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ENGINEERING EVALUATION AND ANALYSIS FOR THE IMPROVEMENT OF MILITARY STANDARD GENERATORS

VOLUME 1 OF 2 VOLUMES

RALPH J. ADOLPH
LOU G. LAWRENCE
GARRY W. PERKINS
ERIC THORWALDSON

VSE Corporation
2550 Huntington Avenue
Alexandria, Virginia 22303-1499
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Prepared For:

U.S. Army Belvoir Research, Development and Engineering Center
Power Generation Division (STRBC-FG)
Fort Belvoir, Virginia 22060-5606

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SUMMARY

This Final Report provides an in-depth look at on-going projects for improving the Mobile Electric Power Generating System (MEPGS) sets. A detailed comparison of existing MEPGS requirements for generators against proposed requirements for commercial generators procured for tactical military use is presented. From this comparison, a list of areas and characteristics of the MEPGS sets, which fall short of the requirements imposed by the draft Required Operational Capability (ROC) document are presented. Major areas include: noise, reliability, Electro Magnetic Pulse (EMP), and built-in test equipment.

This report analyzes industry response and suggestions for improvement of the MEPGS set family. Respondents' suggestions fell primarily in the areas of Reliability, Noise and Infrared (IR) suppression. The majority of recommended actions were general in nature, but the vendors were consistent in the areas they felt could be improved.

Design modifications are proposed for all MEPGS sets considered in this study to upgrade the requirements in the areas of noise suppression and reliability. Major emphasis is placed on improvements to the 15, 30, and 60 kW generator sets.

PREFACE

This engineering evaluation and analysis report, which consists of two volumes, was prepared under Contract No. DAAK70-86-D-0023, Task Order No. 0067, for the Belvoir Research, Development and Engineering Center (Belvoir), Fort Belvoir, Virginia.

The required effort contained in the task order statement of work is quoted below.

> "Review and analyze Government Furnished Data (GFD) identifying potential designs and redesigns of assemblies, subassemblies, components and/or end items (Military Standard Generation Sets 5 kw through 100 kw) with consideration for improving the end items for their intended use in the Military environment. This evaluation shall consider, but not be limited to reducing costs; avoiding the use of Government and industry specifications; and engineering designs that inhibit competitive procurement."

1.0 SCOPE

1.1 Scope. This evaluation and analysis of the Military Standard Generator Improvement Program considered generator set sizes 5-100 kw, Diesel Engine Driven (DED), in their skid mounted, power unit, and power plant configurations, hereafter referred to as Mobile Electric Power Generating Systems (MEPGS). The basis for the evaluation and analysis consists of quality deficiency reports (QDRs), equipment improvement recommendations (EIRs) from the field, sample data collection (SDC) reports, recommendations by industry based on the Belvoir Research, Development and Engineering Center (Belvoir) and Troop Support Command (TROSCOM) survey letters to industry, and the current requirements document. Generator set technical data reviewed included, but was not limited to, technical manuals; military specifications MIL-G-52884, MIL-G-52889, their individual equipment subsets; military standards MIL-STD-633 and MIL-STD-1332. The scope for this improvement effort specifically cites the intent to perform work with industry participation that will lead to improvements in the following areas, with the greatest emphasis on the first two areas:

- o Noise reduction
- o Improved Reliability
- o Protection from electromagnetic pulse (EMP)
- o Reduced infrared signature
- o Reduced weight

1.2 Purpose. The purpose of this engineering evaluation and analysis is to identify potential designs/redesigns and/or improvements that are valid and feasible, both in time and cost effectiveness, which can be applied to the current family of military standard generator sets with the goal of improving their operational reliability, availability, and maintainability (RAM), and enhancing survivability through the use of noise suppression, infrared signature suppression and electromagnetic pulse protection techniques and materials.

1.3 Objectives. For the purpose of this evaluation and analysis the current draft of Required Operational Capability (ROC) for Commercial Generator Set and Assemblages (CGSAs) was utilized as the established requirement objective. This report identifies potential areas of improvement that are set forth as the baseline goals of the ROC, while simultaneously considering the currently programmed mobile electrical power requirements. Comparison of existing MIL-STDs and the proposed performance and technical characteristics outlined in the ROC serve to identify areas of difference and their possible affects on reliability, noise suppression, infrared signature suppression, survivability, weight reduction, and cost factors. Evaluations of the responses received as a result of the Belvoir and TROSCOM survey letters to industry are discussed and those with valid potential improvements are identified. Design/redesign changes suggested by industry or otherwise evident due to differences between existing MEPGS sets and the CGSA ROC are evaluated and analyzed. Conclusions and recommendations are then offered.

1.4 Background. Since the formal charter creating the Project Manager-Mobile Electric Power in 1967, the immediate goal of reducing the number of

different types and models of generator sets has been met. Concurrently, the Project Managers and Belvoir's mission included goals for improvements in the development, procurement value, production engineering, and logistic support. The improvements needed for Reliability, Availability, Maintainability and Durability (RAM-D) along with survivability and logistic support solutions are by nature a continuing process. As advances in technology have brought about change, this has also caused the Project Manager and Belvoir to keep in close touch with industry in order to evaluate their solutions and applications to the new technology.

This increased role of the Project Manager's and Belvoir's responsibilities have been the driving force for implementation of numerous programs to provide MEPGS users with more efficient, reliable, and survivable power sources. These programs implemented by Belvoir cover a wide range of potential improvements and to adequately discuss all of them would require in-depth reports on each however, the following are a sampling and brief synopsis of some of the more critical current programs which could impact on the potential for improving MEPGS to meet ROC requirements.

- The Vehicle Under-the-Hood Program was originally conceived as back up source of power for critical weapon and C3I systems. The goal has been refined and redefined as an attempt to eliminate all requirements for dual generators on a single trailer. The current program approach envisions the use of a vehicle engine to produce short term back-up AC power.

- The Distribution/Illumination System, Electrical (DISE) program was developed to achieve a variety of objectives aimed at providing standardized man-portable electrical distribution equipment for various configurations. DISE provides reliable, easily assembled power networks in modular design. Consisting of cabling and circuit protection equipment, the systems provide the means to subdivide and distribute electricity from power sources to various equipment and complexes to meet their specific power requirements. Through the distribution process the user is offered a wider range of power, available in both serial and parallel connections, thus consolidating electrical requirements under a single source. DISE allows the use of fewer numbers of generator sets within an operational cell, and in maintaining cell dispersion, the survivability factor is significantly increased.

- As technological advances have created new materials and manufacturing processes and capabilities, programs were initiated to utilize these advances. The total package integration of shelter and Integrated Power and Environmental Control Systems (IPECS) is one such program. Today's field requirements are mostly satisfied by generator sets mounted on and transported by separate trailers. Current Military directives; require the use of both GED and DED generators in various models, sizes and configurations to supply power for both the tactical equipment needs, and for heating and cooling of shelters. The power being used to heat and cool the various shelters consume an average of 55 % of the total power required. The primary objective of IPECS is to

provide an integrated system to provide primary tactical equipment power, heating, cooling, and Nuclear, Biological, Chemical (NBC) filtering in a single unit transported on or in the equipment shelter.

- Signature suppressed power is another area of concern. The Signature-Suppressed Diesel-Engine-Driven (SSDED) program's goal is to improve the survivability of command and control, weapon systems, and maintenance/logistics complexes in a hostile tactical environment. To accomplish this goal the SSDED program intends to provide state-of-the art generator sets in the 15 kw through 60 kw sizes, in both 50/60 and 400 Hz, that are audio and IR-suppressed, nuclear hardened, and NBC survivable.

- The 15 and 30 kw noise kit program was initiated to develop acoustic noise reduction kits, which will quiet the existing 15 and 30 kW military standard generator sets. The resulting noise reduction will be from 82dBA to 70dBA at 7 meters. Kits are to be field installable on either skid or power unit configuration and interchangeable by size, regardless of frequency. The kits will not degrade the reliability or maintainability characteristics of the basic set. The first production contract award is scheduled in FY 87. Refer to Appendix G for further details on these kits.

- The 5 and 10 kw noise kit program was initiated to develop acoustic noise reduction kits, which will quiet the existing 5 and 10 kW military standard generator sets. The resulting noise reduction will be from 82dBA to 70dBA at 7 meters. Kits are to be field installable on either skid or power unit configurations. The kit will not degrade the reliability or maintainability characteristics of the basic set. The first production contract award is scheduled for FY 88. Refer to Appendix F for typical information for this effort.

- In addition to the above on-going programs, the Project Manager has directed product improvements to improve the RAM-D of the currently field MEPGS generator fleet. Improvements made in the past have included such items as; the breakerless ignition, which eliminated standard ignition points and capacitors, reduced cost, and improved cold weather starting; the Load-Sensing Electric Hydraulic (LEH) governing system for 15 kW/30 kW/60 kW sets which replaced the electro-hydraulic governor with a totally electric governor and resulted in a 30 percent increase in reliability, simplified maintenance procedures, and operational cost savings. In a relatively short period, the Project Manager-Mobile Electric Power and Belvoir accomplished a number of the original objectives and has begun work on many additional improvements. Continuing efforts are required to improve NBC survivability through the use of Chemical Agent Resistant Coating (CARC), Electromagnetic Pulse (EMP) protection, thermal-blast hardening and protection from typical noise and infrared signatures. DOD and industry through NDI programs, foreign market surveys/investigations, Military Adaptation of Commercial Items (MACI) efforts, and in-house study efforts continue to identify new technology, materials, and equipment. As stated in the original charter for the Project Manager-

Mobile Electric Power the goal was (and still is) to supply our forces with reliable, efficient, cost effective power. While time has not changed the original goals; technology, doctrine, and shifting ideologies have continually altered how these goals are to be achieved, and have shown us new ways to increase survivability. However, the situation as it exists gives cause to act quickly to improve the current MEPGS fleet and procure a new fleet that meets the Army's goals. That situation is as listed.

o The Army Generator Fleet

- 80% Gasoline Driven Engines
- 70% of the fleet is 10 + year old
- Does not meet latest user requirements

2.0 DISCUSSION

2.1 ROC versus Current MEPGS Requirements. A tabular comparison of military specifications which governs the current military standard generator sets versus the performance and technical requirements of the ROC are presented in Appendix A. Current standards and specifications are extensive and were integrated from a compilation of three groups.

(1) MIL-STD-633
(2) MIL-G-52884/MIL-G-52889
(3) MIL-G-52889/1/2/3 and
MIL-G-52884/2/5/8

Group (1) contains general specifications for physical and operational characteristics of performance, delineated for each classification of generator. Group (2) presents a more detailed set of requirements for the generator classification. The two specifications listed in group (2) distinguish between generators in the smaller size (5 kw/10 kw) and the larger size (15-200 kw). The complete procurement requirements are also covered in group (2), however, they are not "stand alone" documents. Group (3) covers detailed requirements for individual generator sizes.

The values tabulated in Appendix A were based on the following order of precedence in regards to the three groups of documents referenced above: Group three (3) followed in order by group two (2) and group one (1). If specific reference could not be found relating to items specified in the CGSA ROC, individual generator set Technical Manuals for each size unit were consulted.

Several baseline requirements of the MEPGS sets were eliminated from comparison due to the CGSA ROC's excluding them from consideration. Therefore only the following generator sets have been tabulated in Appendix A for comparison:

- Diesel Engine Driven
- Tactical
- Utility

In the case of the 10 kW MEPGS set, there is a 400 Hz design, used for utility purposes and for this reason has been included in the comparison. Since all other MEPGS utility sets are 50 or 60 Hz, ROC requirements were tabulated on the basis of 60 Hz sets.

2.2 Similiar Requirements for ROC and MEPGS. Any study utilizing a comparison of two or more baselines will ascertain factors where one option is different from another in specific areas and vice versa. Before presenting the differences we must first define the areas where the ROC and MEPGS requirements are similar. The following electrical requirements are essentially the same, with the exception of the 100 kW set (See section 2.2.1.2.1). As explained previously, the MIL-SPECs were used as the primary document, rather than the MIL-STDs (Refer to Appendix A):

ELECTRICAL CHARACTERISTICS
VOLTAGE
- 4 hour steady state variation (%)
- Recovery after dip (Secs)
- Recovery after rise (Secs)
- Recovery to 95% rated voltage (Secs)
- (unbalance, Unbalanced load) (%)
- Phase balance (%)

FREQUENCY
- Regulation (%)

INCLINED OPERATION (max deg. from level)
FUEL
- Diesel Fuel (VV-F-800) Compatibility

FUEL TANK CAPACITY
FUEL SYSTEM
- Air Bleeding Capability
- Water Bleeding Capability

NOTE: An assumption is made here that an air purging capability is desired for the primary fuel system. This capability is provided for by a deaerated fuel tank or day tank. There is no design capability in the current sets to automatically bleed air from the secondary high pressure fuel system. If the fuel is allowed to run dry, and air is allowed to enter the secondary system, the fuel system will require partial dismantling to purge the system. The capability for draining water is available through a manual valve located on the bottom of the fuel filters.

EMI RESTRICTIONS PER MIL-STD-461
STARTING SYSTEM
- Battery Start and Charging
- Slave Receptacle

PARALLEL OPERATING CAPABILITY
SAFETY/HUMAN FACTORS ENGINEERING
GAGES AND MONITORING EQUIPMENT
- Protection from Destructive Malfunctions
- Devices to Monitor Operation of Gen Set
- Fault Indicators for Set Malfunctions and Shutdown (fault lights)

NBC SURVIVABILITY
- Set Operation Possible in MOPP IV Gear
OIL SYSTEM
DRAIN ACCESSIBILITY

The preceding items create the baseline from which to compare those requirements which are either more stringent or less stringent when comparing the MEPGS versus the CGSA ROC. The sections that follow will address those areas of differences between the MEPGS and CGSA ROC.

2.2.1 MEPGS Requirements in Excess of the ROC. In many instances the MEPGS requirements presented are either not addressed specifically in the ROC, or more restrictive than those in the ROC. There are, by far, more requirements called out in the current MIL-SPEC/STD for MEPGS which are not addressed in the ROC.

2.2.1.1 MEPGS Requirements Not Addressed Specifically in the ROC. Baseline requirements set forth in the ROC are not as detailed as the specifications found in Group two (2) and Group three (3) listed in section 2.1 The ROC identifies the type of general specifications contained in MIL-STD-633. Many of the more detailed requirements are not addressed and are outlined below by category:

A. MIL-STD-633 items not addressed by ROC
- voltage connections
- generator set dimensions and weight

B. MIL-G-52889/52884 items not addressed by ROC
- voltage connections and ratings
- winterization kits
- operating and critical speeds
- maximum power output
- oil temperature
- general characteristics (e.g., winding and insulation resistances, temperature rise, short circuit, phase sequence, frequency and voltage drift, efficiency.)
- control system characteristics
- grounding rod
- treatment and painting
- testing (except as referenced in MIL-STD-1332 by ROC)

C. MIL-G-52884/2/5/8 items not addressed by ROC
- engine horsepower
- exciter field current
- transient reactance
- negative sequence impedance

D. MIL-G-52889/1/2/3 items not addressed by ROC
- transient reactance
- negative sequence impedance
- field current
- ac circuit interrupter

2.2.1.2 MEPGS Requirements More Restrictive Than ROC. The general functional and electrical performance requirements as outlined in the ROC for CGSAs are consistent with those standards for utility generator sets IAW MIL-STD-1332. The ROCs environmental and storage guidelines are IAW AR70-38. Additionally the generator sets must be equipped with lifting and tie-down provisions IAW MIL-STD-209, however, the following paragraphs discuss those areas of performance and functionality where directives are more restrictive than those in the ROC.

2.2.1.2.1 Voltage Requirements.Generator sets in the 10-60 kW size, in both the current version and the ROC, are classified as Utility Class 2B IAW MIL-STD-1332: However, the ROC specifies the 100 kW as 2B and the 5 kW as a Class 2C Utility set. Current 5 kW sets are classified Utility 2B and the 100 kW must meet the requirements for a Precise Class 1 as defined by MIL-STD-1332. Due to the considerable differences between the requirements specified for Class 1 Precise and Class 2B Utility sets, the 100 kW sets will not be directly compared in the following sections. Note, however, that Appendix A does compare MEPGS versus ROC 100 kW sets. Voltage regulation requirements as currently specified for the 60 Hz generator sets are 3% for both ROC and MEPGS sets. The ROC 5 kW set, however, allows for a 4% regulation. This regulation applies from no load to rated load for all voltage connections, (i.e., 120V, single phase, 2 wire; 120V/240V, single phase, 3 wire; 120V/208V, 3 phase, 4 wire).

The proposed guideline for ROC and MEPGS generator sets with regard to voltage dip, must be less than 20% (with the set initially operating at rated voltage/frequency and following any sudden change in load from a no load to rated load condition. The proposed ROC 5 kW, 60 Hz generator set allows for a 30% dip with application of rated load IAW MIL-STD-1332.

The voltage rise for the MEPGS sets must be less than 20%, with the set operating at rated voltage/frequency, when the load is suddenly reduced from rated to no load. The ROC proposes a voltage rise of 30% under the same conditions.

Voltage dip (application of 200% current) for the 10 kW, 60 Hz and 10 kW, 400 Hz MEPGS sets must be less than 35% with an application of 200% of the current rating IAW MIL-STD-633. The ROC 10 kW 60 Hz set is allowed 40% under the same current IAW MIL-STD-1332.

The maximum waveform deviation factor for the 5 kW, 60 Hz MEPGS set must be less than 5% for 3-phase and 6% for single phase IAW MIL-STD-633 where as the limit for maximum waveform deviation for the proposed ROC set is 6% for 3-phase and 7% for single phase IAW MIL-STD-1332.

The individual harmonic waveform deviation factor for the 5 kW, 60 Hz MEPGS set is specified at less than 2% for 3-phase and 3% for single phase IAW MIL-STD-633. ROC 5 kW, 60 Hz guidelines allow 3% for 3-phase and 4% for single phase.

2.2.1.2.2 Frequency Requirements.Current generator sets in the 5 kW-60 kW range must meet frequency requirements that are more stringent than those set

forth for the proposed ROC generator sets. The first of these is the 30-second steady state variation requirement.

All constant load conditions from no load to the rated load for the MEPGS 5 kw 60 Hz set must maintain the frequency within a given bandwidth equal to 2% of the rated frequency without repetitive frequency variations (hunting) IAW MIL-G-52889. The ROC 5 kW 60 Hz set is allowed 4% of the rated frequency IAW MIL-STD-1332.

The MEPGS 5kW, 60 Hz generator operating in an ambient temperature condition (constant voltage and constant load) from no load to rated load, must maintain the frequency within 3% bandwidth of the rated frequency for a four hour operational period while the proposed ROC generator is allowed a 4% deviation under similar conditions.

For the requirements of undershoot (application of rated load); recovery after undershoot; overshoot (rejection of the rated load); and recovery after overshoot, the following comparisons apply to both MIL-STD and ROC generator sets in the 5-60 kW sizes for transient performance conditions:

	MIL-STD	ROC
- Application of rated load	3% undershoot	4% undershoot
- Recovery		3 sec.4 sec.
- Rejection of rated load	4% overshoot	4% overshoot *
- Recovery		3 sec.4 sec *

* ROC 5 kW sets are allowed 5% rejection and 6 seconds recovery. MEPGS sets in the 15 kW 50/60 Hz, 30 kW 50/60 Hz, and 60 kW 50/60 Hz have a frequency adjustment of +4% to -3% and the 10 kW 400 Hz sets range is ±5 %. All sets within the proposed ROC are allowed a range of ±3 %.

2.2.1.2.3 Environmental Requirements. The required operating temperature range @ 100% of rated load at sea level for MEPGS sets is -25 to +125 degrees (F) while ROC sets are required to operate at -25 to 120 degrees (F). MEPGS sets must operate at 100 % rated load at an altitude of 5000 ft and +107 degrees (F), while ROC sets are required to operate at 90 % rated load. MEPGS sets must operate at 90 % of rated load at an altitude of 8000 ft and +95 degrees (F), while ROC sets are not rated at this condition.

2.2.1.2.4 Storage. Storage Temperature range at any relative humidity, is specified as -65 to +155 degrees (F) for all MEPGS from 5 to 100 kW IAW MIL-STD-633. The ROC sets are required to withstand storage temperatures from -50 to 160 degrees (F) in accordance with the hot through extreme cold climatic conditions set forth in AR 70-38.

2.2.1.2.5 Turbine Fuel. MIL-STD-633 specifies that all MEPGS, from 5 to 100 kW must have the capability of using aviation turbine fuels JP-4 and JP-5 (MIL-T-5624) in emergencies. The CGSAs have no requirements for emergency use of aviation turbine fuels.

2.2.1.2.6 Transportability

2.2.1.2.6.1 Lifting Provisions. All MEPGS lifting provisions require the sets to have a minimum yield strength of 800% of the total weight IAW their specific MIL-SPECS of the set. IAW MIL-STD-209, the ROC sets CGSAs have a requirement to have lifting provisions with a strength of 480% of the total set weight.

2.2.1.2.6.2 Towing Provisions. The MEPGS towing provisions must to have a minimum yield strength of 500% of the total weight of the set IAW their specific MIL-SPECs. ROC sets have no requirements specified for towing provisions.

2.2.2 ROC Requirements Which Upgrade MEPGS Requirements. The following is a discussion of the line items tabulated in Appendix A where the ROC requirements are an upgrade to the MEPGS. These items call for stricter design requirements when compared with the current MEPGS sets.

- VOLTAGE ADJUSTMENT RANGE. On the larger ROC sets (15-100 kW), a larger top end voltage adjustability is required over the current generator sets. This advantage (an additional +2%) allows the ROC sets to provide a greater operating voltage for special types of equipment.

NOISE @ 7 METERS. The ROC requirement is stricter for all size sets, compared with existing generator sets. The goal of 70dBA @ 7 meters will significantly aid in reducing detectability by enemy forces, and also reduce the potential for hearing loss/damage by operating personnel. Since noise suppression, in conjunction with Infrared (IR) suppression, is a desireable feature within the tactical environment, Section 2.3 explores current technology available to upgrade current generator sets, particulary in respect to noise suppression.

RELIABILITY (MTBF/MTBOMF). The required MTBF for the ROC set is considerably higher than that specified for the current generator sets. However, data which will be presented in Section 2.3.2 and Appendix B reveals that actual operational figures for MEPGS sets rarely meet specified MTBF target values. Further discussion is presented in Section 2.3.4.

FLUID LEVEL CHECK DURING OPERATION. The primary fluid which requires checking is assumed to be the lubricating oil, since coolant is not applicable to all generator sets. The larger MEPGS sets (15 kW and above) have the provision to check oil levels during generator operation. This capability is not reflected with the 5 and 10 kW sets, based on the maintenance schedule and information presented in the Technical Manuals (TMs).

DCA, STE/ICE, DISE. Although these capabilities are under consideration for inclusion on the ROC sets, the capabilities are not currently required on MEPGS sets.

