters, belts, etc., needs to be supplied to the battlefield. The fuel consumption was decreased by 16%, so less fuel is needed to operate the sets. The TQGs also implemented the single fuel forward policy of the DoD in accordance with DoD Directive 4140.25. All TQGs will operate on JP-8 or Commercial Diesel fuels. The weight of the TQGs was reduced by 19%, therefore reducing transportability issues and costs. Reliability was increased by 50%, which reduces the need for replacement parts delivered to the battlefield. Each of these improvements contributes to the overall reduction of the logistics burden and reduction of the life cycle cost.

The third generation, AMMPS, which is currently in development, extended the standardization of parts by requiring all 5 through 60 kW configurations to use the same control system. The result of this standardization has not been realized at this point in the program. As the program transitions from the Research and Development phase to the Production phase, the impacts of this standardization will be evaluated.

Complete standardization of the DoD MEP source fleet will never be totally realized. Programmatic factors such as time and cost will hamper the effort. To reach complete standardization would mean that every generator set of each configuration would be of the same design. The level of funding needed to accomplish this task is never provided. Hence the fleet is fielded over multiple contracts based on funding provided in each defense budget. Each contract will introduce changes to the configuration due to new requirements, obsolescence of parts and the introduction of new technologies. Unless the funding levels change, the standardized fleet will always contain different designs for each configuration and the DoD PM-MEP will always be required to manage the fleet.

CONCLUSION

Throughout history, professional soldiers understood the importance of logistics and how managing logistics can win wars. History has proven how the reduction of the logistics burden improves the maneuverability of a fighting force. Standardization of configurations and parts is key to reducing the size logistics burden. The industrial revolution and the concept of interchangeable parts enabled parts standardization. The interchangeable parts concept allowed manufacturers to produce standard parts that could be used to repair equipment in the field. These parts replaced the craftsman who manufactured the parts on an individual basis. These parts could be carried along with the maneuvering army instead of the craftsman and the support necessary for their survival.

The US military started implementing standardization of weapons with the National Arsenals in the 18th century and continued through all items such as uniforms and trucks. Electricity changed the way war is conducted. Today's military requires electricity on the battlefield in order to operate the communications, air defense systems, environmental control, etc. The need for standardization of electric power sources on the battlefield became evident during the Vietnam Conflict where the generator sets became logistically unsupportable. The DoD decided to create a standardized DoD fleet of MEP sources and create the Project Manager – Mobile Electric Power to manage the DoD Fleet of MEP sources.

PM-MEP developed the DoD Standard MEP sources fleet as defined in Mil-Std 633. This fleet has been modified and improved throughout the years. It has been modernized with three major programs: Military Standard, Tactical Quiet Generators, and Tactical Electric Power. However, due to funding restraints, complete standardization will never be realized. There will always be multiple designs of the same configuration due to overlap between the programs. Through standardization, the primary goal of reducing the logistics burden has been accomplished and further reduction will continue through the work of the personnel in the DoD PM-MEP office.

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[16] Cross, James B., COL, "Army Mobile Electric Power", PM-MEP Presentation, Jan 19, 1994

APPENDIX

Excerpt from Mil-Hdbk 633

CHARACTERISTICS DATA SHEET
5 kW Tactical Quiet Generator

Nomenclature	Gen Set, 5 kW, DED, 60 Hz	Gen Set, 5kW, DED, 400 Hz
Model Number	MEP-802A	MEP-812A
NSN	6115-01-274-7387	6115-01-274-7391
LIN	G11966	G12102
SSN	M535	M518
Specification	MIL-DTL-53133/1	MIL-DTL-53133/2
Wet Weight	888 lb.	911 lb.
Fuel consumption	.57 gal/hour	.56 gal/hour
Trailer mounted configurations	PU-797; PU-797A; AN/MJQ-35; AN/MJQ-35A, AN/MJQ-36	none

Dimension: LxWxH (in.): 50.4 x 31.8 x 36.2; Cube: 34 cu. ft.

Engine: Diesel, Onan DN2M, 2 cyl, 11.0 hp @ 1800 RPM, 24 VDC starter, liquid cooled.

Fuels: Diesel DL-1, DL-2 and jet fuel JP-8, Jet A-1. Fuel capacity: 5 gallons

Electrical: Drip proof generator enclosure, fungus & moisture treated, solid state voltage regulator, brushless rotary exciter, solderless connectors, 60 Hz: Onan, 4 pole; 400 Hz: Onan, 24 pole. Convenience receptacle on 60 Hz set.