BATTLE SHORT. This feature is required on all ROC sets but is not a standard feature on the small current sets (5 and 10 kW), which reduces their capability to perform missions under a maximum range of circumstances.

SECURE LIGHTING. None of the MEPGS sets are equipped specifically with this feature. However, non-detectability in the current sets is aided by the low wattage bulbs used, and control panel covers on the larger sets.

HIGH ALTITUDE EMP. The ROC requirements call for survivability. This requirement is not addressed in the current generator sets. An analysis of EMP damage is presented in Appendix I. This document provides an assessment of the potential damage that can occur in certain electrical components of the MEPGS sets (30 kW precise power) during EMP.

TRAILER CAPACITY. The table in Appendix H presents the payload capacity for each trailer dedicated to carry the individual generator sets. Trailer payload values were computed from the associated MEPGS trailer specification sheets. The calculated weights for the generator sets were obtained from both MIL-STD-633 and the individual TMs. Also presented are actual weights as measured by Belvoir. Even with 400 extra pounds of ancillary equipment, none of the MEPGS trailers are overloaded, with the exception of the 60 and 100 kW trailer. The 60 kW set, without ancillary equipment, is barely within trailer payload restraints. However, the inability of the 100 kW set to field its own weight, not to mention the inability to carry ancillary equipment makes additional weight-adding design improvements/ modifications doubtful for this set.

2.3 Impact of Current Research Studies in Infrared and Noise Suppression and Reliability. Current research programs that have the potential to affect the generator fleet are predominantly within the areas of IR and noise suppression. The following paragraphs address a few techniques currently being studied.

2.3.1 Design Objectives Proposed by the ROC. The objectives as outlined in the ROC clearly define the following requirements, pertaining to IR and noise suppression, for all generator sets in all configurations:

- Have an aural signature not greater than 70dBA at 7 meters (essential)
- Non-detectable by an unaided soldier beyond 400 meters in fair weather with winds less than 3 miles per hour regardless of employment techniques (Desirable)
- Infrared signature reduction

2.3.2 Infrared Signature Reduction. IR and noise suppression are closely related, however, the reduction of IR signatures presents several technical problems. In order to reduce the IR signature, the external temperature of the outer walls must be at or below the ambient temperature of the environment surrounding the outer shell. All MEPGS sets currently in use have ambient air from the environment pulled around the alternator and engine assembly prior to passing through the radiator. This approach effectively cools the alternator and the engine assembly and influences the IR signature. Although various configurations of airflow design and insulation techniques provide reduced IR signature during operation, they do not aid in reduction during periods of non-operation. When the generator set is idle, (not running), solar energy

will raise the thermal imagery level of the generator's outer shell allowing for relatively easy detectability of it's signature. Additionally, increased insulation within the housing for both IR and noise suppression raises the internal temperature of the housing, thus increasing the relative thermal pattern.

Current research in low emissivity coating, utilizing networks of active sensors, has the potential to reduce IR signatures, but this research is not currently conclusive.

2.3.3 Noise Suppression. The present fleet of generator sets historically have not been subjected to the stringent noise attenuation requirements as proposed in the ROC. As a result, the majority of the action taken to resolve the noise problem has been in the form of various product improvement programs (5 kW/10 kW and 15 kW/30 kW noise kits). See Appendix F and G, respectively.

Noise suppression is deemed feasible as indicated by responses received from the market survey in Section 2.4.2. Such engineering is technologically sound and operationally effective; however, effective noise control will involve additional cost expenditures and increased weight considerations. The cost associated with noise suppression is driven by the overall design complexity. Solutions to the noise suppression problem often require the resources of acoustical specialists, special materials, and intricate design considerations, all of which tend to drive development and production costs upward.

The technology to design and produce generator sets which meet the baseline of the ROC is both feasible and attainable. Through the use of state-of-the-art materials, design/modification of the generator sets, and proper application and operational procedures the goals for noise control can be met. Taking into consideration that the current MEPGS fleet does not meet the proposed specification (70dBA or less) at 7 meters, for noise suppression, the following are considered potential improvements to obtain the desired goal:

- Replace existing components known to be major noise source with improved components (i.e. fans of both new materials and lower operating speeds, mufflers/silencers)
- Isolate and control identifiable noise sources, through the use of specially designed sound absorbitive materials, air inlet/outlet baffles and traps, etc.
- Isolate mounting beams, skid mounts, housings and engine assemblies through the use of soft mounts/dampers to reduce vibration and transmission paths of noise.
- Enclose the generator set in light weight sound suppression kits, specifically designed to absorb and diffuse sound emanations.

In order to meet the established baseline goals, data for utilizing kits is presented in Appendixes F and G. These Appendixes present noise test data and design considerations. The remainder of this section deals with the specifics of noise suppression with respect to the Regency Net Program.

The Regency Net Program's purpose was to reduce the noise levels for both tactical and health/safety considerations. The product improvement kit was developed utilizing a modified 15 kW generator whose power output was increased to 20 kW specifically for the Regency Net Program(photographs taken of a prototype are presented in Appendix M). The estimated generator noise level prior to modifications was 86dBA, with a design objective of 65dBA at 7 meters.

Modifications to the generator set included a new 40 degree pitch, multi-wing 9-blade engine fan (See figure 1). The fan is an air foil design with adjustable blade pitch which contributed to significantly higher performance and increased efficiency while producing lower noise levels. This fan has a 22 inch diameter with true air profile blades molded of polypropylene. Polypropylene blades are capable of operation in ambient temperature ranges of -40 to +185 degrees (F) and has a recommended tip speed of 295 ft. per second.

Additional modifications included a muffler by Universal Silencer, with vertical exhaust (See Figure 1) and a 5 inch pulley (which was later replaced with a 5-1/2 inch pulley). Even though the larger pulley contributed to increased noise across the full spectrum of measurement, noise levels consistently remained below 62dBA. A new 1/2 inch plate aluminum fan shroud and fan belt were added, along with a new Bolt Beranek and Newman Inc. intake air cleaner/silencer.

Ft. Belvoir Research, Development, and Engineering Center's (Belvoir) intake and exhaust sound suppression mufflers were added by Belvoir at the radiator and generator ends of the set (See Figure 1). The radiator end muffler was mounted utilizing the existing holes used for load bank mounting. The generator end muffler required new mounting holes to accommodate the baffle. It should be noted that these mufflers increased overall length by 38 inches. Other modifications included the following (Reference Figure 1):

- Sound coat insulation on side door panels

- Top housing extension lined with 3 inch Owens-Corning 703 fiberglass, wrapped in .5 mil mylar, held in position with perforated metal plates

Two additional modifications were performed on the housing which consisted of replacing two roof sections with new design sections (height raised 13 inches) and all instruction plates were removed and replaced with plates made on a heavy paper material, encapsulated in plastic and attached, by ring, to the inside of the housing.

These modifications were performed on a utility set with the entire generator assembly shock mounted on four Barry shock mounts (See Figure 1). A precise kit was added, along with a precise relay box and an electric governor system.

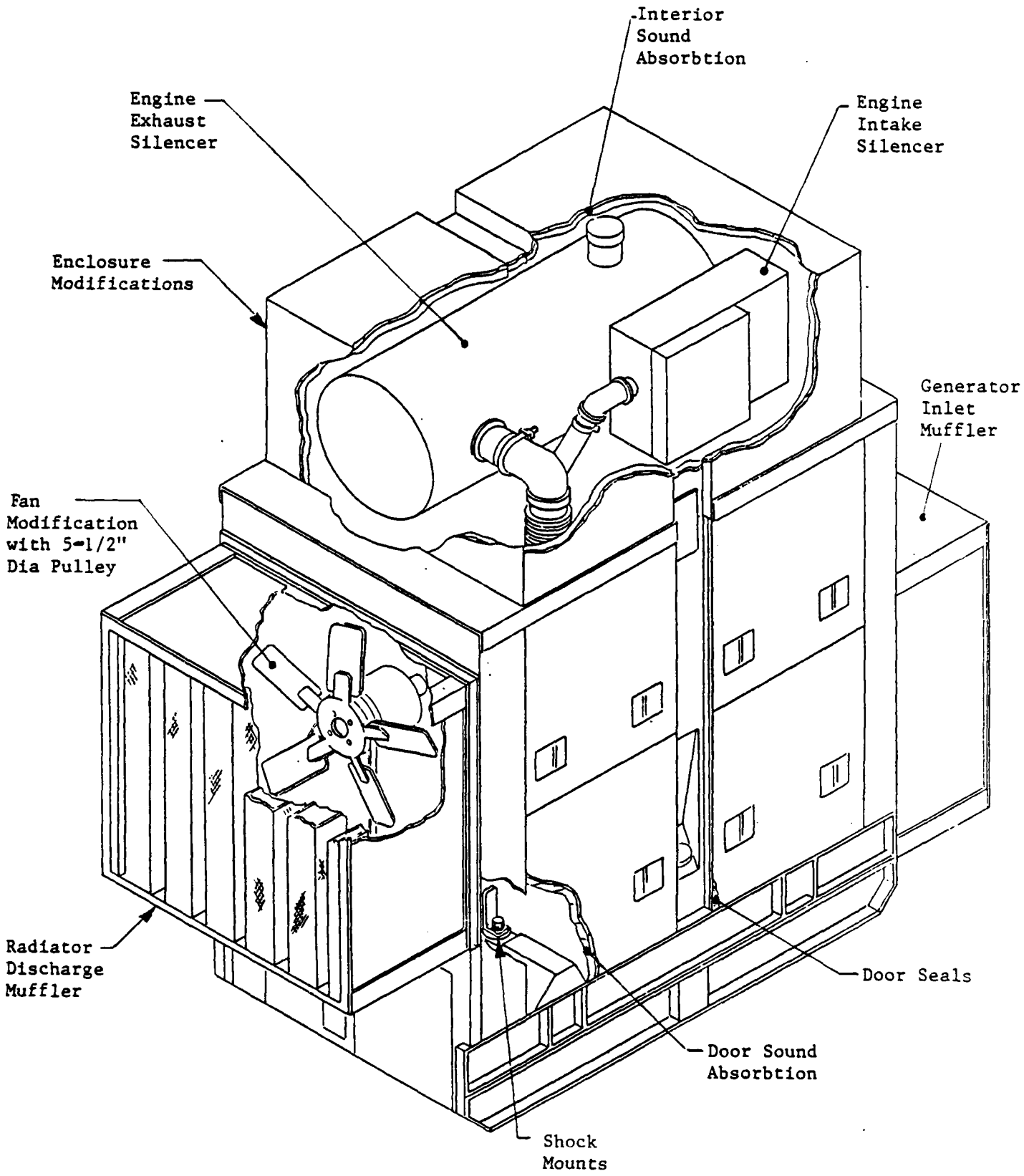


Figure 1. Regency Net (Modified 15 kW) Gen Set Noise Suppression Modifications

2.3.4 Reliability Data. To identify areas where reliability improvements can be targeted, historical data such as Sample Data Collection Reports, Equipment Improvement Reports, and Quality Deficiency Reports were examined and analyzed. These reports are generally segregated by generator size and frequency, with the maintenance information being provided in a variety of formats and details. Consistently, higher MTBF figures and detailed documentation was provided by the Aberdeen Proving Ground, while substantially lower and inconsistent data came from field sources.

While controlled laboratory testing, simulating a variety of field conditions, yields vast amounts of data, this data is limited in application, because of the difficulty in determining conditions such as competence, experience level and training of maintenance personnel within a field unit at any given time.

The ultimate measure of reliability is under field conditions, where the generator sets are subjected and maintained under the actual conditions. With this premise in mind the field data presented does highlight malfunctions and corrective actions, but they tend to lack the uniformity of detail and follow-up actions normally available utilizing the Army Maintenance Management System (TAMMS) reports.

Analyzing the data submitted yielded the following trends, which are discussed by set kW ratings.

2.3.4.1 5kW Set. As presented in Appendix B, very little information has been documented on the 5 kW generator set resulting in a low confidence level for reliability data. The data collected yields a Mean Time Between Operational Mission Failure (MTBOMF) of 242 hours. The electrical system (batteries, starters, converters, and gages) accounted for 77.6% of these actions and were top ten parts replacements.

2.3.4.2 10 kW Set. The 10 kW generator set MTBOMF figures for both the 60 Hz and the 400 Hz models were consistent at approximately 615 hours. It should be noted that the data presented was entirely collected at the Aberdeen Proving Grounds. Over a period of a year and 11,000 operating hours, only 18 of the 59 unscheduled maintenance events were considered OMF events. The engine fuel system and the power plant system recorded the majority of the unscheduled maintenance events, including the replacement of two fuel injection pumps, a fuel tank, an engine assembly, and a cylinder head assembly. One note of particular significance between the 5 and 10 kW sets, given the limited data, was in the area of battery and gages. The 10 kW generator sets did not experience the same degree of electrical problems documented in the 5 kW sets. One explanation of this discrepancy may be the difference in physical configuration between the 5 kW and 10 kW sets. The 5 kW set has two cylinders, while the 10 kW has four. Vibration levels are lower in the four cylinder set, thus reducing the number of vibration related gage failures. Other explanations could be the lack of sufficient data, controlled versus field data collection methods, design deficiencies, or any one or more of these areas.

2.3.4.3 15 kW Set. The 15 kW generator set data reflects the greatest number of failures in the generator control system and the power plant system assemblies. Utilizing the existing data the MTOBMF ranged from 234 hours under field data collection to 335 hours collected at Aberdeen. Over the 6 year/107,000 operating hours of data collection, 90 hydraulic actuators were replaced, along with 46 control units, 27 battery sets, and 25 engine assemblies. In November 1982 some generator sets were modified by replacing the existing electro-hydraulic governor units with electric units. These units were tested from 11/82 to 6/85 with 12,460 operating hours logged with no documented governor-related failures.

2.3.4.4 30 kW Set. The data submitted for review and analysis on the 30 kW generator sets is far too inconsistent to accurately analyze trends in OMF events. Data presented on the 60 Hz sets ranged from an MTBF of 320 hours during a 500 hour evaluation to a 2000 hour test at Aberdeen which yielded an MTBF of 751.5 hours. The 400 Hz figures reveal an MTBF of 588 hours during a 500 hour evaluation at Aberdeen, while field sample data collection over 5,723 operational hours in the field resulted in an MTBF of 68.9 hours. System deficiencies were evident in the control system area, with fluctuating or no voltage and fluctuating engine speed as the predominant problems. The second high failure category is in the engine fuel system, where problems consisted mainly of fuel leaks, dirty filters, and inoperative fuel injectors.

While the test data on the 15 kW/30 kW generator sets cannot be considered a reliable data base from which analysis could be used to pinpoint specific items of concern, certain OMF trends are obvious. Figure 2 is a general breakdown of those items which consistently plagued the 15 kW/30 kw sets.

Those items which fall in the prime mover category accounted for the least amount of failures, which can be construed to state that the engine assembly is reasonably reliable.

Problems within the Engine Fuel System category seem to be evenly divided between the injectors, fuel pumps, and those malfunctions directly related to fuel contamination such as clogged filters. It is difficult to provide an assessment of corrective action for the fuel injection and fuel pump assemblies without performing a complete data collection specifically targeted at these items for an extended sampling period. Problems associated with fuel filtration can be attacked through closer Q.A. fuel inspections, tighter maintenance intervals, and education of field maintainers on recognition and follow-up when trends such as this develop.

Battery and associated charging alternator problems associated with Engine Electrical are found at approximately the same percentage of failure throughout all models/sizes of generator sets currently in use today. In terms of unscheduled maintenance actions and costs involved (for replacement parts and man-hours), this area should be thoroughly investigated to remedy this problem.

While the Generator Control System is the second leading contributor to OMF problems, it is also the one area where potential corrective actions are readily apparent. The assemblies and components that make up the control

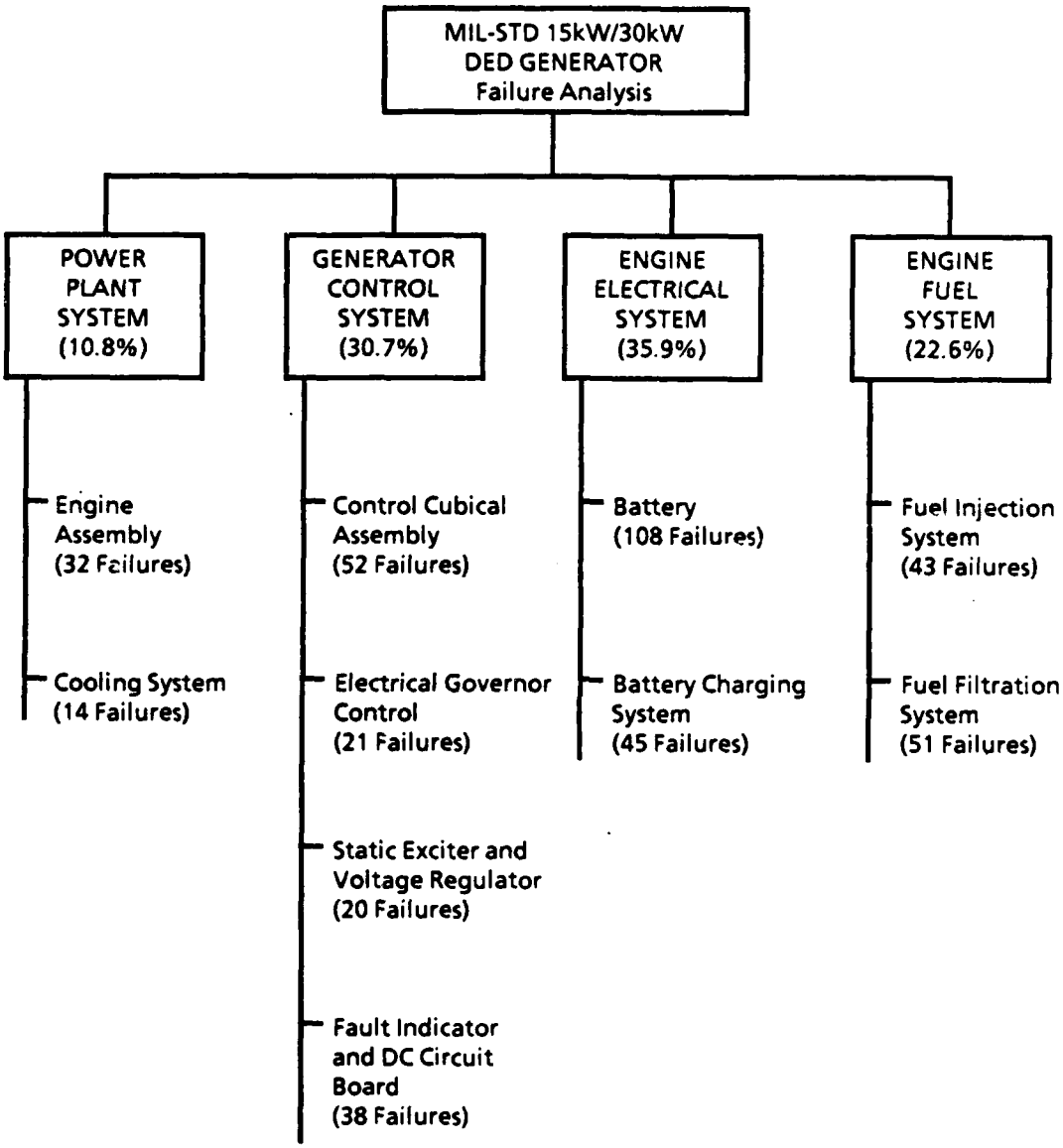

MIL-STD 15kW/30kW
DED GENERATOR
Failure Analysis
POWER PLANT SYSTEM (10.8%)
GENERATOR CONTROL SYSTEM (30.7%)
ENGINE ELECTRICAL SYSTEM (35.9%)
ENGINE FUEL SYSTEM (22.6%)
Engine Assembly (32 Failures)
Cooling System (14 Failures)
Control Cubical Assembly (52 Failures)
Electrical Governor Control (21 Failures)
Static Exciter and Voltage Regulator (20 Failures)
Fault Indicator and DC Circuit Board (38 Failures)
Battery (108 Failures)
Battery Charging System (45 Failures)
Fuel Injection System (43 Failures)
Fuel Filtration System (51 Failures)

Figure 2

system utilized in the generator set fleet may have been considered state-of-the-art twenty-five years ago, but not so today. The current control technology basically utilizes individual closed loop circuits with a number of individual relays for each test, fault monitoring, and operational control function that makes up the electronic control and protective circuitry of the generator sets. The complexity of such a system requires intricate wiring harnesses, added weight, additional costs in logistical support, and has contributed to a decrease in reliability, as evidenced by the various relay and control failures documented over the years. The technology that exists today has the potential capability to correct these problems.

2.3.4.5 60 kW Set. Analysis of the 60 kW generator sets did show some trends/patterns even with the lack of reliable data and proper sampling techniques. During the sampling period of 7/76 through 6/78 the reported MTBF ranged from 375 hours to 564 hours. In the next collection period 7/85 through 7/86 the reported MTBF was only 122.8 hours. In reviewing the numerous EIR's for the 60 kW sets, replacement of the engine assembly resulted in the highest maintenance cost category during both reporting periods and was substantially increased in the latest sampling period. All too often the EIRs listed the problem, causing engine failures, (thrown rods, etc.) as being the phenomenon known as "Wet-Stacking", where unburned diesel fuel and lubricating oil accumulates in the exhaust manifold and muffler of engines that are run at very light loads for extended periods of time. Studies investigating the wet-stacking phenomenon have concluded that although wet-stacking can present "house-keeping" problems, there is no evidence that it causes engine failures. Diesel engines operating for extended intervals at reduced thermal efficiency (caused by low loading and/or low engine speed) can suffer premature wear, in extreme cases, as the result of lubricating oil dilution by unburned fuel. This condition, as well as wet-stacking, can be controlled though the proper application of generator loads. Proper generator loading can be determined through a system load assessment whereby generator size is closely matched to power requirements. Standardization of tactical configurations utilizing load factor analysis would enable field commanders to effectively utilize generator set resources for maximum effectiveness with increased reliability. Proper sizing will increase fuel efficiency.

Other areas of concern with the 60 kW generator sets were water pump and L.E.H. governor failures, both of which were subsequently modified/replaced. During a one year, 251,000 hour operating period prior, 103 governor control units, 109 actuators, 62 generators, and 37 static exciter units were replaced, along with an additional 5000 plus parts. These failures were largely attributable to the 400 Hz precise power set governors. Taking into consideration all of the GFD available for review, the average MTBOMF is calculated to be 354 hours, which is approximately one-half of the ROC objective of 600 hours.

Coupled with the numerous problems/malfunctions and unacceptable MTBOMF ratings, the manufacturer, Allis-Chalmers, is no longer producing the model 3500 series engine used in the 60 kW set. The proper selection of a replacement engine can be used to achieve the goals, as outlined in the current ROC, in terms of reliability, noise and IR suppression. A selection program to replace the engine can take advantage of existing technology to:

(1) Reduce generator set weight.

(2) Improve Reliability.

(3) Incorporate improved solid-state control system elements where applicable.

(4) Integrate both noise and IR suppression techniques field kits/modifications.

(5) Reduce required logistical support in terms of material and manpower.

(6) Reduce life-cycle costs.

2.3.4.6 100 kW Set. During the analysis period between the interim report and this final report VSE independently obtained and researched one item of supplemental data for the 100 kW, 50/60 Hz generator sets. This document contains the results of an evaluation of Development Test III. The test was conducted at Aberdeen Proving Ground during the period 02/74 through 08/74 on five 100 kW sets. Although the document cannot be utilized to develop any statistical basis for conclusions or recommendations, the following is a summarization of the data.

The sets met the functional and operational requirements under normal environmental conditions, but could not fulfil mission requirements for operation at 125 degrees (F). The design of the fuel burning winterization kit did not allow proper combustion nor provide sufficient heat for cold engine starting under the -65 degree (F) criterion. Problems were experienced with the alternators, routing of the wiring harness, time meter, and reverse power relay. In the case of the alternator failures, one failed at 100 hours of operation and the other at 400 hours.

In terms of reliability, three sets were tested for 1500 hours each with 5 operational failures documented. Test evaluators stated that with an 80% confidence factor the calculated true MTBF was between 485 hours and 1850 hours. The conclusion reached by test evaluators was that the performance and reliability of the 100 kW, 50/60 Hz generator set met the design requirements under normal environmental conditions. The generator set will be capable of satisfactory general field usage after the deficiencies are corrected.

2.3.4.7 Summary. While specific recommendations can be found in Section 4.1 of this report, it is evident that improvements are necessary to increase the reliability and maintainability of MEPGS sets. Trade-off studies with regard to acquisition costs, life cycle costs, with all elements of logistical support must be systematically approached and dealt with regardless of the course of action decided upon.

2.4 Industry Survey/Responses. A market survey (Appendix C,) requesting ideas for improving the MEPGS sets in sizes ranging from 5 kW through 100 kW was submitted to 64 industry representatives (Appendix D). The survey requested responses to specific questions regarding their capabilities, areas

TABULAR SUMMARY OF INDUSTRY RESPONSES BY AREA OF CONCERN

VENDORS	RELIABILITY						NOISE REDUCTION	IR SUPPRESSION	NOTHING TO OFFER
	01 STRUCTURAL FRAME	02 ENGINE FUEL	03 ENGINE ELECTRIC	04 POWER PLANT	05 GENERATOR CONTROL	06 GENERATOR ASSEMBLY			
LCE	X	X	X		X		X	X	
ALTURDYNE		X			X		X	X	
WHITE		X					X	X	
ONAN		X					X	X	
FERMONT		X	X	X	X		X	X	
KOHLER			X	X	X		X	X	
DEUTZ			X				X		
CUMMINS				X					
UNITED TECH					X				
GRUMMAN					X		X		
LIMA						X			
MICH. TECH							X	X	
BBN LABS							X	X	
GLAR BAN								X	
POONE ASSOC									X
HOMELITE									X
VTEC-LAB									X
TELEDYNE TOTAL POWER									X
RMS					X				

Table 1

for potential improvements, cost estimates, noise and infrared suppression improvements.

To date, 19 of 64 responses have been received, of which 4 declined to participate. Table 1, "Tabular Summary of Industry Responses By Area of Concern," is provided as a cross matrix of those who responded and the specific areas where the respondent had comments or suggestions of potential improvements. The actual industry letter responses are reproduced in Appendix E. The following sections will address the three areas of primary interest:

- o Reliability
- o Noise Reduction
- o Infrared Suppression

2.4.1 Reliability. With the exception of one vendor, all responses to the survey provided only general statements concerning reliability improvements. Responses tended to refer to broad areas or subsystems where conceptual improvements were feasible. The majority of the respondents expressed concern at the 350 MTBOMF specified in the provided reliability tree. As can be noted in Table 1 at least one industry representative responded in each of the six sub-categories listed under Reliability. All responders expressed optimism that their methodology could greatly improve the existing MTBOMF and generalized approaches that they would take if tasked to undertake the problem. Some stated that the survey, as provided, did not indicate an adequate maintenance history detailing the frequency of component failures and failure modes. Other responders simply stated that significant reliability improvements could be obtained by substituting their particular component as a direct replacement for the currently used MIL-STD component in the existing generator sets.

Deutz Corporation recommended replacement of existing engines with their engines, while Kohler Co cites their engine supplier, Cummins, as a qualified source. The Lima Electric Company recommended replacing the entire generator set with their assembly as the means of improving the reliability program. Specific information describing how these proposed components are superior to the existing MIL-STD components or to their competitors were not detailed, however, numerous reassurances were given tnat the overall reliability of the generator program would realize substantial improvements.

One area where some specific recommendations were make is within the existing electromechanical control system. Four companies provided comments in this area, with two, Kohler and Alturdyne, making general statements concerning the replacement of the existing system with microprocessor-controlled components.

RMS Technologies Inc. provided an information package for improving the Control System. Their proposal consisted of replacing the governor control unit, tactical relay box, special relay box, precise relay box, static exciter/voltage regulator, fault indicator, and electrical governor control with a microprocessor-driven, control box assembly. RMS stated that the control system and wiring harness would be significantly simplified, with the net result being a 50% reduction in the generator control system failures.

RMS provided cost estimates and a milestone graph which depicted approximately 6 months to complete the design and prototype phase at a cost of $359,790.

Grumman Aircraft Systems stated that technology has not matured to the point where specific components are available with well defined cost, weight and performance characteristics. They expanded on their capabilities and experience in the development and design of complex systems, reliability analysis, and laboratory testing and failure analysis. However, they did not provide estimates on the amount of improvement that could be realized or an estimate of the costs involved in any of the areas.

Estimations of increased reliability from responders which did address the control system as a potential area for reliability improvements ranged from 30 to 400 % with MTBF predicted as high as 1900 hours. United Technologies estimated that the component parts count within the control system could be reduced by as much as 50%, thereby reducing the risk of failure.

Very few specifics regarding exactly which components could benefit from solid state technology were given by the majority of the vendors. This could have resulted from the lack of specific information in the survey concerning the exact parts which had high failure rates and the circumstances involving their failure. The Control Cubicle was targeted by most responders due to the survey reliability tree, Appendix C, showing that 50 out of 103 control system failures occurred in the Control Cubicle Assembly. Most vendors that mentioned components listed only items such as digital gages and meters, solid state relays, and microprocessors and digital circuitry. Although it is possible to substitute these particular components they are not truly off-the-shelf plug ins.

VSE recommends caution in the use of solid state devices within the control cubicle and the replacement of the engine governor assembly as a means of improving reliability.

The fuel systems currently in use on the MEPGS sets have integral mechanical governors which are utilized for fuel system control. They provide adequate speed control for utility power generation. IF precise speed control is required, the engine governor is augmented with an electro-hydraulic governor. These devices have consistently exhibited a higher failure rate than that of the mechanical governor unit. Thus suggestions for a microprocessor controlled system would only have applicability to precise sets for improved reliability. It would not be considered a cost effective alternative for utility sets.

Additional problems associated with microprocessor generator control circuitry includes the necessity to adequately cool the components in order to survive high operating temperatures. When cooling is marginal the reliability decreases.

The use of microprocessors will also present problems in the area of EMI/RFI and must be shielded to minimize these problems. Within this same area is the problem of EMP survivability. This is clearly illustrated by the EMP analysis presented in Appendix J. A 30 kW, precise power military

generator set, equipped with a solid state electronic governor, was the subject of the analysis. As the analysis indicates, the components within the system can be expected to experience some form of upset during EMP exposure.

The following areas of concern must also be considered when using solid state devices as replacements in the current system:

- o MOS of maintenance personnel will have to be upgraded
- o Logistics
  - Replacement of repairable items with non-repairable might lower inventory quantity, but could increase inventory cost.
  - Dual inventory/logistical support required outlining modification program
- o Life Cycle
  - A long time period will transpire before cost savings, due to reduced manufacturing cost, can be realized because of development cost and near-term cost listed above.

In summation while comments (with the exception of RMS Technologies) were general in nature, there is exhibited optimism for improving the generator set reliability. Given more time, an approach to obtaining more specific details is to request additional information from those expressing interest in the reliability program and supplying each with detailed information on component failures, operational usage at time of failure, and fault analysis. There is no doubt that improvement in reliability is possible, but the cost, logistics impact, and time to complete is not readily evident from these init responses.

2.4.2 Noise Reduction. Ten responses were received, outlining approaches to noise suppression improvements; see Table 1. Six of the ten respondents described conceptual approaches to noise suppression which ranged from generalities to explicit details. The remaining four respondents either have production models or have prototyped noise suppression generator sets in one or more of the 15, 30 and 60 kW sizes. Before addressing each response, some generalities are described below:

- o Current design and conceptual design approaches are very similar. These include lining the generator housing or providing an insulated housing kit, substituting larger, more effective muffler systems, and modifying all inlet/outlet passages with baffles of varying designs.
- o Due to each approach being an add to/on concept weight will increase. Estimates of weight increase are probably optimistic and range from 5 to 15 %.

- o Estimates of size increases ranged from no increase in dimensions to increases of 36 inches in length to 16 inches in height and 12 inches in width.

White Engines, Inc, Kohler Co., BBN Laboratories, Inc., and Alturdyne have developed prototypes. The amount of information presented by each of the organizations varies significantly in volume, however all information presented is clear, concise, and based on documented evidence.

The reply of White Engines, Inc. addressed the questions outlined in the industry survey and included test documentation, conducted by Area-Therm Corporation in November 1985. Area-Therm's test was performed on a modified 30 kW, 60 Hz, generator set which included a noise suppression and IR kit. (See Section 2.4.3 for IR discussion). Modifications to the set included a centrifugal fan with heat exchanger, and muffler with the basic electrical characteristics unchanged, however, the positions of various electrical outlets, the control panel, and the throttle control were altered.

Acoustical measurements were taken at one meter and seven meters. Two prototype noise suppressors were tested. The environment was a black top roadway with buildings on each side of the roadway. The generator set was mounted on a standard military trailer and placed in the center of the road which was 60 feet wide. Suppressor #1 was designed to reduce sound levels to an average dBA level of 65dBA at 7 meters. Readings at 7 meters ranged from 60-62dBA. The second prototype was constructed with a smaller heat exchanger and a significantly different acoustical design. Its noise levels at 7 meters ranged from 62-66dBA. Average noise readings for unsuppressed 30 kw sets are typically on the order of 86dBA at 7 meters. Area-Therm concluded that minor corrections to the exhaust suppression design could easily bring the noise level down to 63dBA or lower under any operating conditions.

White Engines Inc. stated that they could incorporate this same technology on the 60 kW set with similar results. Kohler Company's approach was the utilization of a larger muffler with several cubic feet of double-wrapped silencing material. The internal housing of the generator set was lined with a thick acoustic foam in order to absorb the mechanical noise radiated through the engine housing. Additional modifications involve installing an efficient sound attenuator at the cooling air entry and at the cooling air exit behind the radiator. Kohler applied these techniques on 15 and 60 kW sets for both SSDED and modified commercial prototypes, with resultant noise levels in the range of 65dBA at 7 meters in any direction.

BBN Laboratories Inc. developed noise suppressed sets for the 1.5 kW GED, 30 kW DED, and 60 kW gas turbine driven sets (GTED). Their design concept consisted of a combination of specially designed silencers, cooling-fan modifications, sound absorbtion, vibration isolation and damping techniques. These techniques were developed and applied to a 30 kW generator set. This modification resulted in a 16-18dBA reduction in the acoustic signature, which translated to a 70-72dBA measurement at 7 meters. Their proposed ideas for the 60 kW sets include intake and exhaust silencers and acoustic linings. Additionally they recommend increasing the size of the cooling fan air intake opening, thus allowing the use of reduced fan speed, achieving an estimated 8-

10dBA reduction. They also intended to reduce structureborne noises by the installation of neoprene isolation mounts. While this type of treatment has a high certainty of success, it is difficult to install as a retrofit since the entire generator must be removed from the housing and the mounting beams modified to accept the new isolators.

Alturdyne currently produces sound suppressed generator sets for the U.S. Air Force, Model EMU-36/E, Ground Launch Cruise Missile System. This particular model is a 60 kW, 400 Hz set that features a weatherproof/sound attenuated enclosure, multi-fuel capabilities, nuclear hardening, IR suppression, precise power, bite-analog diagnostics and is designed to operate in extreme environmental conditions. Additionally nine 60 kW and 125 kW generator sets have been purchased by the Army for evaluation and have demonstrated 65dBA at 7.5 meters. Among their recommendations are softer mounts in greater numbers, absorbitive insulation, traps/baffles of cooling air intake and discharge, and improved silencers.

Analysis of the suggestions received, with respect to noise suppression, have generally taken the same approaches to achieve the desired 70dBA at 7 meters. Unfortunately these methods all add considerable weight. The 60 kW MEPGS set cannot tolerate an increase in weight or size, and still get mounted on a 2-1/2 ton trailer. Size increases are potentially troublesome when addressing transportability. The goal of 70dBA at 7 meters is obtainable and readily available, but a review of weight, sizing, and cost should be undertaken before proceeding with major modifications. Rail impact survivability must also be considered when new, softer engine mounts, to reduce the transmission of engine vibrations, are selected.

2.4.3 Infrared Suppression. As noted in Table 1, nine vendors responded to the IR suppression portion of the survey. Eight of these nine specifically stated that integration or noise and IR suppression is the most feasible approach due to the interrelation of components. As in the area of noise suppression the majority of the responses are generalizations in lieu of specific approaches.

Grumman Aircraft Systems Division, Grumman Corporation offers a theoretical solution to the application of IR techniques that describes best the commonalities presented by the other respondents. Due to the related hardware items, combined noise and IR suppression design is interrelated and can be classified as follows:

- Components that are common to both noise and IR suppression and required for the common suppression purpose (e.g., common acoustic and thermal insulation of the generator set housing walls, overall engine exhaust system, overall air outlet duct, radiator fan, and generator fan).

- Thermal suppression components which impact on noise levels (e.g., engine exhaust IR suppressor and its air fan, air outlet IR suppressor and its fan, redesigned radiator/radiator fan, insulation over parts of engine and exhaust system, housing internal and/or external background thermal matching)

- o Noise suppression components which impact on thermal design (e.g., acoustically treated air inlet/outlet ducts, muffler discharge interface with engine exhaust IR suppressor)

- o Noise suppression components without impact on thermal design (e.g., engine vibration isolation)

The categorization of the related items is used only to demonstrate the requirement for closely interwoven solutions to noise/IR suppression. The majority of the vendors suggestions for suppressing the IR signature included the above classified items. This relationship is also evident in the increases that would result in both weight and dimensional sizes. The average increase in weight for the combined noise/IR kit was estimated as 710 lbs. and the average weight of the IR kit alone was estimated at 565 lbs.

Michigan Technological University stated that the specifications, as written in the SSDED program, do not allow sufficient flexibility in design to develop a reliable, effective and cost efficient IR suppression system. Rather than applying the normal techniques for signature suppression, they proposed to apply a spectrally reflective IR coating in place of the standard CARC paint and that the generator IR signature be defined with the apparent surface temperature as a reference point, not the absolute surface temperature.

The inside housing wall of the double wall structure would be coated with a highly reflective paint which will reduce the thermal radiation exchange internal to the generator set. The outer walls would be biased colder then the anticipated background area using special IR low emissivity coatings, which according to the respondent, are currently being developed at their facility In addition to the spectral type coatings. Temperature and radiant energy sensors will be employed to maintain the outside wall temperatures, utilizing internally generated heat, at a zero degree reference in relation to the outside environment. The result is effectively an IR countermeasure in lieu of an attempt to build boxes around the thermal signature. This concept is a system that will continuously actively sample its outside environment and alter the thermal characteristics of the housing to match the varying thermal characteristics of its environment.

With this approach weight and dimensional sizing would not be a factor. However, this is a theoretical approach in its infant stage of development.

Michigan Technological University did address another area that was not found in any other reply to the survey. They stated that the load leads extending from the generator set (when extended far from the set) create a substantial "que feature" that is evident when viewing generator imagery. They currently do not have a defined design approach to this problem.

Three of the respondents stated that they have prototyped or manufactured combined noise/IR suppression kits. These three companies are White Engine Inc, Alturdyne, and Onan.

White Engines provided test data showing surface temperatures at levels no higher than ambient under solar heating conditions. To achieve these results a new housing, radiator and muffler were integrated into the set.

Alturdyne's 60 kW, 400 Hz generator, model EMU-36/E, which was described in the noise suppression area features infrared suppression also. However, no indication was given in their reply as to the methods employed.

Onan stated that they have developed a system for decreasing the IR signature of 15, 30, and 60 kW sets. They gave no real specifics other than to state that they would suppress the highest levels of temperature, such as the exhaust manifold and muffler. They estimate weight increases of 600 lbs and dimensional increases of 3 inches in length, width, and height.

With the exception of the Michigan Technological University's "active IR countermeasure" theoretical approach, all respondents are essentially advocating the same areas of improvement with respect to combined noise/IR kits.

3.0 Additional Potential Areas for Improvements. After careful analysis of the GFD and industry responses received during the formulation of this report, it became apparent that certain areas for improvement had not been addressed. Having been extensively involved with the MEPGS generator program for many years, VSE has gained considerable experience and knowledge with relation to the operational requirements and problems associated with the program. These improvements were also reviewed from the standpoint of Safety/Human Factors Engineering and, where relevant, these points are also presented.

3.1 Solar Battery Charging. Within the data analyzed concerning battery failure, it was noted that low voltage for cranking the 24 Vdc generator set starting system had been experienced in many of the reported malfunctions. Reduced voltage can result from any combination of events, including:

- discharged battery
- losses due to cable problems
- faulty electronic indicators
- insufficient recharging after initial cranking
- long periods of storage/inactivity

One possible solution to the problem is to offer a constant state of recharging through the use of a passive solar charging system. A representative of this type of system is presented in Appendix J. This particular device is manufactured by Sovonics of Troy, Michigan. The solar panels are lightweight, relatively small (24" x 18"), and help to offset battery discharge during periods when the set is not in use. The rate of charge generated by the panels is dependent of the amount of incident solar energy, but typically ranges from 350ma to 35ma. When purchased in quantity, a system capable of maintaining a charge on two typical generator set 12 Vdc batteries cost approximately $240.00 per system.

The U.S. Army Tank Automotive Command (TACOM) in Warren, Michigan is currently evaluating two of these systems for battery charging maintenance. The inherent flexible nature of this device's solar panels lends itself to field ruggedness. With the available, optional magnetic backing, mounting of the panels is easily accomplished. The system could be issued as auxiliary support equipment for the generator sets, which would minimize logistical support requirements.

3.2 Sealed Batteries. Another potential improvement in the battery area is the use of maintenance-free (sealed) batteries. Several failures in the electrical system were identified as resulting from low fluid levels in the generator set batteries. Current requirements call for periodic inspection of the fluid level, and replenishment when required. However, after long periods of storage or as a result of oversight, the procedures are not always adhered to as required. The removal of this inspection requirement and resultant source of charging system failures would aid in increasing MTBF ratings. Conventional lead acid batteries, when exposed to high temperatures, suffer an accelerated loss of fluid through evaporation, which would not be experienced with the sealed type battery. Although sealed batteries would circumvent this problem, PRO-Battery Inc. reports that the cranking power of the sealed battery is reduced in extremely cold climatic conditions. Despite this reduction in capacity, the elimination of the maintenance required for the current batteries and the resultant increase in readiness make the sealed battery a viable alternative worthy of further investigation.

3.3 Electronic Battery Charger. Still within the area of battery/charging system improvements is the concept of solid state battery charging. This concept has been tested and proven out in certain U.S. Air Force turbine-powered generator sets with defined improvements in reliability (refer to Appendix N). Application of this technology in replacing the current belt driven alternators can reduce certain inherent belt and associated mechanical failures that reduce system reliability. This system would also delete the periodic inspection and tightening required for the belt. It will also eliminate premature alternator bearing failure that may result when maintenance personnel over tighten the belt assembly. The use of a solid state charging system reduces the hazard of exposed rotating parts by eliminating the belt and associated drive components. However, since the alternator pulley also serves the additional function of the idler for the water pump and/or cooling fan, a suitable modification must be designed to accommodate this function.

3.4 Enhanced Fuel Filters/Strainers (Water Separation). Another primary area where potential improvement can be accomplished is the fuel system. The current method of water/fuel separation in the filter canister is adequate to bleed off water from the fuel system. The potential problem with this method is due to the lack of attention to periodic maintenance procedures which requires manually draining the water from the system. There is no device on the current sets to alert the operator as to when there is water accumulation in the fuel filter. If scheduled maintenance is ignored or neglected, the introduction/spill over of water into the secondary fuel system contributes to numerous recorded malfunctions. Technology exists to provide an automatic high water level warning light on the control panel, utilizing an impedance

sensor submerged in the base of the fuel filter canister. Fuel filter/water separators are available commercially, with fuel heater, manual purge valve and remote water level indicator, from several manufacturers (one such product is presented in Appendix K). Filter/water separators from two manufacturers (Stanadyne and DAVCO) with stated features have been tested in generator sets (15 kW and 30 kW) used by PATRIOT Missile System. One 15 kW generator set (MEP-113A) and a 30 kW generator set, modified with such a filter/water separator, have demonstrated that successful start and operation can be accomplished at -10 degrees (F). These units were tested at Belvoir's cold chamber test facility during October 1985 through December 1985. (See Appendix L for details).

3.5 Replace Engine. Current performance of the engine in the 60 kW generator set and the hazards associated with this engine such as noise levels and excessive weight, in conjunction with the knowledge that the manufacturer no longer offers this engine, warrants replacement. Safety and HFE factors to be considered in the procurement of a new engine are weight, noise levels, type of cooling system and, NBC survivability. To be cost effective, engines considered as replacement candidates should be functionally and dimensionally capable of fitting within the existing generator envelope and interfacing with the remaining generator components. Reduced weight of the engine selected would allow the incorporation of a sound suppression kit, improve reliability and lower trailer weight thereby increasing its capability of carrying ancillary equipment.

3.6 Control Cubicle Assembly, Relays. The control cubicle assembly presented a high number of unscheduled events during reliability and maintenance testing. Analysis of accumulated sample data revealed that control box failures were contributed to by, fluctuating voltage, no voltage, fluctuating engine speed and wiring harness chaff. Corrective action consists of replacement of existing relays with solid state relays. The ones to be removed are: K-1 (start relay); K-2 (pre-heat); K-3 (crank); K-4 (Aux fuel solenoid); K-5 (governor solenoid). This change is based on an assumption that the reliability characteristics in terms of performance will significantly increase. The change will incorporate solid state relays, hermetically sealed, where appropriate covered with polycarbonate shield, improved wiring harness, and multi-slotted connectors. The solid state devices can be individually switched out one for one, since the solid states devices can be made with the same pin configuration.