Voltage connection	1 phase 120 V, 2 wire	1 phase 120/240 V, 3 wire	3 phase 120/208 V, 4 wire
volt adj range	114 - 126 V	228 - 252 V	205 - 220 V
freq adj range	–3%	–3%	–3%

Electric Power Rating: 5 kW, 0.8 power factor @ 4000 ft/120 °F. Derate 3.5% per 1000 ft (4000 to 8000 ft). Max power: 110% rated.

Electric Power Quality	Voltage	Frequency
Regulation (max)	3%	3%
Modulation (max)	2.5%	
Short term steady state stability (30 sec)	2% bandwidth	2% bandwidth
Long term steady state stability (4 hr)	3% bandwidth	3% bandwidth
Application/rejection of rated load recovery:	20% dip, 20% rise 3 sec	3% under/4% over 3 sec
motor load (low power factor), recovery	35% dip, 5 sec to 95% initial voltage	
Max waveform deviation factor	6% (1 ph); 5% (3 ph)	
Individual waveform harmonic	3% (1 ph); 2% (3 ph)	

Reliability: 442 hour MTBOMF. Maintenance ratio: less than 0.05

Protective Devices: Automatic shut down with emergency bypass for low fuel, low oil pressure, coolant over temperature, and overload. Instrumentation: On/off switch, Hour/volt/frequency meter, oil pressure. EMI: Suppressed to MIL-STD-461 limits. EMP: HAEMP per MIL-STD-2169.

Technical Manual

manual type	Army	Air Force
Operators Manual	TM 9-6115-641-10	TO 35C2-3-456-11
Unit, Direct Support	TM 9-6115-641-24	
Repair Parts and Special Tools List	TM 9-6115-641-24P	
Lubrication Order	LO 9-6115-641-12	
Warranty Technical Order	TB 9-6115-641-24	

Environmental Capability: -25 °F to 120 °F, rain, humidity, altitude, sand/ dust, transportation, -60 °F cold storage, salt spray, fungus.

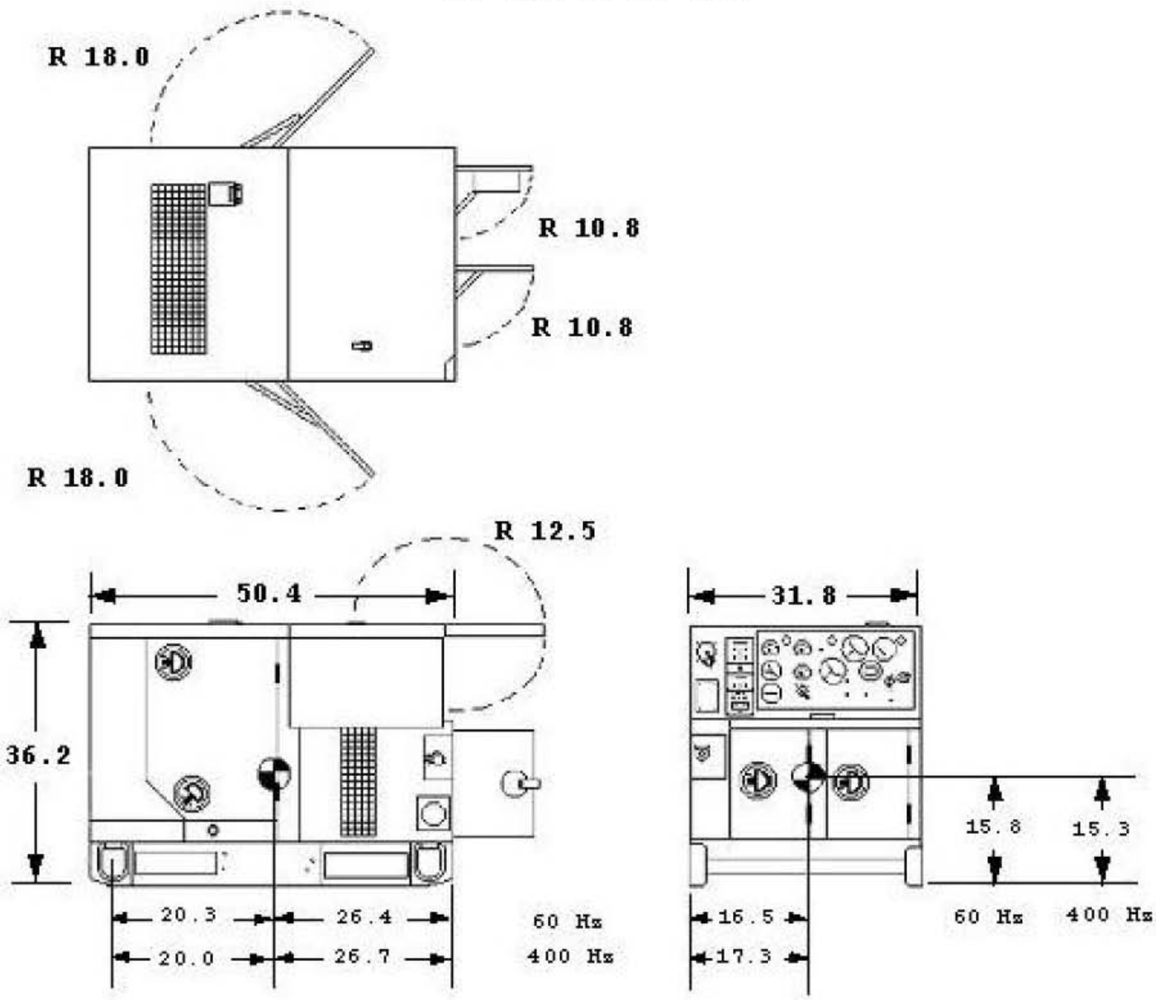
Noise: 70 dBA @ 7 meters (23 ft).