4.0 Conclusions. Results of the evaluations and analyses have identified specific areas of dissimilarity between the current documented requirements for MEPGS generator sets versus proposed requirements set forth in the Required Operational Capability statement. Concurrently, potential product improvement actions which would result in increased reliability, simplified maintenance procedures and reduction of attendant noise ramifications have been addressed. The following paragraphs provide a succinct discussion of findings as they relate to major topics of ROC versus MEPGS differences, noise suppression, IR, and reliability.

4.1 ROC Versus MEPGS Differences. The CGSA units generally have less stringent but broader requirements than the MEPGS units. The scope of the CGSA unit requirements is expanded to include NBC survivability/operability with respect to high altitude Electromagnetic Pulse (EMP), compliance with AR70-71, and set operability with MOPP IV gear. Areas in which the CGSA units have significantly more stringent requirements are noise suppression, reliability and testing/monitoring equipment.

The ROC for the CGSA units does not specify requirements for generator set dimensions or weight, voltage connections and ratings, or grounding systems. The CGSA units are designed to comply with MIL-STD-1332 Class 2, Electrical Performance Standards, which are less stringent than respective MIL-SPECs for the MEPGS units. The MEPGS requirements are also more stringent with respect to environmental requirements, tiedown and lifting requirements. In conclusion, the CGSA ROC requirements should, as a minimum, clearly outline the required technical and performance characteristics as they are currently addressed by the MIL-STDs and MIL-SPECs governing the MEPGS fleet. Any finalized set of standards/specifications to be utilized as developmental and/or procurement action should be a combination of both the CGSA ROC requirements and MEPGS specifications. This will assure that all documentation has been upgraded/revised to include all salient and desired requirements of the ROC and those applicable requirements of the current MEPGS fleet.

Modifications to the MEPGS set designs will upgrade the sets in areas where the CGSA requirements are more stringent and should allow for the adoption of current specifications that can be utilized on the new fleet. In conclusion, these modifications will serve as an interim upgrade, pending final disposition of the MEPGS family.

4.2 Noise Suppression. Absence of specific and stringent noise limit criteria in current standards and specifications has resulted in fragmented attempts to lower the hazards and aural signatures associated with MEPGS generator sets. As new sound attenuation technology emerges, the ability to quiet generators has proven to be attainable and operationally acceptable. Thus, the focus of major attempts to resolve noise problems has been in a retrofit mode, often in Product Improvement Programs.

Noise suppression designs to meet the specifications set forth in the ROC and other MIL-STDS, are not without trade-off implications. Often, weight constraints are prohibitive, designs are not compatible with system operational requisites, and state-of-the-art materials and expertise are extremely costly. All of these must be balanced against the perceived necessity to reduce noise for both tactical and health/safety considerations.

Results of the industry surveys provided substantial proof that adequate sound reduction is attainable. White Engines, Inc., Kohler Co, BBN Laboratories, Inc. and Alturdyne developed various prototypes which met the 70dBA at 7 meter maximum criterion. Their designs, while somewhat varied, adhered closely to proven and conceptual sound attenuation engineering techniques. These techniques were presented by companies such as Onan, in their responses to the industry letter survey, and include:

- o Replacing existing components known to be major noise sources with improved components (i.e. fans of both new materials and lower operating speeds, mufflers/silencers)

- o Isolating and controlling identifiable noise sources, through the use of specially designed sound absorptive materials, air inlet/outlet baffles and traps, etc.

- o Isolating mounting beams, skid mounts, housings and engine assemblies through the use of soft mounts/dampers to reduce vibration and transmission paths of noise.

- o Enclosing the generator set with lightweight sound suppression kits, specifically designed to absorb and diffuse sound emanations.

However, due to these approaches typically being retrofit, weight will increase; optimistically from 5 to 15 % of system total. Also, in most cases, established envelope restrictions will be violated.

In addition to these efforts, another successful application of sound technology was the Regency Net Program. Modifications included adoption of a new engine fan, new fan shrouds, different mufflers, addition of intake and exhaust baffles, and addition of sound insulation and shock mounts. The results of the program are an undeniable success and add validity to the fact that sound suppression standards are achievable.

In similar efforts, VSE currently is developing sound attenuation enclosures to meet the 70dBA at 7 meter requirements for the 5 and 10 kW sets. Again, the weight trade-off is a reality, running approximately 325 lbs and 375 lbs respectively. The major difference with these sets, however, is that they are air-cooled. This establishes design parameters which vary from liquid-cooled units.

Without question, it has been proven that the goal of 70dBA at 7 meters is obtainable, but careful analysis of weight, size, operability, maintainability, tactical requisites and life cycle cost impacts must be assessed prior to beginning any major modification or improvement program. Ultimately, these will validate the application of sound attenuation technology on certain sets, (15 kW, 30 kW and 60 kW) while eliminating such application on others (100 kW).

4.3 IR Suppression. Any effort to suppress the IR signature of the generator sets should be done in close conjunction with the noise suppression effort. Certain noise suppression modifications increase the IR signature as a consequence, and this type of modification must be avoided. Combined kits have been developed by industry for various generator sizes, all using similar technology such as enclosures with thermal insulation and cooling air fans. IR suppression to acceptable levels is achievable, however, and could be pursued further by industry if tasked to do so.

4.4 Reliability. A review of government furnished reliability data has uncovered several areas where corrective action or design improvements potentially could improve the MTBOMF of the generator sets. The most pronounced of these areas are the Engine Ignition System (specifically batteries), the Fuel System, and the Control Assembly. Specific conclusions are listed for each size of generator set as follows:

- 5 and 10 kW Generator Sets. The smaller diesel engine generator sets have many commercial counterparts in service today. The heavier weight of the MEPGS sets make the portability of the CGSAs quite appealing. It is apparent then that an eventual phase out of these sets or a major design modification of these two sizes will eventually result. However, during the interim period of MEPGS set procurement and field operation, several recommendations can be made to upgrade these units to meet the requirements of the CGSA ROC. Battery problems are extremely frequent and reliability improvements could be made in this area. Analysis of control system failures reveals that vibration is a major cause of component malfunction. Solid state relays, which are inherently less affected by vibration than their conventional mechanical counterparts, could improve the reliability of the control relays, gages, and other components.

- 15 and 30 kW Generator Sets. These sets have the greatest potential for modification efforts to bring their characteristics in line with the CGSA ROC. In addition to the problem areas mentioned for the 5 and 10 kW sets, water-laiden fuel was a cause of many operational mission failures in this generator set grouping. A fuel filter modification could prevent such preventive maintenance problems.

- 60 kW Generator Sets. Engine failures were quite frequent in this size set warranting an investigation of total engine replacement to improve reliability. The wet stacking that has been reported to cause such engine failures could be eliminated by performing load-factor analyses on the generator sets in actual field use and match more closely the generator size with the load requirements. Battery and control system failures similar to those of the smaller sizes also were noted and could be improved by solid state technology and battery replacement.

With respect to engine replacement, it was concluded that the use of state-of-the-art engines will reduce the total generator set assemblage weight. The use of newer, state-of-the-art solid state control system elements should be incorporated as much as possible, to augment existing generator set solid state and mechanical devices. This inherently will improve reliability, while reducing life-cycle costs.

Although the increased use of current solid state technology can improve the reliability of the control system, extreme caution should be used when considering this solution. Solid state improvements present unique problems of their own, and can only be considered for certain components. A microprocessor-based control system such as proposed in the Industry Survey should be considered only as a part of a complete rebuild of the generator

sets, to include improved engines, housing, noise/IR suppression kits, and incorporated EMP/NBC survivability.

- o 100 kW Generator Sets. The current weight of this set does not allow any significant modifications to be made to meet the stringent guidelines of the ROC. This being the case, relatively minor modifications could be applied to improve reliability in the near future, but an eventual redesign or phase out of the entire set appears certain.

Additionally in conclusion, it also appears that the reliability of the field data itself could be improved by placing more emphasis on accurate and complete EIRs, QDRs, and SDCs. Industry Survey responses from LCE indicate that the development of proper preventive maintenance and performance monitoring procedures can result in increased reliability through a reduction in equipment failures.

It should be noted that prior to the implementation of any design improvement it must first be evaluated using the following criteria:

- Validity/feasibility
- Time required for implementation
- Cost of production
- Field or depot retrofit
- Logistics impacts

5.0 Recommendations. The following recommendations are consistent with the stated purpose of this engineering evaluation and analysis, which is to identify potential redesign/improvements for MEPGS sets.

5.1 General Recommendations: 5 Through 100 kW Generator Sets. Certain design modifications are recommended for all of the subject generator sets, with the objective of improving reliability in the current sets. The recommended modifications are:

(1) Issue positive solar charging systems as auxiliary support equipment for each generator set, to offset battery discharge.

(2) Investigate the cold start performance of various batteries. With favorable results, replace conventional lead acid batteries used in the 24 Vdc starting systems.

(3) Select and incorporate the use of a solid state battery charger to enhance the existing charging system. Perform design modifications to ensure compatibility with existing hardware.

(4) Replace existing electro-mechanical relays K1, K2, K3, K4 and K5 with their solid state counterparts. It is recommended that these components be further examined for suitability of service. This change is best facilitated if the solid state relays are hermetically sealed, covered (where applicable) with a polycarbonate shield, used with an improved wiring harness, and switched out on a one-to-one basis utilizing the existing socket pin

configuration. Since no one-to-one solid state relay replacements are currently known, these components will likely require a development effort.

(5) Identify specific sets where excessive vibration has lead to wiring harness chaffing and remount/reroute harness to eliminate potential control system shorting.

(6) Contact a few of the respondents to the Industry Survey for a more in-depth analysis of their proposed improvements. As a minimum, it is recommended that the following areas be further investigated through liaison with industry: 5, 10, 15 and 30 kW set fuel system and reliability improvements, and improved maintenance procedures.

5.2 Specific Recommendations.

5.2.1 5 and 10 kW Generator Sets.

(1) Pursuant to the favorable results of on-going development for sound suppression modifications for the 5 and 10 kW sets at VSE, it is recommended that this noise suppression kit be utilized for MEPGS sets. Acceptance of this design modification eliminates any requirement for further noise suppression analyses for the 5 and 10 kW sets.

5.2.2 15 and 30 kW Generator Sets.

(1) It is recommended that the existing fuel filters/strainers be retrofit/modified with an automatic high water level warning light on the generator set control panel. Utilize an impedance sensor submerged in the base of the fuel filter canister. (NOTE: This would require a design modification to the canister.)

(2) It is recommended that the basic principles of the sound attenuation design modifications employed in the Regency Net prototyped be utilized and applied to the 15 and 30 kW generator sets.

5.2.3 60 kW Generator Sets.

(1) It is recommended that a suitable engine replacement be identified considering the below listed factors:

- Weight reduction
- Improved reliability
- Reduced noise level
- Interface compatibility with existing generator components and overall dimensional envelope

(2) Investigate and incorporate, where feasible, a state-of-the-art microprocessor control system into the replacement engine package.

(3) Utilize the basic principles of the sound attenuation design modifications employed in the Regency Net prototypes, as required.

(4) Retrofit existing fuel filter/strainers with an automatic high water level warning light on the generator set control panel. Utilize an impedance sensor submerged in the base of the fuel filter canister. (NOTE: This would require design modification to the canister.)

5.2.4 100 kW Generator Sets.

(1) Retrofit existing fuel filter/strainer with an automatic high water level warning light on the generator set control panel. Utilize an impedance sensor submerged in the base of the fuel filter canister. (NOTE: This would require design modification to the canister.)

Appendix A
Tabulation of ROC and MIL-STD Requirements

CHARACTERISTIC	MIL STD 5 KW 60 HZ	ROC 5 KW 60 HZ	MIL STD 10 KW 60 HZ	MIL STD 10 KW 400 HZ	ROC 10 KW 60 HZ	MIL STD 15 KW 50/60 HZ	ROC 15 KW 60 HZ	MIL STD 30 KW 50/60 HZ	ROC 30 KW 60 HZ	MIL STD 60 KW 50/60 HZ	ROC 60 KW 60 HZ	(NOTE 1) MIL STD 100 KW 50/60 HZ	ROC 100 KW 60 HZ
1) ELECTRICAL CHARACTERISTICS													
i) VOLTAGE													
a - Regulation (%)	3	4	3	3	3	3	3	3	3	3	3	1	3
b - 30 sec. steady state variation (%)	2	2	2	2	2	2	2	2	2	2	2	1	2
c - 4 hr. steady state variation (%)	4	4	4	4	4	4	4	4	4	4	4	2	4
d - DIP (Application of Rated Load %)	20	30	20	20	20	20	20	20	20	20	20	15	20
e - Recovery After DIP (Secs)	3	3	3	3	3	3	3	3	3	3	3	0.5	3
f - Rise (Rejection of Rated Load %)	20	30	20	20	30	20	30	20	30	20	30	15	30
g - Recovery After Rise (Secs)	3	3	3	3	3	3	3	3	3	3	3	0.5	3
h - DIP (Appl. of 200% current) %	35	-	35	35	40	40	40	40	40	40	40	30	40
i - Recovery to 95% rated V (Secs)	5	-	5	5	5	5	5	5	5	5	5	0.7	5
j - 3 ph. Wave form (Max Deviation %)	5	6	5	5	5	5	5	5	5	5	5	5	5
- 1 ph. Wave form (Max. Deviation %)	6	7	6	6	6	-	-	-	-	-	-	-	-
k - 3 ph. Wave form (Max Indiv Harmonic %)	2	3	2	2	2	2	2	2	2	2	2	2	2
- 1 ph. Wave form (Max. Indiv Harmonic %)	3	4	3	3	3	-	-	-	-	-	-	-	-
l - Unbalance (unbalanced load) %	5	5	5	5	5	5	5	5	5	5	5	5	5
m - Phase Balance (%)	1	1	1	1	1	1	1	1	1	1	1	1	1
n - Adjustment Range (Min) %	+5 -1	+5 -5	+5 -1	+5 -1	-	+15 -5	+17 -5	+15 -5	+17 -5	+15 -5	+17 -5	+15 -5	+17 -5
ii) FREQUENCY													
a - Regulation (%)	3	3	3	3	3	2-3	3	2-3	3	2-3	3	0.3	3
b - 30 sec steady state variation (%)	2	4	2	2	2	2	2	2	2	2	2	0.5	2
c - 4 hr steady state variation (%)	3	4	3	3	3	3	3	3	3	3	3	1	3

CHARACTERISTIC	MIL STD 5 KW 60 HZ	ROC 5 KW 60 HZ	MIL STD 10 KW 60 HZ	MIL STD 10 KW 400 HZ	ROC 10 KW 60 HZ	MIL STD 15 KW 50/60 HZ	ROC 15 KW 60 HZ	MIL STD 30 KW 50/60 HZ	ROC 30 KW 60 HZ	MIL STD 60 KW 50/60 HZ	ROC 60 KW 60 HZ	(NOTE 1) MIL STD 100 KW 50/60 HZ	ROC 100 KW 60 HZ
ii) FREQUENCY (Cont'd) d - Undershoot (APPL. of Rated Load %)	3	4	3	3	4	3	4	3	4	3	4	4(2)	4
e - Recovery After Undershoot (Secs)	3	4	3	3	4	3	4	3	4	3	4	2	4
f - Overshoot (Rej. of Rated Load %)	4	5	4	4	4	4	4	4	4	4	4	4(2)	4
g - Recovery After Overshoot (Secs)	3	6	3	3	4	3	4	3	4	3	4	2	4
h - Adjustment Range (Min) %	+3 -3	+3 -3	+3 -3	+5 -5	+3 -3	+4 -3	+3 -3	+4 -3	+3 -3	+4 -3	+3 -3	+3 -3	+3 -3
iii) OVERLOAD CAPABILITY a - Short Durations IAW MIL-STD-1332	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2) NOISE @ 7 METERS (MAX dBA)	79(3)	70	77(3)	77(3)	70	80(3)	70	82(3)	70	86(3)	70	85(3)	70
3) ENVIRONMENTAL OPERATING CONDITIONS *a - Temp range @ 100% rated load and sea* level (°F)	-25/125	-25/120	-25/125	-25/125	-25/120	-25/125	-25/120	-25/125	-25/120	-25/125	-25/120	-25/125	-25/120
b - Rated load @ 5000 ft and 107°F (%)	100	90	100	100	90	100	90	100	90	100	90	100	90
c - Rated load @ 8000 ft and 95°F (%)	90	NR	90	90	NR	90	NR	90	NR	90	NR	90	NR
4) INCLINED OPERATION (max deg. from level)	15	15	15	15	15	15	15	15	15	15	15	15	15
5) STORAGE Temp Range @ any Rel. Humidity (°F)	-65/155	-50/160	-65/155	-65/155	-50/160	-65/155	-50/160	-65/155	-50/160	-65/155	-50/160	-65/155	-50/160
6) FUEL a - Diesel Fuel (VV-F-800) Compatibility	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b - Turbine Fuel (MIL-T-5624) Compatibility	Yes	NR	Yes	Yes	NR	Yes	NR	Yes	NR	Yes	NR	Yes	NR
7) FUEL TANK CAPACITY: a - Operation at rated load (hrs)	8	8	8	8	8	8	8	8	8	8	8	8	8
8) FUEL SYSTEM: a - Air Bleeding Capability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b- Water Bleeding Capability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	X	Yes	Yes	Yes	Yes

CHARACTERISTIC	MIL STD 5 KW 60 HZ	ROC 5 KW 60 HZ	MIL STD 10 KW 60 HZ	MIL STD 10 KW 400 HZ	ROC 10 KW 60 HZ	MIL STD 15 KW 50/60 HZ	ROC 15 KW 60 HZ	MIL STD 30 KW 50/60 HZ	ROC 30 KW 60 HZ	MIL STD 60 KW 50/60 HZ	ROC 60 KW 60 HZ	(NOTE 1) MIL STD 100 KW 50/60 HZ	ROC 100 KW 60 HZ
9) EMI RESTRICTIONS PER MIL-STD-461	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10) STARTING SYSTEM: a - Battery Start and Charging	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b - Slave Receptacle	Yes	Yes	Yes	Yes	Yes	NR(5)	Yes	NR(5)	Yes	NR(5)	Yes	NR(5)	Yes
11) PARALLEL OPERATING CAPABILITY	NR	NR	NR	NR	NR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
12) SAFETY/HUMAN FACTORS ENGINEERING a - IAW MIL-STD-882		Yes			Yes		Yes		Yes		Yes		Yes
b - IAW MIL-STD-454(14)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
c - IAW MIL-STD-1472(13)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
d - IAW MIL-STD-1474	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
13) RELIABILITY (MTBOMF, hrs) (minimum acceptable)	250	500	250	250	600	335	600	335	600	250	600	NS	600
14) GAGES AND MONITORING EQUIPMENT: a - Protection from Destructive Malfunctions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b - Are Fluid Levels Accessible for CHECK and ADDING During Set Operation?	(12) No	Yes	(12) No	(12) No	Yes	Yes(11)	Yes	Yes(11)	Yes	Yes(11)	Yes		Yes
c - Diagnostic Conn. Assy (DCA) and STE/ICE	No	NR	No	No	NR	No	Yes	No	Yes	No	Yes	No	Yes
d - Distribution Illumination Systems, Elec. (DISE) Interface Capability	No	Yes	No	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
e - Devices to Monitor Operation of Gen Set	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
f - Fault Indicator for Set Malfunctions and shutdown	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
g - Battle Short	No	Yes	No	No	Yes	Yes(11)	Yes	Yes(11)	Yes	Yes(11)	Yes	Yes(11)	Yes
h - BLUE/GREEN (SECURE) Lighting	No	Yes	No	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

CHARACTERISTIC	MIL STD 5 KW 60 HZ	ROC 5 KW 60 HZ	MIL STD 10 KW 60 HZ	MIL STD 10 KW 400 HZ	ROC 10 KW 60 HZ	MIL STD 15 KW 50/60 HZ	ROC 15 KW 60 HZ	MIL STD 30 KW 50/60 HZ	ROC 30 KW 60 HZ	MIL STD 60 KW 50/60 HZ	ROC 60 KW 60 HZ	(NOTE 1) MIL STD 100 KW 50/60 HZ	ROC 100 KW 60 HZ
15) TRANSPORTABILITY: a - Lifting Provisions, Strength of (% of total set wgt.)	800	480[7]	800	800	480[7]	800	480[7]	800	480[7]	800	480[7]	800	480[7]
b - Towing Provisions - Strength of (% of total set wgt.)	500	NS	500	500	NS	500	NS	500	NS	500	NS	500	NS
c - By Air, Sea, Rail, Surface	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
D - Exernally Air Transportable (EAT) By Light-To-Medium Rotary Wing Aircraft		Yes			Yes		Yes		Yes		Yes		NA
e - By Low Velocity Air Drop (LVAD)		Yes			Yes								
F - By Low Altitude Parachute Extraction (LAPES)		Yes			Yes		Yes		Yes		Yes		NA
16) NBC SURVIVABILITY: a - High Alatitude Electromagnetic Pulse (EMP)		Yes			Yes		Yes		Yes		Yes		Yes
b - IAW (AR 70-71)		Yes			Yes		Yes		Yes		Yes		Yes
c - Set Operation Possible In MOPP IV Gear		Yes			Yes		Yes		Yes		Yes		Yes
17) OIL SYSTEM: a - Engine oil Sampling Valve		NR			NR		Yes		Yes		Yes		Yes
b - Oil Change Possible In 20 Mins. By 1 Person?	Yes[9]	Yes	Yes[9]	Yes[9]	Yes	Yes[9]	Yes	Yes[9]	Yes	Yes[9]	Yes	Yes[9]	Yes
18) TRAILER CAPACITY[10]: a - Ability To Mount Ancillary Equipment (400 lbs) On Trailer With Gen Set W/O Exceeding Trailer WGT Limit	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes

CHARACTERISTIC	MIL STD 5 KW 60 HZ	ROC 5 KW 60 HZ	MIL STD 10 KW 60 HZ	MIL STD 10 KW 400 HZ	ROC 10 KW 60 HZ	MIL STD 15 KW 50/60 HZ	ROC 15 KW 60 HZ	MIL STD 30 KW 50/60 HZ	ROC 30 KW 60 HZ	MIL STD 60 KW 50/60 HZ	ROC 60 KW 60 HZ	(NOTE 1) MIL STD 100 KW 50/60 HZ	ROC 100 KW 60 HZ
19) DRAIN ACCESSIBILITY:													
a - Oil	(11) Yes	Yes	(11) Yes	(11) Yes	Yes	(11) Yes	Yes	(11) Yes	Yes	(11) Yes	Yes	(11) Yes	Yes
b - Coolant	NA	Yes	NA	NA	Yes	(11) Yes	Yes	(11) Yes	Yes	(11) Yes	Yes	(11) Yes	Yes

Notes:

1 - MIL-STD-633 was used as governing document
2 - 75% of rated load
3 - Noise at 7.6 meters
4 - NR means No Requirement called out in the military specifications
5 - Actual fielded units have slave receptacles, as called out by the original Purchase Description.
6 - NS means Not Specified
7 - Calculated in accordance with MIL-STD-209, Sect. 5.1.1.1
8 - NA means not applicable or required
9 - Based on accessible positioning of oil filter and drain per Tech manual
10 - Towed assemblage weights tabulated in Appendix H
11 - Based on diagrams associated with the individual set tech manuals
12 - Tech manuals do not provide for lube oil checks during operation
13 - Invoked by MIL-STD-1474 for MIL-STD sets
14 - Invoked by MIL-STD-1472 for MIL-STD sets

Appendix B
Reliability

5 KW

REF.

400 Hz - No data available

60 Hz - Based on data collection between 8/80 and 7/82, 50420 operating hours were logged with 208 Operational Mission Failures. This yields a Mean Time Between Failure (MTBF) of 242.4 hours. A (pg. 33) A (pg. 34)

The total number of unscheduled maintenance events in the period was 595. A (pg. 34)

The top 10 unscheduled parts replacement is as follows: A (pg. 35)

Part	Quantity Replaced
Battery	88
Muffler	38
Hour meter	26
Starter	16
Fuel gage	16
Regulator	13
Oil pressure gage	10
Frequency meter	9
Frequency converter	9
Stator	8

REF.

60 Hz - Tests performed at Aberdeen Proving Ground completed in May 1979 and November 1981 resulted in a MTBF of 638 hrs during 4600 operating hours, and 650.8 during 1500 operating hours. — A (pg. 15)

No other data available.

400 Hz - Cumulative results spanning report periods of 7/85 - 12/85 and 1/86 - 6/86 showed 11,065 operating hours, 59 unscheduled events, with 18 of these being not Mission Capable events. MTBF = $\frac{11,065}{18}$ = 614.7 hrs — B; C (pg. vi); C (pg. 53)

The 59 unscheduled events were in the following categories:

Category		Number of Events
02	Engine fuel system	20
04	Power plant system	21
05	Control box assy	9
03	Engine ignition assy	3
00	Generator set	4
01	Structural frame assy	1
06	Generator assy	1
	TOTAL	59

C (pg. 71)

Replacements of fuel injector pumps, drain cocks, fuel filters and tubes, and the repair of a fuel tank assembly accounted for the engine fuel system registering the highest number of unscheduled events. Repair of an oil filter assembly and replacement of an air cleaner cap, engine oil, air filters, a governor control cable, and a hydraulic cylinder assembly account for unscheduled maintenance to the power plant system. — C (pg. 68)

Total unscheduled parts replacement is as follows:

Part Replaced	Quantity
Engine oil	40 gal
Filter element	6
Air cleaner element	6
Filter assembly	6
Fuel filter	6
Total time meter	5
Battery	3
Packing	2
Fuel injection pump	2
Fuel supply tube	2
Drain cock	2
Gasket	2
Fuse	2
Rotary switch	2

C (pg. 80)

10 KW (Continued) 2 of 2

REF.

Part Replaced	Quantity
AC volt meter	2
Air cleaner cap	1
Cylinder head assy	1
4-Cyl diesel engine	1
Fuel cartridge	1
Fuel tube	1
Fuel tank	1
Starter	1
Knob	1

REF.

60 Hz - A test of 938.7 operating hours performed at Aberdeen Proving Grounds in May 1982 showed a MTBF of 335 hrs. — A (pg. 15)

- Sample Data Collection field data over roughly the same period (8/80 - 7/82) consisted of 37,223 operating hours with A MTBF of 300.2 OMF events totaled 124 — A (pg. 16) A (pg. 37)

- The top 10 unscheduled parts replacement for this period (8/80-7/82) is as follows: — A (pg. 38)

Part	Quantity Replaced
Battery	27
Electrolite	16
Tank, ether	6
Relay	6
Exciter, static	6
Engine, diesel	4
Starter	4
Alternator	4
Fire extinguisher	4
Rheostat, voltage	4

400 Hz - SDC cumulative field data collection from 8/80 to 7/86 logged 107,232 operating hours, 854 unscheduled events (458 of these were OMF events) for a MTBF of 234 hrs. — D (pg. 8) D (pg. 14)

- The 854 unscheduled events occurred in the following categories: — D (pg. 29)

Category		Number of Events
05	Control box	306
04	Power plant system	204
02	Engine fuel system	130
00	Generator set	45
03	Engine ignition system	63
19	Hydraulic system	91
01	Structural frame assy	12
06	Generator assy	3
	TOTAL	854

D (pg. 29)

The highest unscheduled maintenance events reported were in the control box assembly, consisting of various meter and gauge/ indicator replacements and repairs. The unscheduled events that accounted for the largest portion of the power plant system man-hours were replacement of engine assemblies. — D (pg. 27)

Total unscheduled parts replacement for this cumulative period is as follows: — D (pg. 40)

REF.

Part	Quantity Replaced
Engine oil	319 quart
Actuator unit	90
Fuel filter secondary	51
Control unit	46
Oil filter element	27
Battery	27
Engine assembly	25
Frequency meter	22
Air filter element	21
Diesel fuel	20 gal
Alternator, generator	16
Lube oil	16 quart
Hydraulic fluid	16 quart
Fuel injection pump	15
Drain cock	15
Control governor unit	15
Electric fuel pump	14
V-belt	14
Relay assembly	13
Incandescent lamp	13
Current meter	13
Engine speed switch	12
Incandescent light	11
Incandescent lamp	11
Variable rheostat	10

- In November of 1982 the electro-hydraulic governors of some generators were changed to electric governor units and data was collected on these modified sets. From 11/82 to 6/85 12,460 operating hours were logged, with 46 OMF events, resulting in a MTBF of 270.9. D (pg. 40)

- The top 10 unscheduled parts replacement for this modified generator for the period (11/82 - 6/85) is as follows: D (pg. 40)

Part	Quantity Replaced
Load bank kit	12
Valve seal	8
Shutter gasket	5
Shaft seal	4
Current meter	4
Circuit breaker	3
Speed switch assy	3
Alternator	2
Tube seal	2
Battery	2

15 KW (Continued) 3 of 3

	REF.
The general opinion is that the electronic governor assemblies are much more reliable than the hydraulic governors and experience less unscheduled maintenance.	D App. B

REF.

60 Hz - Test performed at Aberdeen Proving Ground completed in February 1977 and March 1979 resulted in a MTBF of 320 hrs during a 500 hour evaluation, and an MTBF of 751.5 hrs during 2000 hours of operation. — A (pg. 15)

- Sample Data Collection field data over a period between 8/80 and 7/82 compiled 29,157 operating hours, with 64 Operational Mission Failure events giving a MTBF of 455.6 — A (pg. 16) A (pg. 47)

- The top 10 unscheduled parts replacement for this period (8/80 - 7/82) is as follows: — A (pg. 48)

Part	Quantity Replaced
Battery	34
Drain cock	10
KW meter	6
Fuel pump	4
Total time meter	4
Starter	3
Terminal, stud	3
Current meter	3
Voltage meter	3
Fuel filter cap	2

400 Hz - A 500 hour evaluation test was performed at Aberdeen Proving Ground in February 1977 and results indicated an MTBF of 588 hrs. — A (pg. 15)

- The following is a list of the parts that failed during the APG test and the hours at which failed: — A (pg. 17)

Failed Part	APG Hours
Engine timing gears	1262
Over speed switch	2.5/81/210
Wiring	21
Crank relay	81/365
Hour meter	233

- The over speed switch that failed 3 times during the APG test had a fix done to it after testing that field data confirmed was a solution to the problem. — A (pg. 18)

- Sample Data Collection cumulative field data for the period 8/8 - 7/86 logged 5723 operating hours, 135 unscheduled events (83 of these were Operational Mission Failure events) for a MTBF of 68.9 hrs — D (pg. 52) D (pg. 58)

REF.

- The 135 unscheduled events were in the following categories: D (pg. 73)

Category		Number of Events
00	Generator set	10
05	Control box assy	37
03	Engine ignition system	27
04	Power plant system	24
02	Engine fuel system	23
19	Hydraulic system	13
01	Structural frame	1
	TOTAL	135

- The highest number of unscheduled maintenance events were in the control box assembly, with fluctuating frequency, fluctuating or no voltage and fluctuating engine speed as the most common deficiencies. The second category for deficiencies is the engine fuel system including fuel leaks, dirty fuel filters and inoperative fuel injectors. For the engine ignition system the chief deficiencies were weak or dead batteries and a few inoperative alternators. Several oil leaks and dirty filters appeared in the power plant system and leaking of the hydraulic actuator accounted for most deficiencies of the hydraulic system. The structural frame assembly had a missing gasket in the battery box door. D (pg. 71)

- Total unscheduled parts replacement for this cumulative period is as follows: D (pg. 80)

Part	Quantity Replaced
Battery	20
Engine oil	16 quart
Hydraulic actuator	14
Injector pump	8
Control governor unit	6
Antifreeze	6 gallon
Frequency meter	5 set
Watt converter	5
Alternator	4
Oil filter	4
Drain cock	4
Oil pan gasket	4
Gasket kit	3
Incandescent lamp	3
Kilowatt meter	3
Injector pump seal	2
Engine starter	2
Air filter	2

REF.

Part	Quantity Replaced
Rheostat	2
Speed control switch	2
Special assembly relay	2
Load bank kit	2
Static exciter	2
Current meter	2

- Since many times the generators sit idle for several months, what may actually be responsible for many deficiencies is deterioration through lack of use. D App A

REF.

60 Hz - Tests performed at Aberdeen Proving Ground in June 1978 logged 1000 operating hours and gave a MTBF of 375 hours — A (pg. 15)

- No other data available.

400 Hz - A 3000 hour test completed at Aberdeen Proving Ground in September 1977 produced a MTBF of 564 hours — A (pg. 15)

- Sample Data Collection field data for the period 7/76 through 6/77 covered 251,384 operating hours and documented 96 unscheduled maintenance events. No MTBF can be calculated however since it is unknown how may of these events result in mission failures. — A (pg. 53), A (pg. 55)

- The top ten replacement parts for this period (7/76 - 6/77) are as follows: — D (pg. 56)

Part	Quantity Replaced	A (pg. 57)
Air filter element	1828	
Filter element	1704	
Filter element	1031	
Actuator	109	
Control governor	103	
Generator	62	
Excitation	37	
Pump assembly	34	
Relay assembly	22	
Indicator	18	

- Cumulative SDC field data collected between 7/85 and 6/86 over 5527 operating hours resulted in 75 unscheduled events, 43 of which are non-mission capable, giving a MTBF of 122.8 hours. — C (pg. iv), C (pg. 14)

- The 75 unscheduled events occurred in the following categories: — C (pg. 28)

Category	Number of Events
05 Control box assy	35
04 Power plant system	15
02 Engine fuel system	14
00 Generator set	5
19 Hydraulic system	4
03 Engine ignition system	2

60 KW (Continued) 2 of 2

REF.

- Adjustments to the governor control units and replacements of hour meters and frequency meters account for the control box assembly registering the highest number of events. Replacements of engine assemblies, governor assemblies, and oil and air filters account for unscheduled maintenance to the power plant system. C (pg. 26)

- Total unscheduled parts replacement for this period (7/85 - 6/86) is as follows: C (pg. 36)

Part	Quantity Replaced	
Oil filter	26	
Governor	6	gallon
Hydraulic oil	6	
Actuator assembly	5	
Fuel pump meter	4	
Oil filter element	4	
Total time meter	4	
Fuel pump	3	
Engine assembly	2	
Primary fuel filter	2	
Secondary fuel filter	2	
Filter element	2	
Alternator belt	2	
Radiator hose	2	
Gasket	2	
Loop clamp	2	
Relay assembly	2	
Excitation system	2	
Hertz meter	2	sets
Hydraulic fluid	2	quarts
Continuous speed switch	1	
Fuel level switch	1	
Fuel tank	1	
Starter assembly	1	

100 KW

60 Hz - No available data.

400 Hz - No available data.

LIST OF REFERENCES

A - RAM baseline for MIL-STD generators produced by TROSCOM Product Assurance July 1986

B - Sample Data Collection, Logistic Management Analysis Semi-Annual Report 21 July 1985 - 31 December 1985
60 KW 400 Hz DED MEP 115A
10 KW 400 Hz DED MEP 112A
produced by COBRO Corporation for TROSCOM April 1986

C - Sample Data Collection, Logistic Management Analysis Semi-Annual Report 1 January 1986 - 30 June 1986
60 KW 400 Hz DED
10 KW 400 Hz DED
produced by COBRO Corporation for TROSCOM October 1986

D - Sample Data Collection, Logistics Management Analysis Semi-Annual Summary 1 Feb 1986 - 31 July 1986
15 KW 400 Hz DED MEP 113A
30 KW 400 Hz DED MEP 114A
produced by COBRO Corporation for TROSCOM January 1987

Appendix C
Industry Survey Letter and Form

BISHOP

DEPARTMENT OF THE ARMY
US ARMY ELECTRONICS RESEARCH AND DEVELOPMENT ENGINEERING CENTER
FORT BELVOIR, VIRGINIA 22060-5606

February 26, 1987

Power Equipment
Support Team

Mr. Michael Spees
Lima Electric Company, Inc.
P.O. Box 918
Lima, Ohio 45802

Dear Mr. Spees:

The Army is planning a program to build improved prototypes of our current standard family of DoD Diesel Engine Driven Generator Sets in sizes 5kw, 10kW, 15kW, 30kW, 60kW and 100kW. Our primary areas of interest are reliability, noise and infrared suppression.

The purpose of this questionnaire is to solicit industry input for resolving operational problems of the DoD generator set fleet. Completion and return of the questionnaire and any additional information you may wish to furnish, is appreciated. The information thus furnished may be the basis for procurement of services and material for purposes of experimentation, and for eventual incorporation into the improved generator set fleet. In the interest of protecting your company's technology, it is requested that any information furnished at this time be of a non-proprietary nature; furthermore, it must be understood that any information furnished as a result of this questionnaire is without obligation to the Government. Your information is requested by March 16, 1987.

Please contact me if you have any questions at (703) 664-5596.

Sincerely,

Noel D. Bishop
Chief, Power Equipment Support Team
Power Generation Division
Logistics Support Directorate

Enclosure

QUESTIONNAIRE

1. Are you a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets? Please describe. _____

_____.

If you manufacture other diesel engine driven equipment, what is the equipment?

_____

2. What is an estimated average yearly usage for your equipment? _____

What is the estimated operating cycle of your equipment (8 hours per day, 5 days per week, etc.)? Please describe. _____

_____.

3. By what methods do you receive feedback from users on your equipment (application, engineering, sales, warranty replacements, etc.)? Please describe. _____

_____.

4. If you are not a manufacturer, what is your position in the market place? Please furnish description._____

_____.

5. The DoD generator sets, once in user hands, are operated outside, exposed to the elements in many parts of the world and are exposed to all climatic conditions. Their operating cycle may be around the clock, for extended periods, with short shut down intervals for servicing or they may sit idle, being operated only a few hours per month. The majority of our sets are trailer

mounted on open trailers and during some field exercises they are frequently transported over roads ranging from highways to open cross country terrain. The sets are typically operated by soldiers primarily trained to operate other equipment such as radios, radar, trucks, etc. Typically they are maintained by trained repairmen with limited experience. If you are interested in the reliability portion of the program, please consider the above, look at the attached reliability tree and answer the following questions:

a. Based on your experience, what part(s) of the tree do you think you can improve? _____

_____.

b. How much improvement do you think you can provide? _____

_____.

c. Describe your approach for making the improvements. _____

_____

_____.

d. Furnish a cost estimate for your program. _____.

6. The generator set described in the attached figure is a typical military liquid cooled diesel engine driven generator set. It is designed so that the engine fan pulls air through the generator end for cooling the electrical apparatus, as well as combustion air and cooling air for the engine. The air is discharged through thermostatically controlled louvers on the radiator end. The 120hp at 1800 RPM/6 cylinder turbocharged engine uses a 15hp standard four blade metal fan for moving the air. The engine muffler is located within the set housing and the engine exhaust is out the radiator end near the top. The generator is single bearing, four pole, with a synchronous speed of 1800 RPM.

The engine generator set assembly uses a three point mounting, two generator feet and an engine trunnion mount, and is mounted directly to the skid base. The present noise level of the set is 87dBA at a 7 meter distance from the set. The set has a metal housing, with all bolted construction. The present housing + muffler offers very little sound attenuation. Considering the above, please answer the questions applicable to your area of interest.

a. Please describe your general approach for lowering the noise emitted from the set in any direction to 70 dBA at 7 meters. _____

_____

_____

_____.

b. What would be your guesstimation of the set weight and dimensional increase required for your sound attenuation effort? _____

_____

c. Please describe your general approach for decreasing the infrared signature of the set. _____

_____

_____.

d. What would be your guesstimation of the set weight and dimensional increase required for decreasing the infrared signature of the set? _____

_____

_____.

e. If you are interested in both the sound and infrared reduction efforts, how do you foresee their interrelation? _____

_____

_____.

f. What would be your guesstimate of the net set weight and dimensional increase for both efforts? _____

_____.

MILITARY STANDARD
MOBILE ELECTRIC POWER
ENGINE GENERATOR STANDARD FAMILY
MEP-006A, 60 kW, 50-60 Hz, DIESEL ENGINE-DRIVEN GENERATOR SET
CHARACTERISTICS DATA SHEET

CLASSIFICATION

Description: 60 kW @ 0.8 power factor, 50/60 Hz, 120/208 V, 240/416 V

Model:	MEP-006A	Type:	I (tactical)
NSN:	6115-00-118-1243	Class:	2 (utility)
Spec:	MIL-G-52884/8	Mode:	I (50/60 Hz)

PHYSICAL CHARACTERISTICS

Dimensions: See Figures 35 and 36 on pages 125 and 126.

Weight: 4240 lbs (1923 kg).

Mobility: Fully housed. Mounted on skid base. Lifting and tie-down attachments provided. Fork lift provision.

Engine: Diesel. Std: MIL-STD-1410. Horsepower: 167 @ 1800 RPM. No. of cyl: 6. Cycle 4. Liquid cooled. 24 VDC electric start. Operating speed: 50 Hz: 1500 RPM, 60 Hz: 1800 RPM. Fuel tank capacity: 55 gallons (approx 8 hours at rated load). Fuel pump lift: 12 feet.

Fuel:
Primary: VV-F-800; Diesel Fuel Oil, types DF-1, DF-2 and DF-A.
Emergency Fuel: MIL-T-5624, Aviation Turbine Fuels, grades JP-4 and JP-5.

Electrical:
Drip proof generator enclosure. Capable of parallel operation. Fungus and moisture treatment. Solid state voltage regulator. Brushless rotary exciter.

Voltage Connection:
60 Hz: 120/208 V, 3 phase, 4 wire. 240/416 V, 3 phase, 4 wire.
50 Hz: 120/208 V, 3 phase, 4 wire. 240/416 V, 3 phase, 4 wire.

Protective Devices: Short circuit protection. Overvoltage protection. Overload protection. Reverse power protection. Low oil pressure cut-off switch. High temperature cut-off switch. Low fuel level cut-off switch. Overspeed cut-off switch.

Instrumentation: Voltmeter. Frequency meter. Ammeter. Hourmeter. Wattmeter (% load). Oil pressure gage. Battery charging ammeter (% current). Fault indicating system. Coolant temperature indicator. Fuel level.

FUNCTIONAL/OPERATIONAL CHARACTERISTICS

Reliability: Mean Time Between Failures (MTBF): 500 hours (specified).

Fuel Consumption: 6 gph at rated load.

Electromagnetic Interference: Suppression to MIL-STD-461 limits.

	Voltage	Frequency
Steady State Stability (variation)		
Short Term (30 sec)	2% Bandwidth	2% Bandwidth
Long Term (4 hours)	4% Bandwidth	3% Bandwidth
Transient Performance		
Application of rated load	20% Dip	3% Undershoot
recovery	3 Sec	3 Sec
Rejection of rated load	20% Rise	4% Overshoot
recovery	3 Sec	3 Sec
Application of simulated motor load	40% Dip	
recovery	5 Sec	
Waveform		
Maximum Deviation Factor	5%	
Individual Harmonic	2%	
Regulation	3%	2-3% (Adjustable)

Adjustment Range for Standard Voltage Connections

120/208 V Conn: 60 Hz: 197 to 240 V. 50 Hz: 190 to 213 V.
240/416 V Conn: 60 Hz: 395 to 480 V. 50 Hz: 380 to 426 V.

Frequency Adjustment Range: 58 to 62 Hz. 48 to 52 Hz.

ENVIRONMENTAL DATA

Power Output at Environmental Conditions:

60 kW, 60 Hz, Sea Level: Minus 25° F (-31.7° C) to plus 125° F (+51.7°C)
60 kW, 60 Hz, 5000 feet: Minus 25° F (-31.7° C) to plus 107° F (+41.7° C)
50 kW, 50 Hz, Sea Level: Minus 25° F (-31.7° C) to plus 125° F (+51.7° C)
50 kW, 50 Hz, 5000 feet: Minus 25° F (-31.7° C) to plus 107° F (+41.7° C)
Winterization system extends lower temperature limit to minus 65° F (-53.9° C).

Shock and Rough Handling: 10 mph railroad impact. 12 inch end drop. Truck and trailer transportation.

Attitude: Operate with base level or inclined no more than 15 degrees from level.

Noise Level: 86 dbA @ 25 feet.

OPTIONAL EQUIPMENT

See 4.4.3 of MIL-STD-633 for additional information on optional equipment.