Human Factors: In accordance with MIL-STD-1472 and MIL-STD-1474.

Optional Equipment: None

CHARACTERISTICS DATA SHEET
5 kW MEP-802, 60 Hz/MEP-812, 400 Hz Skid Mounted Tactical Quiet Generator

MEP-802A or MEP-812A

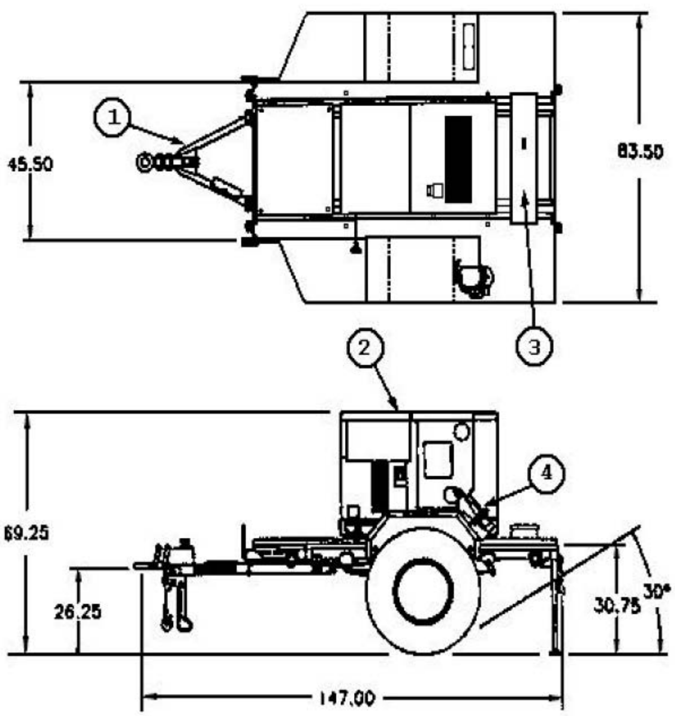


CHARACTERISTICS DATA SHEET
PU-797*, TQ POWER UNIT, DED, 5kW, 60 Hz, TRLMTD

NSN	6115-01-332-0741	Dimensions (in.)	147.0 x 83.5 x 69.3
LIN	G42238	Op. Weight	2320 lb.
SSN	R62700	Ship weight	2360 lb
ASSMB	TA-13229E5705	Ship Cube	410 cu ft
SPEC	MIL-P-53132/5	Camouflage	97403-13228E1608

COMPONENT	QTY	FIND	IDENTIFIER
3/4 Ton modified Trailer, M116A3	1	1	97403-13229E5757
Generator set, TQ DED, 5 kW, 60 Hz, MEP-802A	1	2	6115-01-274-7387
Accessory box	1	3	97403-13229E7946
Fire extinguisher, 5 lb., A-A-1106	1	4	4210-00-270-4512

* Some PU797As, NSN: 6115-01-413-3820, which use a High Mobility Trailer in lieu of the M116A3, were fielded but are no longer manufactured.