Description	NSN	Weight lbs (kg)	Effect on Dim (ins)
Wntzn Kit (Fuel burning)	6115-00-407-8314	45 (20.4)	Int
Wntzn Kit (Electric)	6115-00-455-7693	40 (18.1)	Int
Wntzn Kit, Aux, Fuel burning	6115-00-463-9098	350 (158.8)	Aux: (41x40x26)
Wntzn Kit, Aux, Elect.	6115-00-463-9099	260 (117.9)	Aux: (36x27x19)
Remote Control Box	6115-00-420-8490	8 (3.6)	Int
Load Bank	6115-00-407-8322	272 (123.4)	Ext: H+15
Wheel Mounting Kit	6115-00-463-9092	564 (255.8)	Ext: L+8,W+32,H+9
Panel, Auto, Load Transfer, 60 Hz	6115-00-477-7932	825 (374.2)	Aux: (44x19x42)
Paralleling Cable	6140-00-197-4934	4 (1.8)	Ext: (L=25 ft)
Relay Assembly, Precise	6115-00-276-7622		Int

REFERENCE DOCUMENTS

Technical Manuals:

Army	Air Force	Marine Corps	Navy
TM	TO		NAVFAC
5-6115-545-12	35C2-3-444-1	TM-00038G-12	P-8-626-12
5-6115-545-34	35C2-3-444-2	TM-00038G-35	P-8-626-34
5-6115-545-24P	35C2-3-444-4	SL-00038G	P-8-626-24P

LO
5-6115-545-12

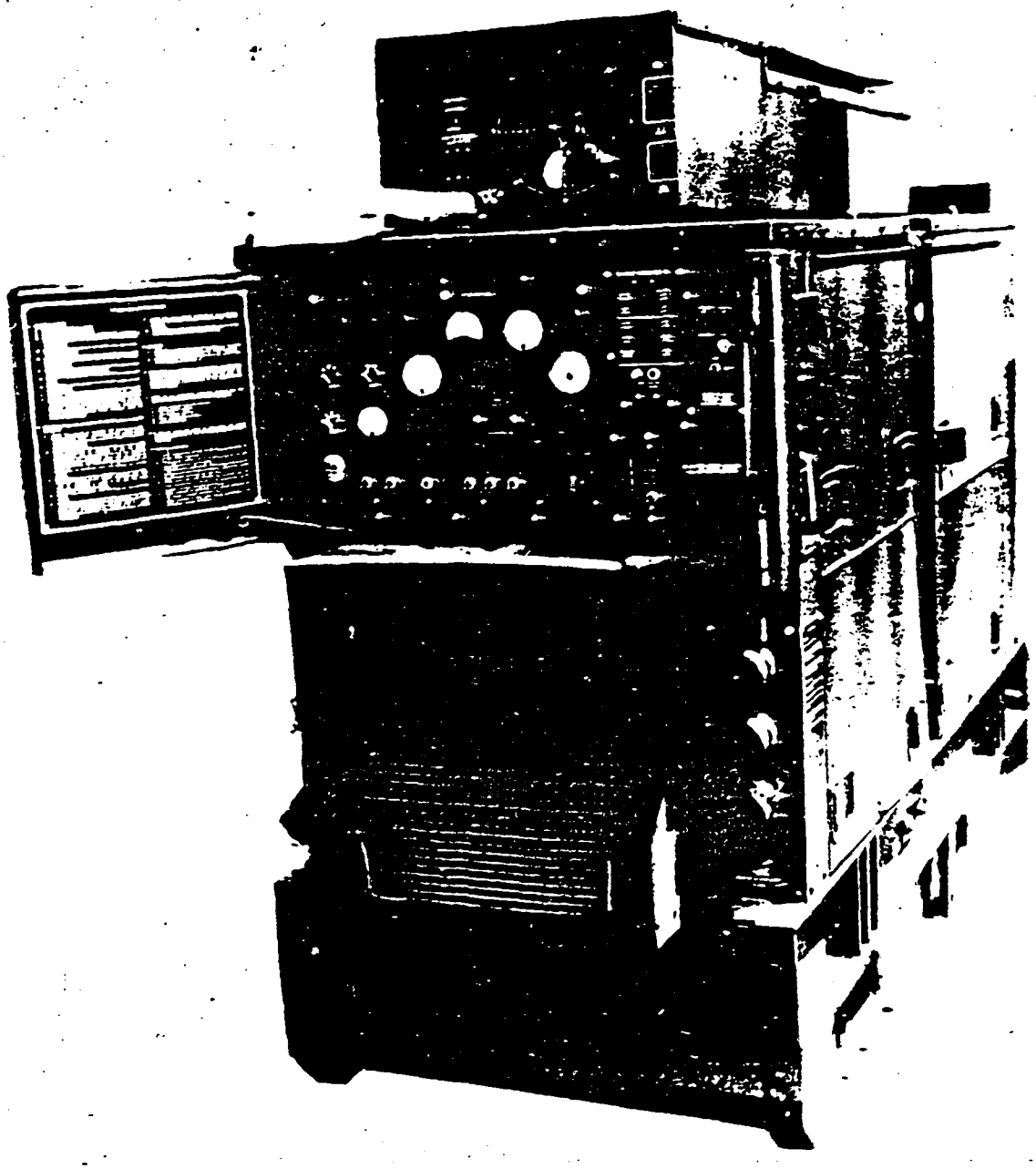
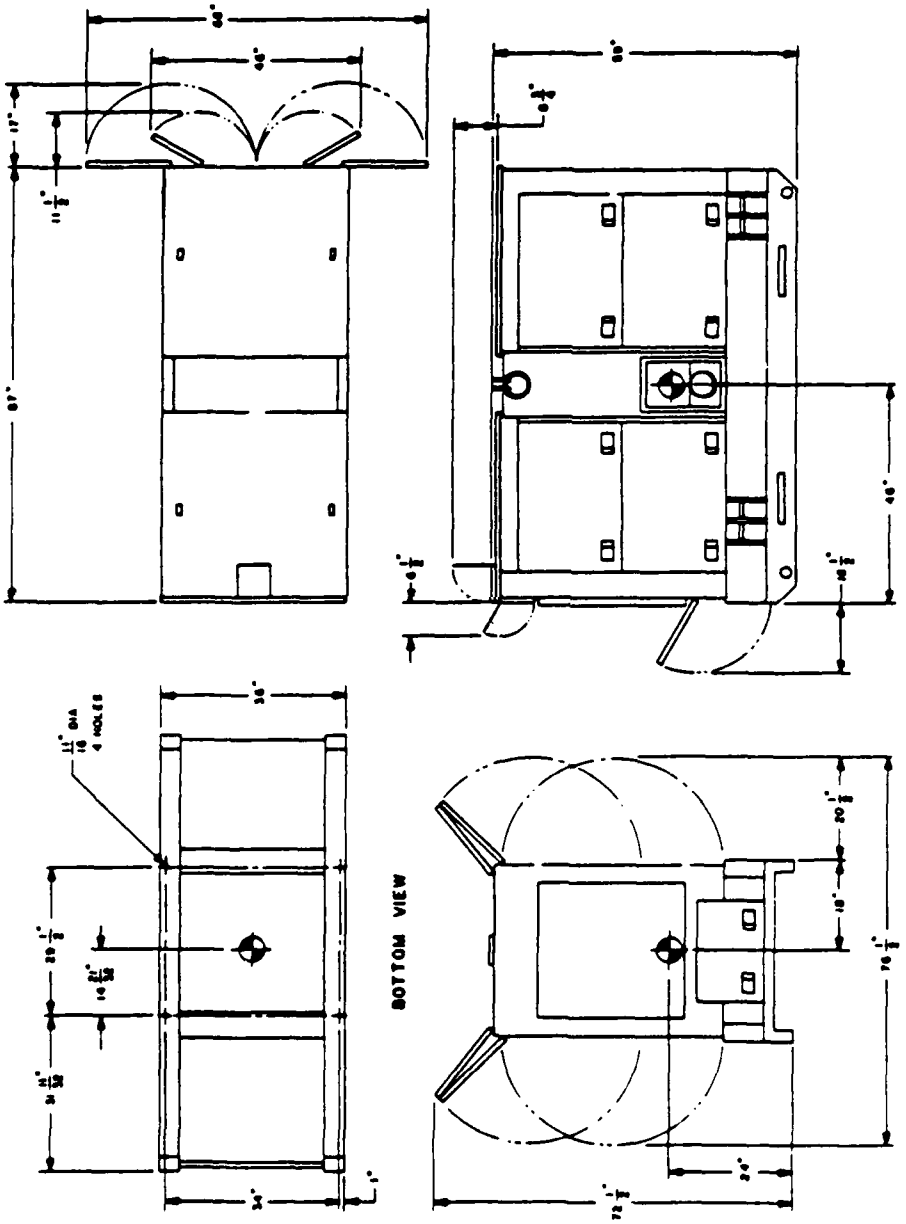


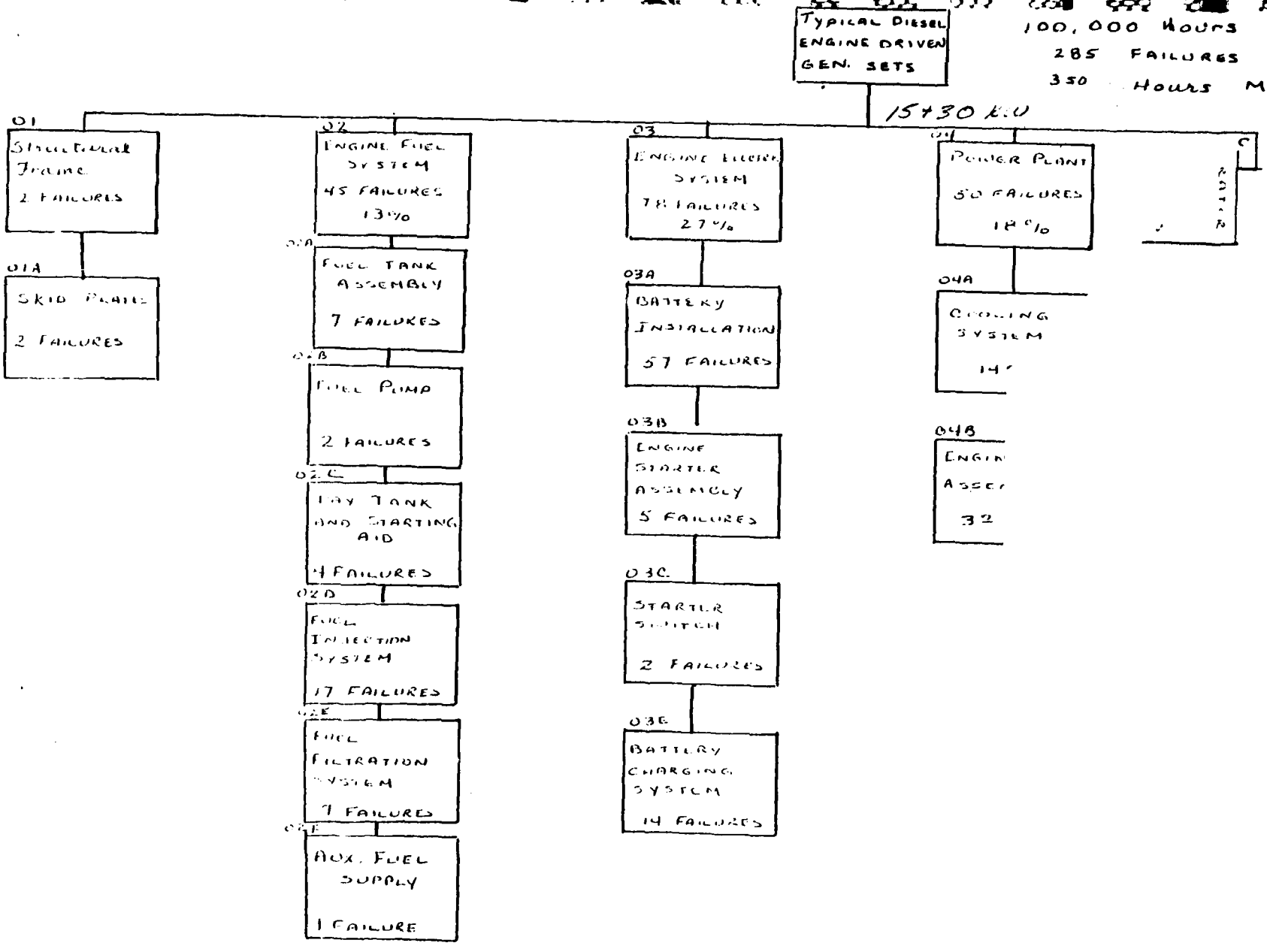
FIGURE 35. MEP-006A (60 kW, 50/60 Hz, [illegible]D).

X-3569

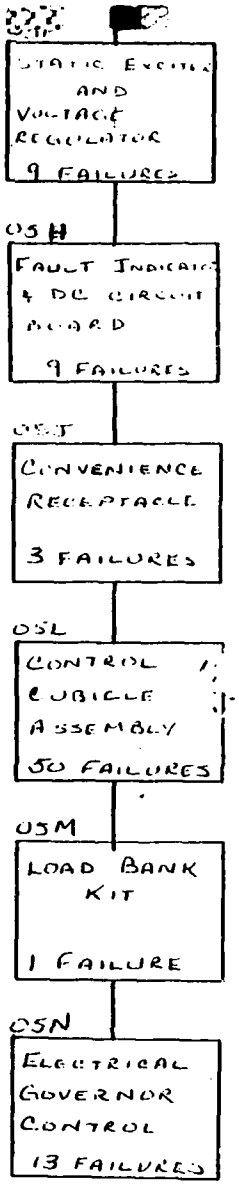


X-3570

FIGURE 36. MEP-006A (60 kW, 50/60 Hz, DED).



Reliability Tree


STATIC EXCITER AND VOLTAGE REGULATOR
9 FAILURES
FAULT INDICATOR & DC CIRCUIT BOARD
9 FAILURES
CONVENIENCE RECEPTACLE
3 FAILURES
CONTROL CUBICLE ASSEMBLY
50 FAILURES
LOAD BANK KIT
1 FAILURE
ELECTRICAL GOVERNOR CONTROL
13 FAILURES

Appendix D
Manufacturers-Survey Names and Addresses

(1) ACME-URDC, Inc.
C/O Air Supply Company
Gwynedd Plaza Suite 302
Springhouse, PA 19477

(2) Allard, Ed Ph.D
7351 H. Lockport Place
Lorton, VA 22079

(3) Alturdyne
8050 Armour Street
San Diego, CA 92111-3788

(4) American Development Corp.
1930 Hanahan Road
North Charleston, SC 29406

(5) American Solenoid Co., Inc.
60 New Brunswick Td.
P.O. Box 430
Somerset, NJ 08873-9990

(6) Applied Concepts Corp.
P.O. Box 190
405 Stoney Creek Blvd.
Edinburg, VA 22824

(7) Aquanautics Corp.
4560 Horton Street
Bldg. Q, #111
Emeryville, CA 94608

(8) ARINC Research Corp.
2551 River Road
Annapolis, MD 21401

(9) BBN Laboratories
10 Moulton Street
Cambridge, NA 02238

(10) BDM Corp.
7915 Jones Branch Drive
McLean, VA 22102-3396

(11) Burdshaw Associates, LTD.
4701 Sangamore Road
Bethesda, MD 20816

(12) CACI
8260 Willow Oaks
Fairfax, VA 22301

(13) Clark Equipment Co.
Clark Laboratory Service
821 East Front Street
Buchanan, MI 49107

(14) Chronur Corp.
P.O. Box 177
Princton, NJ 08642

(15) Designers and Planners, Inc.
2011 Crystal Drive
Arlington, VA 22202

(16) Deutz Corp.
7585 Ponce De Leon
Atlanta, GA 30340

(17) Diesel Engine Sales
2200 East 89th Street
Los Angeles, CA 90002

(18) Electrical Generating
Systems Association
P.O. Box 9257
10251 A. West Sample Road
Coral Springs, FL 33065

(19) Electric Tachometer Corp.
68th and Upland Streets
Philadelphia, PA 19142

(20) Fermont Division
141 North Avenue
Bridgeport, CT 06606

(21) Glar-Ban
199 Wales Avenue
Tonawanda, NY 14150

(22) Grumman Aircraft Systems
Mail Station B06-05
Bethpage, NY 11714-3582

(23) Hartman Electrical Mfg.
C/O Air Supply Company
Gwynedd Plaza II Suite 302
Springhouse, PA 19477

(24) Ingersoll-Rand
501 Sanford Road
Mocksville, NC 27028

(25) International LTD.
10645 Railroad Square
Suite 200-B
Fairfax, VA 22030

(26) Kinetics Group, Inc.
P.O. Box 1071
Mercer, Island, WA 98040

(27) Libby Corporation
P.O. Box 34200
Kansas, City, MO 64120-4200

(28) Lima Electric Co., Inc.
P.O. Box 918
Lima, OH 45802

(29) Michigan Technology University
Division of Research
Keweenaw Research Center
Houghton, MI 49931
or
Houghton County Memorial Airport Road
Calumet, MI 49913

(30) NTS
6845 Elm Street, Suite 511
McLean, VA 22101

(31) Pacific Electron Corp.
7200 E. Fifteen Mile Road
Sterling Heights, MI 48077

(32) Peter Diesels, Inc.
4761 Hugh Howell Road
Tucker, GA 30084

(33) Science Applications
International Corp.
T-4-4, 1710 Goodridge Drive
P.O. Box 1303
McLean, VA 22102

(34) Guyer Santin, Inc.
917 7th Street

(35) Homelite Division
Textron, Inc.
P.O. Box 7047
Charlotte, NC 28217

(36) Interface, Inc.
2066 North 14th Street
Arlington, VA 22201

(37) John R. Hollingsworth Co.
P.O. Box 430
Phoenixville, PA 19450

(38) Kohler Co.
Kohler, WI 53044

(39) Life Cycle Engineering, Inc.
1 Poston Road, Suite 300
P.O. Box 300001
Charleston, SC 29417-3000

(40) Morrison-Knudsen Co.
P.O. Box 7808
Boise, ID 83729

(41) Onan Corp.
1400 73rd Avenue NE
Minneapolis, MN 55432

(42) Paone Associates
8032 Whitting Drive
Manassas, VA 220111

(43) Power Technologies, Inc.
P.O. Box 1058
1482 Erie Blvd.
Schenectady, NY 12301-1058

(44) Snyder Industries, Inc.
4700 Freemont
Box 4853
Lincoln, NE 68504

(45) Southwest Research Institute
P.O. Drawer 28510
San Antonio, TX 78284

(46) Square D Company
P.O. Box 4000
Pinellas, Park FL 34290

(47) Stirling Power Systems
7101 Jackson Road
P.O. Box 1187
Ann Arbor, MI 48103

(48) Sundstrand Turbomach
4400 Ruffin Road
P.O. Box 85757
San Diego, CA 92138-5757

(49) Techmedia Corp.
121 North Orianna Street
Philadelphia, PA 19106

(50) Tecogen, Inc.
45 First Avenue
Waltham, MA 02254-9046

(51) Teledyne W-F Industries
Dyer Industrial Park
P.O. Box C
Dyer, TN 38330

(52) Tri-Ex
P.O. Box
Eatontown, NJ 07724

(53) United Technologies Automotive
P.O. Box 85
One Diesel Drive
Columbia, SC 29202

(54) White Engines, Inc.
P.O. Box 6904
Canton, OH 44706
or
101 11th Street SE
Canton, OH 44707

(55) Springfield Research Associates
7830 Backlick Road
Suite 404
Springfield, VA 22150

(56) Stewart & Stevenson
P.O. Box 1637
Houston, TX 77251-1637

(57) Suma Corp.
2025 Castle Road
Woodstock, IL 60098

(58) Systems Integrated
1630 South Sunkist Street
Anaheim, CA 92806

(59) Technology Applications, Inc.
6101 Stevenson Avenue
Suite 527
Alexandria, VA 22304

(60) Teledyne Total Pwr
3409 Democrat Road
P.O. Box 181160
Memphis, TN 38181-1160

(61) Tiernay Turbines
P.O. Box 20644
Phoenix, AR 85036-0644

(62) TVI Corp.
10700 Hanna Street
Beltsville, MD 20705

(63) VTEC Laboratories, Inc.
212 Manida Street
Bronx, NY 10474

(64) RMS Technologies, Inc.
5 Eves Drive
Evesham Corporate Park
Marlton, NJ 08053

(65) Mechanical Technology, Inc.
968 Albany-Shaker Road
Latham, NY 12110

Appendix E
Industry Survey Letter Responses

RMS
TECHNOLOGIES, INC.

ATE-L-0244
9 April 1987

U. S. Army Research, Development
and Engineering Center
ATTN: STRBE-FGP (Mr. Bishop)
Building #326
Ft. Belvoir, VA 22060

SUBJECT: MEP Questionnaire Response

Dear Mr. Bishop:

Thank you for the opportunity to discuss computer control technology on 20 March 87 and our subsequent PHONCON's in reference to your questionnaire. Attached, please find our response to the reliability portions of that questionnaire. As you are certainly aware, the generator control circuitry accounts for more than one third of all failures of the DOD generator fleet. Our computer control design has a broad effect on the sub-components of the control circuitry by eliminating many of these sub-components and incorporating their functions into the controller software. The additional life cycle cost benefits (more simplified maintenance, reduced manufacturing/PIP costs, reduced weight, reduced complexity, fewer parts in the inventory, etc.) are not addressed in detail in our questionnaire response; however, we would welcome the opportunity to discuss these issues whenever your schedule would permit.

In our PHONCON of 2 April 87, you mentioned your requirement to have a recommendation on improved prototypes by the end of April 87. If it would assist in your decision process, we stand ready to brief you on any technical or

5 EVES DRIVE
EVESHAM CORPORATE PARK
MARLTON, N.J. 08053
(609) 596-5775

management aspect of our proposed project during the week of 20 April 87. I invite you to have any technical personnel present that you may desire, for as detailed a review of the topic as you may wish.

Looking forward to our next visit.

Sincerely,

William G. Flynn
Program Manager
Automatic Test Equipment

WGF:rjb

Attachment

MEPP

QUESTIONNAIRE RESPONSE

1. Not at this time. See questions 4 and 5 below.

2. N/A

3. N/A

4. RMS Technologies is in the unique position to have extensive expertise in both computer control operating systems and power generation design engineering. At present RMS Technologies has initiated a breadboard design effort for a Computer Control Box Assembly (CCBA) that would replace most of the closed loop control circuitry currently employed in DOD Mobile Electric Power Plants (MEPP). RMS Technologies has a proven track record for state-of-the-art software design and development (FAA's Radar Analysis Support System), systems integration (U.S. Navy Local Area Network - White Oaks) and maintenance support (FAA Technical Center - Test Program Set Development). Our present staff includes mechanical and electrical engineers who have more than 35 years of experience in power generation equipment design and maintenance. Our operating system software and functional system software capabilities are vastly more capable than that level of experience necessary to control and monitor DOD standard MEPPs.

5. RMS Technologies proposes to replace the majority of the current generator control circuitry with a solid state, microprocessor driven Computer Control Box Assembly (CCBA). Specifically, the Governor Control Unit, Tactical Relay Box, Special Relay Box, Precise Relay Box, Static Exciter/Voltage Regulator, Fault Indicator and DC Circuit Board, and Electrical Governor Control would be entirely removed from future MEPPs. The Control Cubicle Assembly and MEPP wire harness would be significantly simplified. The removed components would be replaced with the CCBA similar to the one described in the attached Project Assessment. This will reduce Generator Control System failures by approximately 50%. In place of these removed or reduced components, RMS proposes to install the CCBA, consisting of four printed circuit boards (prototype model will have six PCBs) and a power supply housed in three lightweight metal encasements. The replaced components largely become a function of the system software of the CCBA. Although empirical MTBOMF data for the CCBA is not yet available, engineering estimates for comparable solid state circuitry (protected by optic cuplers, filters, metal encasements,

etc.) operating in a field environment would indicate between 2 and 3 failures for each of four PCBs during 100,000 hours of test time. This estimate gives no consideration to the simplified wire harness requirement and the improved reliability resulting therefrom.

In addition to the significant improvements in MEPP reliability, availability, maintainability and durability (RAM-D), the additional benefits of more simplified maintenance procedures, reduced manufacturing or PIP costs, reduced size and weight per unit and possibly most important - the reduced life cycle cost due to less maintenance and fewer spares in the inventory are all benefits that occur from CCBA technology.

RMS Technologies' approach to achieve the above prototype MEPP is outlined in the attached milestone chart. We would require a Government furnished, trailor mounted 60KW MEPP along with a skid mounted engine/generator test model. Nine additional equipments are identified on the attached GFE Equipment List. These equipments could be provided as GFE or leased for a six month period. Our current engineering effort would be changed from a secondary "as time permits" effort to a principal corporate project. Since all management and engineering personnel assigned to this project have extensive prior experience in Army Program Management offices, the project would be conducted in accordance with doctrinal Program Management procedures well known to Government personnel. A maximum amount of Government participation and review of the developing project would be encouraged.

6. N/A

GOVERNMENT DELIVERABLES:

A. A clear Proof of Principal demonstration of the CCBA technology in accordance with a Government provided test plan. RMS Technologies recommends a challenging Test and Acceptance Procedure from Government pre-production test files or that a test plan be jointly developed for this specific project.

B. Return of all GFE equipment at the conclusion of the project.

C. All test and performance data results to be provided for Government review and retention.

COST ESTIMATE

MEPP PROPOSAL

DIRECT LABOR	6,850 Hours	$257,989

- Program Manager
- Project Leader
- Lead Engineer
- Quality Assurance
- Senior Principal Engineer
- Principal Engineer
- Electronic Technician
- Consultants

HARDWARE/MATERIEL		
- Terminals	- Pin Boards	- Control Panel
- Connectors	- POL	- Wire Harness
- Actuator	- Engine Panel	- Enclosures
		$ 26,000
PCB (PROTOTYPES)		$ 14,000
TRANSPORTATION		$ 9,500
TRAVEL		$ 5,000
CONSULTANTS		
- EMI	- Computer Scientist	$ 14,000
EQUIPMENT RENTAL (REDUCED BY GFE)		$ 26,730
OTHER		$ 2,000
	Total ODCs	$ 95,230
	G & A on ODCs	$ 6,571
		$101,801

TOTAL COST*

Direct Labor	$257,989
ODCs with G & A	$101,801
	$359,790

*No fee to be charged on MEPP Project

7APR87

ARMY MEPP

EQUIPMENT REQUIREMENTS (GFE or RENTAL)

ITEM IDENTIFICATION	MONTHLY RENTAL FEE	6 MONTH TOTAL FEE
1. LOAD BANK (75 KVA)	N/A	N/A
2. EPROM PROGRAMMER - DATA I/O CORP 22B	182.00	1092.00
3. OSCILLOSCOPE, HP-1980B	917.00	5502.00
4. FREQUENCY COUNTER, HP-5315B	109.00	654.00
5. FUNCTION GENERATOR, WAVETEK-175	347.00	2082.00
6. LOGIC ANALYZER, HP-1630G	847.00	5082.00
7. SPECTRUM ANALYZER, HP-3582A	798.00	4788.00
8. BRIDGE, GenRad 1657-9700	140.00	840.00
9. RECORDER, LIGHT BEAM HONEYWELL 1858	888.00	5328.00
1889 PLUG-IN	77.00	462.00
1881 PLUG-IN	75.00	450.00
1882 PLUG-IN	75.00	450.00
TOTAL RENTAL FEES:	$4455.00	$26730.00

NOTE: All equipment can be provided GFE to alleviate rental costs.

7APR87

ARMY MEPP

EQUIPMENT REQUIREMENTS (GFE or RENTAL)

ITEM IDENTIFICATION	MONTHLY RENTAL FEE	6 MONTH TOTAL FEE
1. LOAD BANK (75 KVA)	N/A	N/A
2. EPROM PROGRAMMER - DATA I/O CORP 22B	182.00	1092.00
3. OSCILLOSCOPE, HP-1980B	917.00	5502.00
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7. SPECTRUM ANALYZER, HP-3582A	798.00	4788.00
8. BRIDGE, GenRad 1657-9700	140.00	840.00
9. RECORDER, LIGHT BEAM HONEYWELL 1858	888.00	5328.00
1889 PLUG-IN	77.00	462.00
1881 PLUG-IN	75.00	450.00
1882 PLUG-IN	75.00	450.00
TOTAL RENTAL FEES:	$4455.00	$26730.00

NOTE: All equipment can be provided GFE to alleviate rental costs.

RAM-D IMPROVED PROGRAM SCHEDULE: U.S. ARMY MOBILE ELECTRIC POWER PLANT

MILESTONE	MONTH 1	MONTH 2	MONTH 3	MONTH 4	MONTH 5	MONTH 6	REMARKS/NOTES	MILESTONE
PROGRAM MANAGEMENT:								TDP:
PROGRAM MANAGER	<- - -	- - -	- - -	- - -	- - -	- - - >		LEVEL I DRAWINGS
PROJECT LEADER	<- - -	- - -	- - -	- - -	- - -	- - - >		PARTS LISTS
DESIGN/FAB CONTROLLER:								BOM
DESIGN PCB 1	<--->							TMDE/SP TOOLS RQMTS
DESIGN PCB 2		<--->						QA/CM/TEST:
DESIGN PCB 3	<--->							BREADBOARD TEST
DESIGN PCB 4		<--->						PROTOTYPE TEST
FAB PCB 1		<--	---->					QA ACT/INSPECTIONS
FAB PCB 2		<--	---->					ORDER LONG LEAD ITEMS
FAB PCB 3		<--	---->					ORDER OTHER MATERIALS
FAB PCB 4		<--	---->					ASSEMBLE FINAL MEP
DESIGN CTLR CHASSIS	<----	-->						GOVERNMENT DEMO/ DELIVER TEST DATA
FAB CTLR CHASSIS		<--	---->					EMI ANALYSIS
DESIGN ERROR DET/PCB5	<--->							RAM ANALYSIS
FAB PCB 5		<--	---->					LIAISON WITH ARMY
DESIGN SPEED CTL/PCB6		<--->						REVIEWS:
FAB PCB 6		<--	---->					IN PROCESS
DESIGN INTERCOMPONENT WIRE HARNESS	<----	->						DESIGN
FAB WIRE HARNESS		<----	---->					GOVERNMENT ACCEPTANCE
FAB PCB PROTOTYPES				<--->				
ASSEMBLE PROTOTYPES				<--->				
PROGRAMMING:								
PLAN/FLOW CHARTS	<->			<->				
WRITE PROGRAMS	<->			<->				
PROGRAM EPROMS	<->			<>				

QE ELECTRIC POWER PLANTS (18MAR87)

MILESTONE	MONTH 1	MONTH 2	MONTH 3	MONTH 4	MONTH 5	MONTH 6	REMARKS/NOTES
TDP:							
LEVEL I DRAWINGS	<----	-----	-----	---->			
PARTS LISTS	<----	-----	-----	-----	-----	---->	(MEPPS = MOBILE ELECTRIC POWER PLANTS)
BOM	<----	-----	-----	-----	-----	---->	
TMDE/SP TOOLS RQMTS		<----	-----	-----	-----	---->	(< = BEGIN ACTIVITY)
QA/CM/TEST:							(- - - = PART TIME ACTIVITY)
BREADBOARD TEST		<--->					
PROTOTYPE TEST					<--->		(---- = FULL TIME ACTIVITY)
QA ACT/INSPECTIONS	<--	-----	-----	-----	-----	---->	(> = END ACTIVITY)
ORDER LONG LEAD ITEMS	<->						(TDP = TECHNICAL DATA PACKAGE)
ORDER OTHER MATERIALS	<----	-----	-----	-----	---->		
ASSEMBLE FINAL MEP				<->			(BOM = BILL OF MATERIALS)
GOVERNMENT DEMO/ DELIVER TEST DATA						<->	(TMDE = TEST MEASUREMENT & DIAGNOSTIC EQUIPMENT)
EMI ANALYSIS	<->				<->		
RAM ANALYSIS			<->			<->	(SP TOOLS = SPECIAL TOOLS)
LIAISON WITH ARMY	< - -	- -	- -	- -	- -	- - >	(QA = QUALITY ASSURANCE)
REVIEWS:							
IN PROCESS	R	R	R	R	R		(EMI = ELECTRO MAGNETIC INTERFERENCE)
DESIGN	PDR			CDR			
GOVERNMENT ACCEPTANCE						<AR>	(RAM-D =RELIABILITY, AVAILABILITY, MAINTAINABILITY & DURABILITY)
							(R = REVIEW)
							(PDR = PRELIMINARY DESIGN REVIEW)
							(CDR = CRITICAL DESIGN REVIEW)
							(AR = ACCEPTANCE REVIEW)

PROJECT ASSESSMENT

U.S. NAVY (NAEC) SOLICITATION

N00140-85-R-1168

RMS TECHNOLOGIES, INC.

PROJECT ASSESSMENT

U.S. NAVY (NAEC) SOLICITATION

N00140-85-R-1168

COPY 11 OF 15

PGM. CONF. MGMT. W. Flynn

CONTENTS

I. Introduction

II. MEPP and CCBA Hardware

III. AC/DC Power Out - Top Level Circuitry
MEPP Schematic and Drawing Requirements

IV. MEPP Sample Cost Savings

MEPP PRODUCT IMPROVEMENT PLAN

COMPUTER CONTROL ASSEMBLY

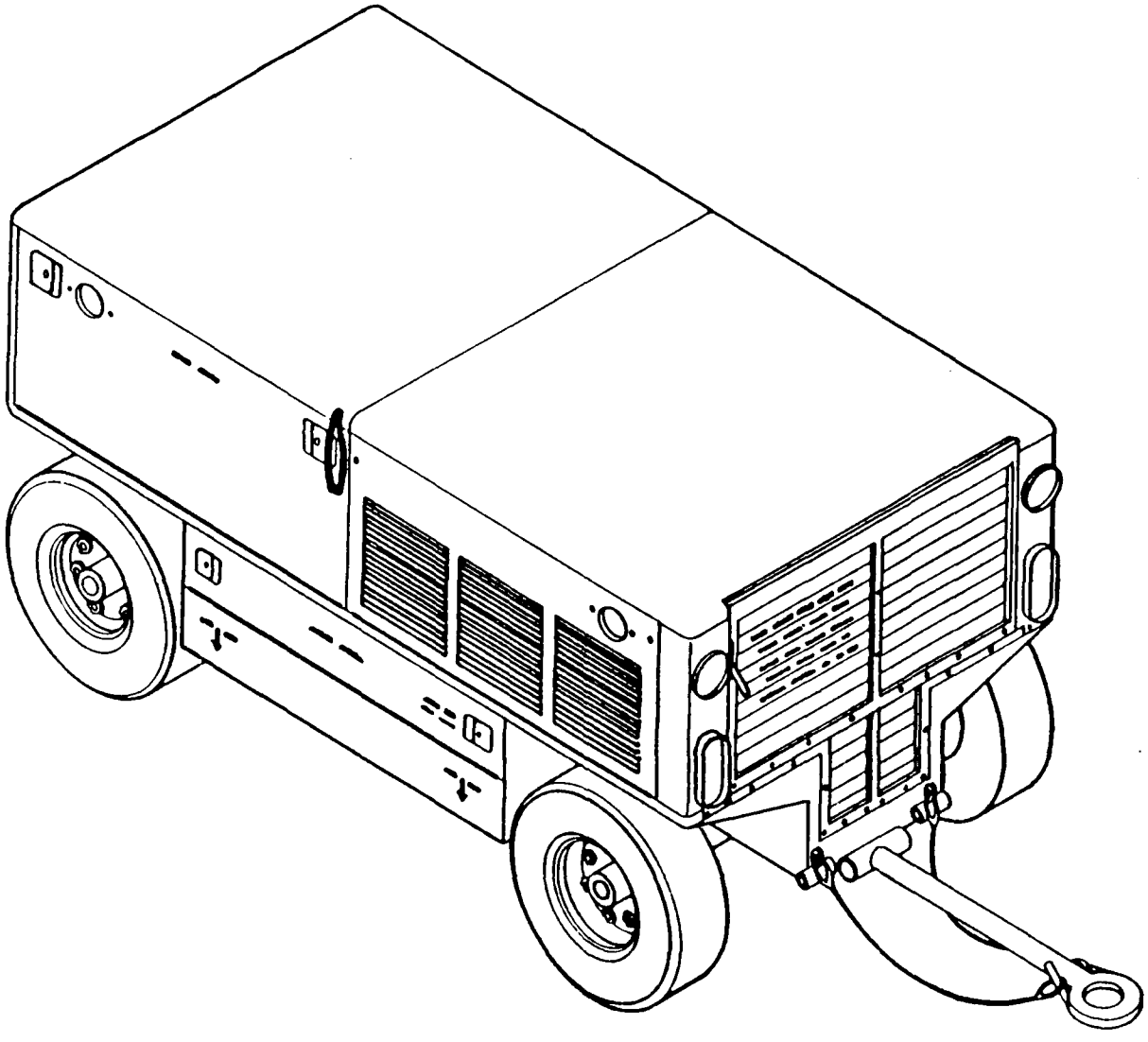
The U.S. Navy's solicitation for a Mobile Electric Power Plant (MEPP) describes a mobile, diesel engine driven, electrical power plant capable of supplying 115/200 VAC, three phase, 400 Hz and 28 VDC power for the electrical servicing of aircraft with a power requirement of 45 KVA or less. The MEPP will consist of two styles. Style I is a four wheel, towable model that will service landbased aircraft. Style II is a four wheel, driveable, self-propelled model for use on the deck of an aircraft carrier.

The technology being offered by power generation companies today has had few significant changes in the control portion of mobile power plants from what was considered "state-of-the-art" twenty years ago. Simply stated, the control technology basically utilizes individual closed loop circuits with individual relays for each test, fault monitoring or control function that comprise the electronic control and protective circuitry of mobile electric power plants. This technology requires complex wire harnesses, unnecessary and significant weight, complexity and logistics support, and a marked decrease in reliability, due to the mean time between failure of numerous mechanical relays. Possibly the most significant factor of using this older technology is the lost opportunity for a reduction in life cycle cost that could be achieved through the employment of a computer control assembly.

The MEPP Computer Control Box Assemply (CCBA) described on the following pages is not a "technological breakthrough" with associated high risks. RMS Technologies has performed an extensive engineering design assessment of computer control technology for electric power plants in general and the U.S. Navy (NAEC) solicitation N00140-85-R-1168 in particular. Our assessment was primarily based on this Navy procurement because it is a current example of a major User's requirement. RMS Technologies is in the unique position to have extensive expertise in both computer control operating systems and power generation design engineering. We have thoroughly assessed this Navy requirement for a MEPP and recommend the following computer control technology for this and future power plant projects.

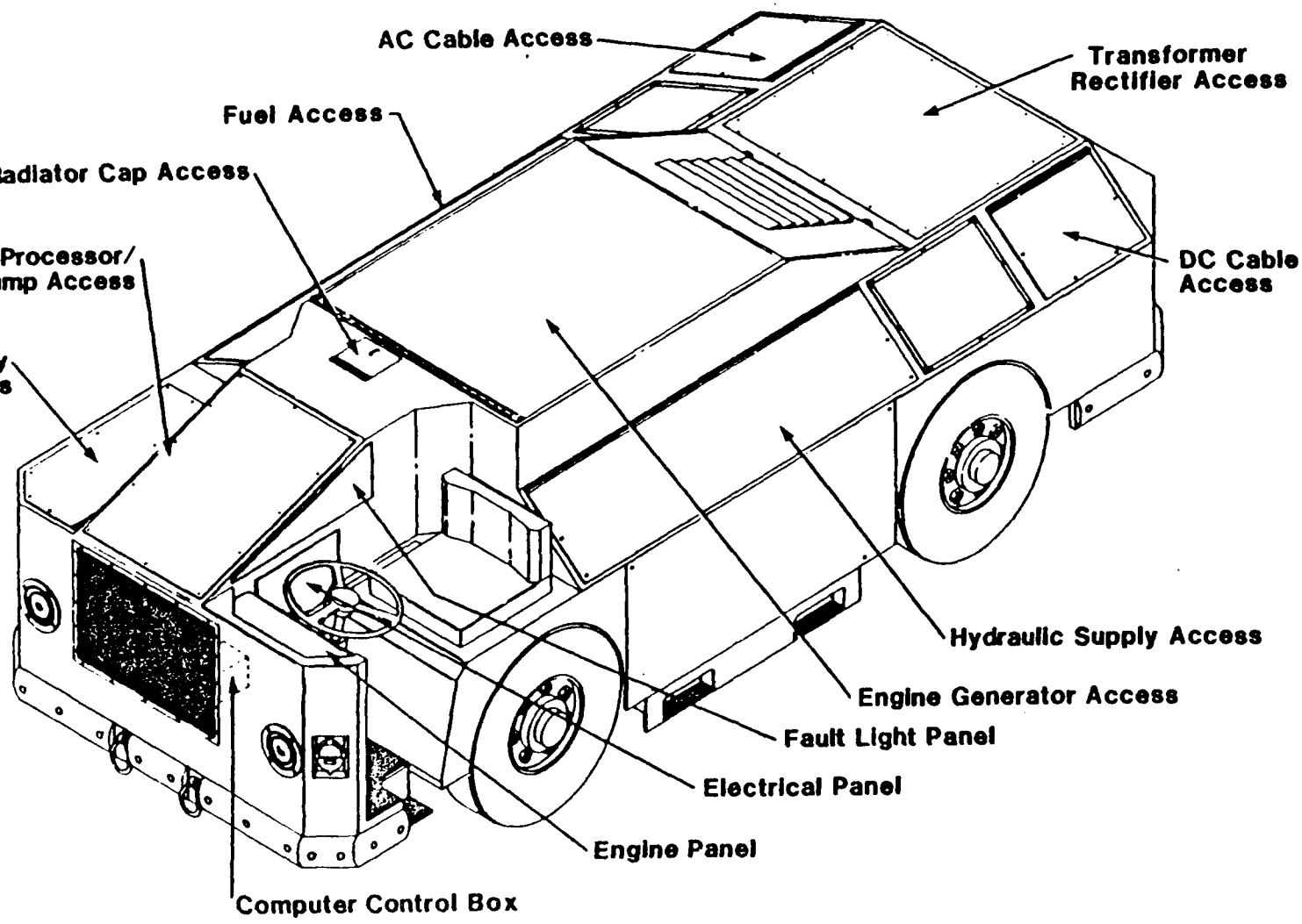
Mobile Electric Power Plant
Style I

RMS TECHNOLOGIES, INC.

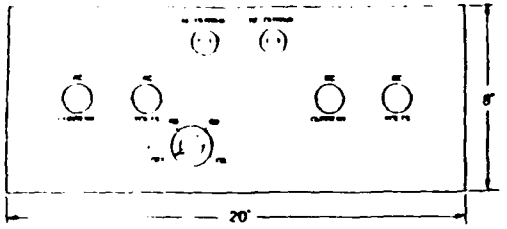


Mobile Electric Power Plant
Style II

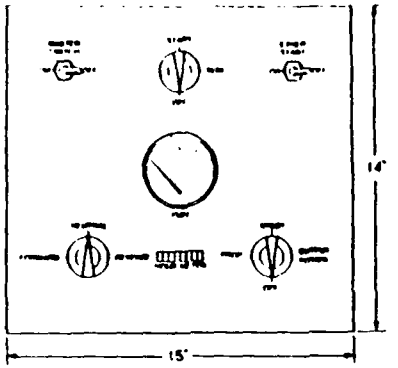
RMS TECHNOLOGIES, INC.