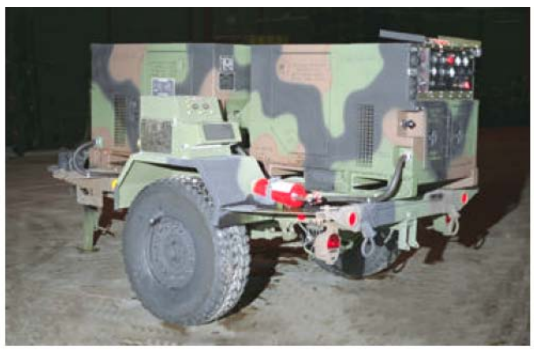


CHARACTERISTICS DATA SHEET
PP-AN/MJQ-35*, TQ POWER PLANT, DED, 5kW, 60 Hz, TRLMTD

NSN	6115-01-313-4216	Dimensions (in.)	154.0 x 83.5 x 69.3
LIN	P28083	Op. Weight	3087 lb.
SSN	M54100	Ship weight	3285 lb
ASSMB	TA-13229E5705	Ship Cube	420 cu ft
SPEC	MIL-P-53132/3	Camouflage	97403-13228E1609

COMPONENT	QTY	FIND	IDENTIFIER
3/4 Ton modified Trailer, M116A3	1	1	97403-13229E5757
Generator set, DED, 5 kW, 60 Hz, MEP-802A	2	2	6115-01-274-7387
Accessory box	1	3	97403-13229E7946
Fire extinguisher, 5 lb., A-A-1106	1	4	4210-00-270-4512
Switch box,	1	5	97403-13229E6535

* A few MJQ-35As, NSN: 6115-01-414-9697, which use a High Mobility Trailer inlieu of the M116A3, were fielded but are no longer manufactured.



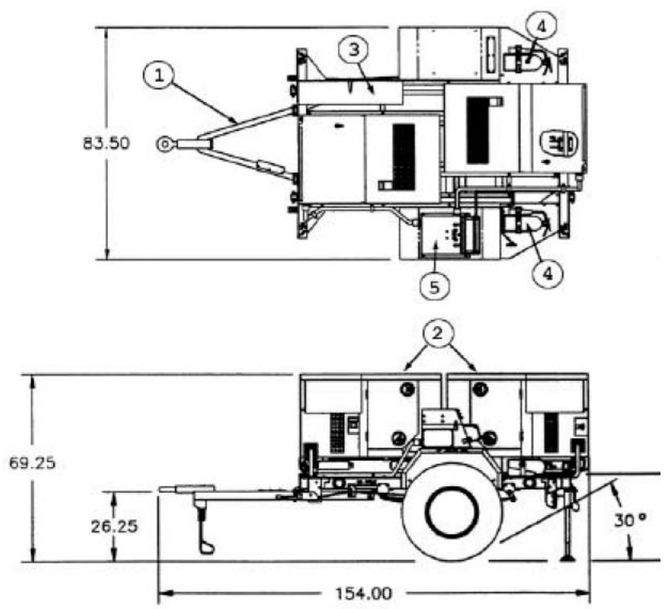


FIGURE A-7 PP-AN/MJQ-35

CHARACTERISTICS DATA SHEET
PP-AN/MJQ-36, TQ POWER PLANT, DED, 5kW, 60 Hz, TRLMTD

NSN	6115-01-313-4215	Dimensions (in.)	154.0 x 83.5 x 69.3
LIN	P28151	Op. Weight	3785 lb.
SSN	M66200	Ship weight	3985 lb
ASSMB	TA-13229E5660	Ship Cube	600 cu ft
SPEC	MIL-P-53132/4	Camouflage	97403-13228E1610

COMPONENT	QTY	FIND	IDENTIFIER
1-1/2 Ton modified trailer, M103A4	1	1	97403-13229E5825
Generator set, TQ DED, 5 kW, 60 Hz, MEP-802A	2	2	6115-01-274-7387
Accessory box	1	3	97403-13229E7946
Fire extinguisher, 5 lb., A-A-1106	2	4	4210-00-270-4512
Switch box	1	5	97403-13229E6535