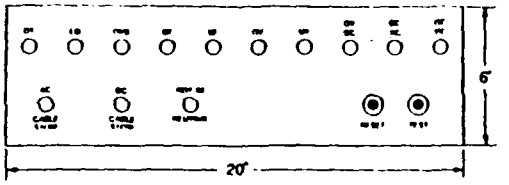
MEPP Computer Control Assembly*



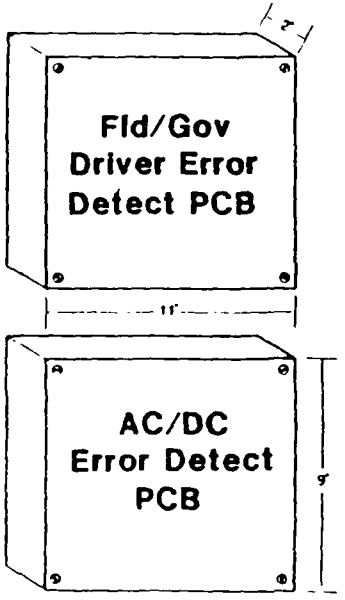
Electrical Panel

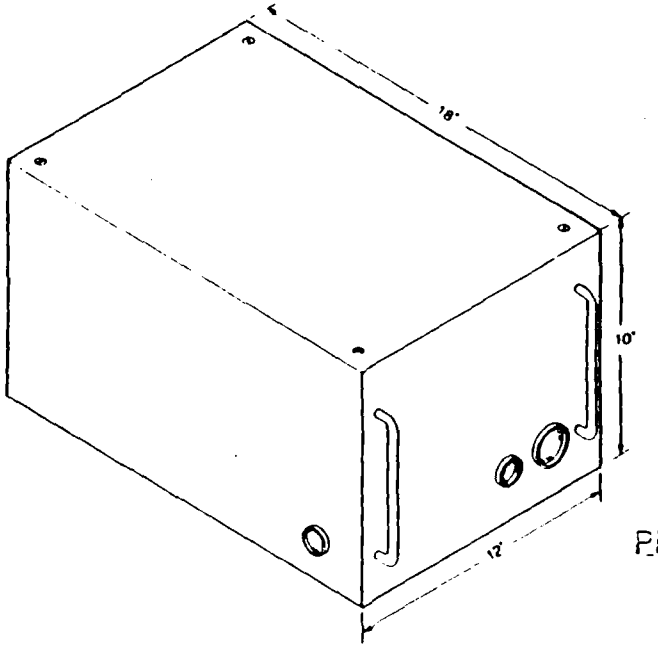


Engine Panel



Fault Panel

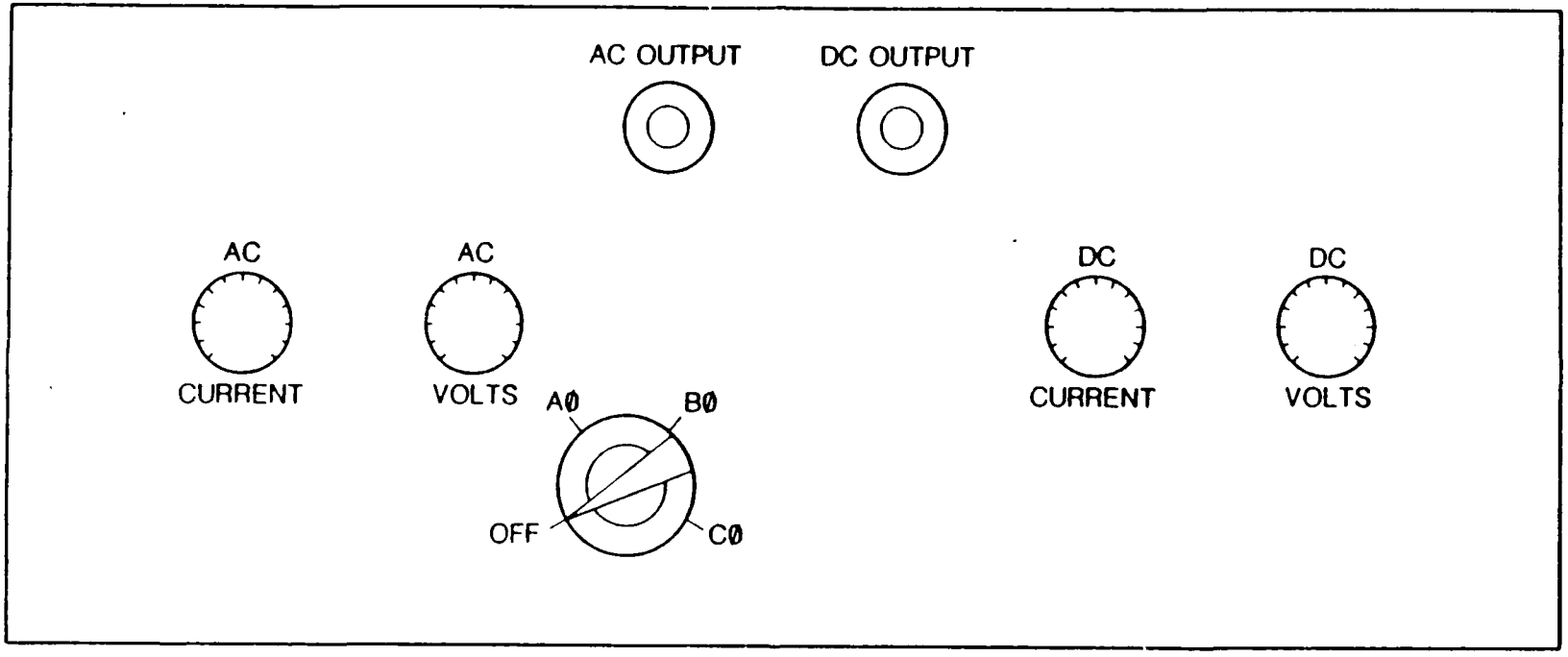




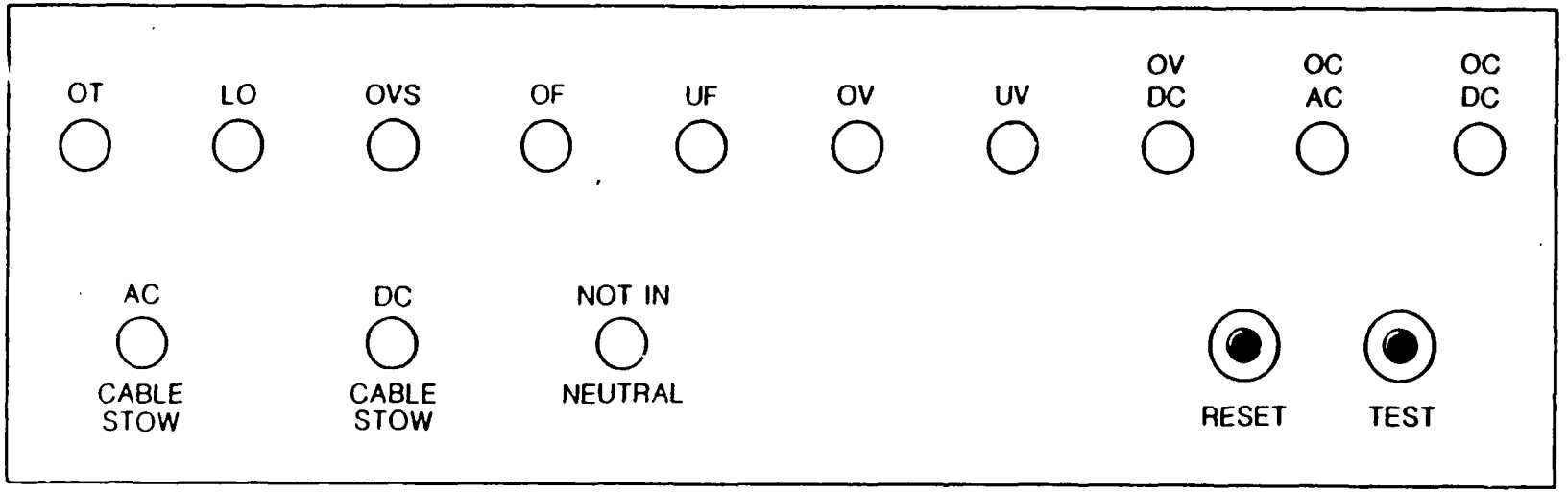
Computer Control Box

* Includes Shielded Twisted Pair Wire Harness Connecting Six Assembly Components to the MEPP

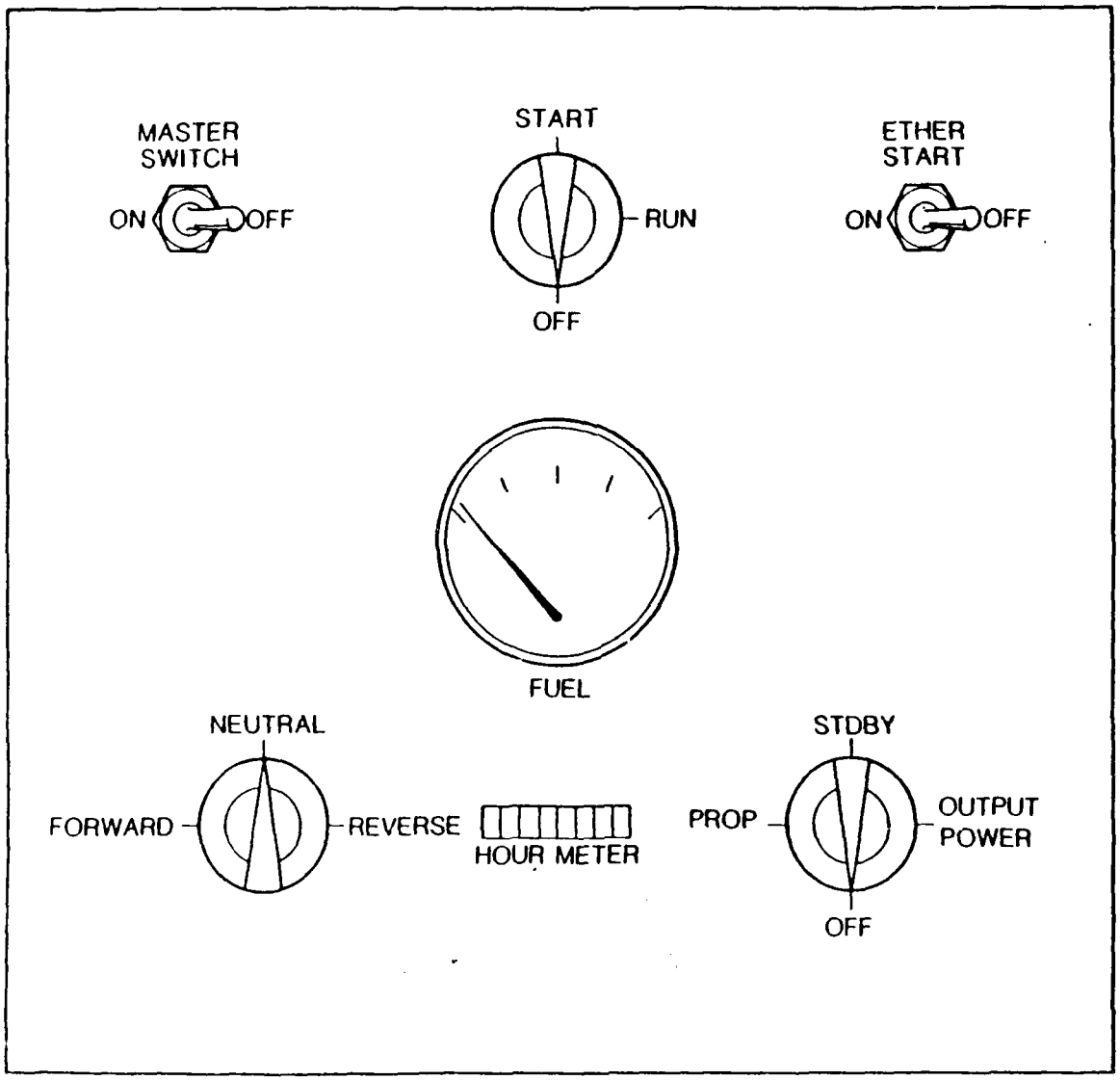
Electrical Panel



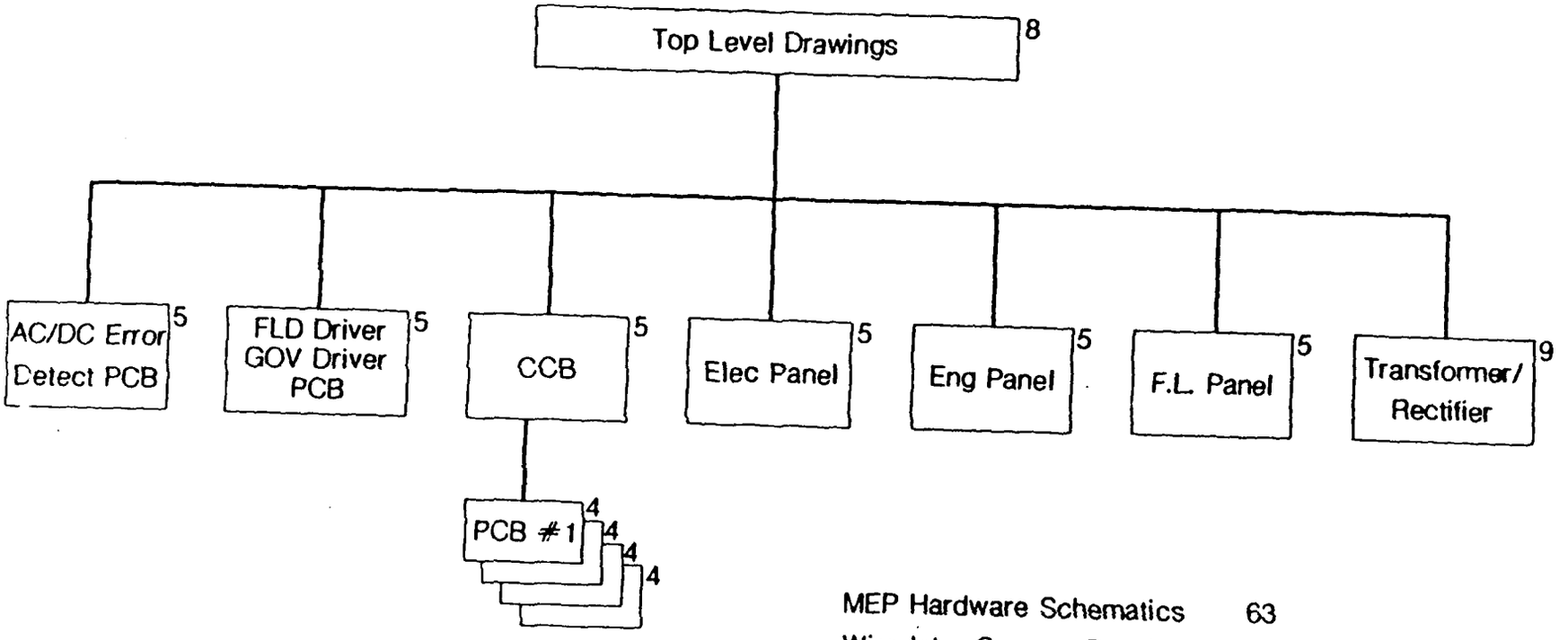
Fault Panel



Engine Panel

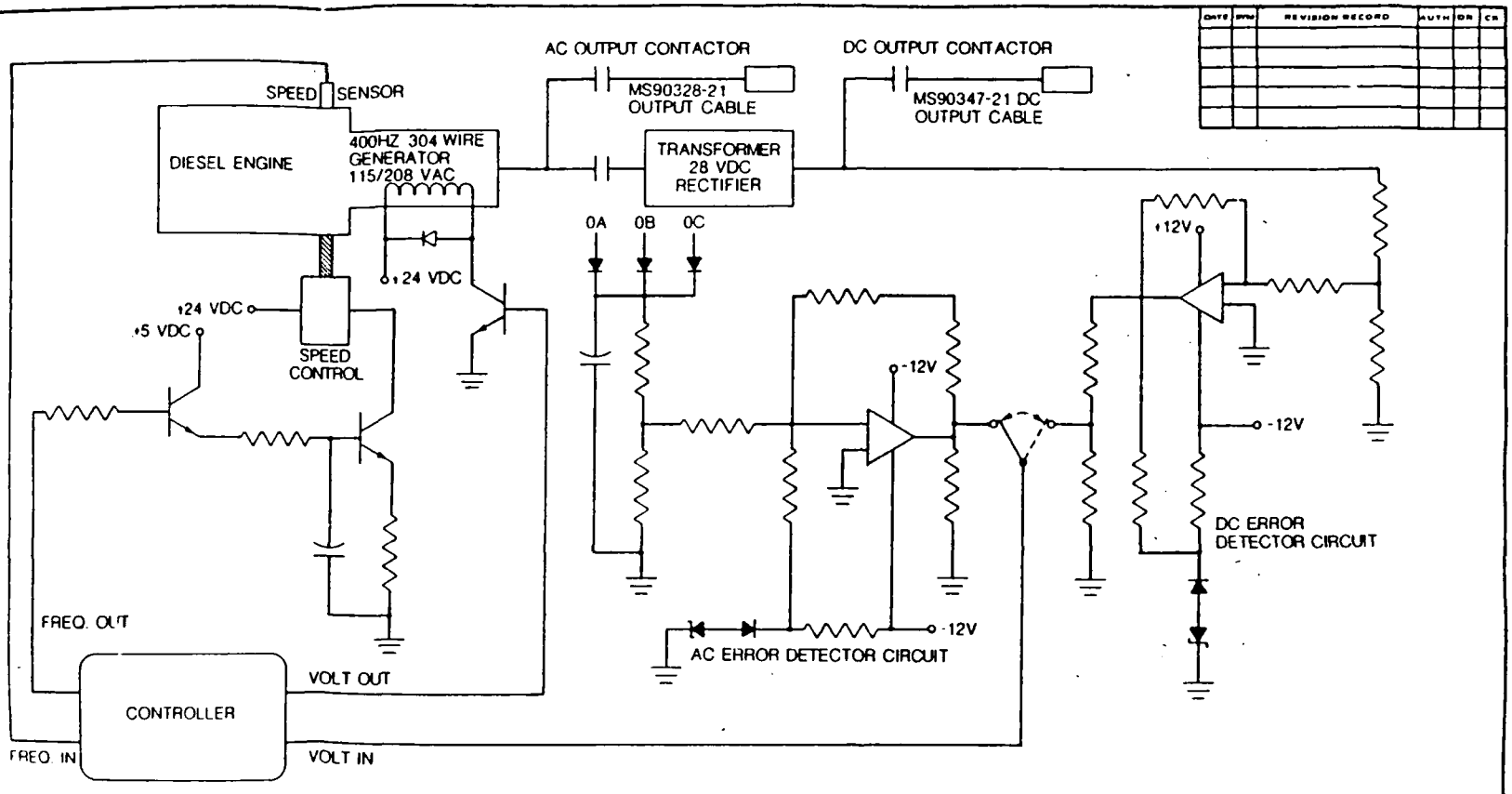


MEP Schematic/Drawing Requirements



MEP Hardware Schematics	63
Wire Inter Connect Drawings (Includes Wire Harness)	16
	79*

*Each will Average 3 Revisions



DATE	BY	REVISION RECORD	AUTH	DR	CK

TOLERANCES	MOBILE ELECTRIC POWER		
DECIMAL	PGM. CONF. MGMT. FLYNN	SCALE	DRAWN BY DAHL
			APPROVED BY DAHL
FRACTIONAL	TITLE AC/DC OUTPUT POWER CONTROL		
ANGULAR	DATE 1/8/87	DRAWING NUMBER MEP-PC-1	

CURRENT TECHNOLOGY

MEPP ELECTRONIC CONTROL CIRCUITRY

The following is a sampling of expensive and complex components that would be totally eliminated on a MEPP if it were designed with the previously described Computer Control Box Assembly (CCBA.) These components would largely become a function of the operating system software of a CCBA. Because of the variety of manufacturers, operational requirements and design variables, the cost and MTBF data could vary by as much as ± 20 %.

ITEM	COST	MTBF	FAILURES PER MONTH	LIFE CYCLE COST
Governor/Controller	$ 3,000	2,575 hrs	.06	???
AC Voltage Regulator	810	1,200 hrs	.13	???
Static Exciter	1,200	3,400 hrs	.05	???
Electronic Fault Relays (5ea)	1,500	1,750 hrs	.46	???
Engine Fault Relays (4ea)	200	2,050 hrs	.31	???
Field Shorting Relay	200	1,700 hrs	.09	???
Circuit Breakers (2ea)	1,060	1,940 hrs	.16	???
			1.26	???

The above sample of components does not address the reduced wire harness complexity, reduced number of MIL STD connectors, reduced internal wiring requirements for control panels or reduced weight of the MEPP itself.

The above sample of components does, however, clearly illustrate the advantages of a CCBA from an operational readiness, manufacturing cost and life cycle cost perspective.

BERT GALLOWAY, Vice President-Military Marketing

TELEDYNE TOTAL POWER
3409 DEMOCRAT ROAD
P.O. BOX 181160
MEMPHIS, TENNESSEE 38181-1160
(901) 365-3600 TELEX: 482-1058 (ITT)

March 25, 1987

Mr. Noel D. Bishop
Chief, Power Equipment Support Team
Logistics Support Directorate
U. S. Army Belvoir Research
Development and Engineering Center
Fort Belvoir, VA 22060-5606

Dear Mr. Bishop:

Teledyne Total Power as such does not manufacture anything, but we do market engines for Wisconsin, Continental, Renault, Wisconsin Robin, Wisconsin 'R' Series, both gasoline and diesels. We would dearly love to get established with a generator manufacturer to perform R & D work where our expertise prevails. As of this date we have not been able to consumate a marriage. We are hopeful that this can and will be arranged in the near future. In the meantime we would like to keep our name on the list. We believe that we have some very good products that feature long life. We would be willing to participate in a program that would provide baselines under generator drive conditions for MTBF. This would entail performing a thousand hour test per each of the 4 engines required for 5, 10, 15 and 30 KW sets and making any improvements over a 12 months period. Estimated cost would be approximately $100,000.00. We will be undertaking a torsional vibration analysis in the near future. As far as noise attenuation goes, we are currently working with vendors on a new muffler and air cleaner design. Some of our new air cooled diesels have an air shroud made of composite material that brings the DBA down to 78 for 7 meters.

I have enclosed a brochure that tells you a little about Total Power's diesels. Our facility here in Memphis (122,000 square feet) houses our major engineering facility (6 test cells and 10 dynos), marketing headquarters worldwide and parts warehousing for our 5000 plus worldwide distributors and service centers.

We will be showing a unit at the 'Power Fair' in Tyson Corners, VA on May 12, 13, and 14. Hope to see you there.

Sorry for the delay in responding. I have been traveling much and only recently have been able to concentrate on my mail. Thanks for your patience.

Sincerely,

Bert Galloway

Bert Galloway
Vice President - Military Marketing

BG/bc

Enclosure

SERIES	MODEL	CYL	CID	MIN. CONT. (HP@RPM)	MAX. CONT. (HP@RPM)	MIN. INT. (HP@RPM)	MAX. INT. (HP@RPM)	MAX. TORQUE (FT. LBS.@RPM)	BORE/STROKE (IN.)	COMP. RATIO	APPROX. DIMENSIONS (IN.) LENGTH	WIDTH	HEIGHT	APPROX. WEIGHT (LBS)
WISCONSIN R SERIES		**HORIZONTAL SHAFT**												
	TRD1-375	1	69	3.3[illegible]000	6.1[illegible]500	4.0@2000	6.5@3600	11@2600	3.1/3.0	19:1	15.6	16.8	19.5	88.3
	TRD1-380	1	69	3.[illegible]x00	7.[illegible]00	3.6@1500	8.3@3600	14@2400	3.1/3.0	19:1	16.2	17.0	20.3	105.8
	TRD1-480	1	87	4.8@1500	9.4@3600	5.3@1500	10.3@3600	19@1500	3.5/3.0	18.5:1	16.2	17.0	20.3	105.8
	TRD1-540	1	99	7.3@1500	11.2@3600	8.0@2000	12.0@3600	22@2600	3.5/3.0	18:1	17.9	17.0	22.0	123.5
	TRD1-605	1	110	6.4@1500	11.6@3000	6.9@1500	12.5@3000	24@1800	3.7/3.3	18:1	17.9	17.0	22.0	125.7
	TRD1-655	2	119	7.9@2000	13.7@3600	8.4@2000	14.8@3600	23@2800	3.1/2.6	19:1	18.9	14.8	18.7	110.3
	TRD2-850	2	156	10.3@2000	17.3@3600	11.4@2000	18.5@3600	30@2400	3.3/3.0	19:1	23.0	19.0	21.6	169.8
	TRD2-955	2	175	9.8@1500	19.8@3600	10.5@1500	21.4@3600	37@1500	3.5/3.0	19:1	23.0	19.0	21.6	172.0
	TRD2-1130	2	207	11.1@1500	21.1@3000	12.2@1500	22.6@3000	43@1800	3.6/3.3	18:1	23.1	21.1	23.4	207.3
	TRD2-1205	2	221	11.8@1500	23.2@3000	13.0@1500	25.0@3000	47@1800	3.7/3.3	18:1	23.1	21.1	23.4	212.0
	TRD2-1495	2	273	15.3@1500	27.4@3000	16.9@1500	29.9@3000	60@1800	3.9/3.7	17:1	26.7	21.1	25.9	291.1
	TRD2-1730	2	317	18.0@1500	29.8@3000	20.0@1500	32.6@3000	71@1800	4.1/3.9	16.5:1	26.7	21.1	25.9	291.1
	TRD2-1735	2	317	24.0@2000	33.9@3000	26.1@2000	36.1@3000	69@2000	4.1/3.9	16.5:1	26.7	21.1	25.9	291.1
	**TRD1-480S	1	87	5.3@2000	7.5@3600	5.5@2000	8.3@3600	14@2000	3.5/3.0	18:1	16.2	17.0	20.3	105.8
	**TRD2-655S	2	119	7.1@2000	11.1@3600	7.5@2000	12.1@3600	20@2400	3.1/2.6	19:1				
		VERTICAL SHAFT												
	TRD1-380	1	69	5.0@2000	7.0@3000	5.3@2000	7.6@3000	14@2400	3.1/3.0	19:1	24.7	17.0	12.4	105.8
	TRD1-480	1	87	5.5@2000	8.1@3000	5.9@2000	9.3@3000	16@2400	3.5/3.0	18.5:1	24.7	17.0	12.4	105.8
	TRD1-540	1	99	7.3@2000	10.3@3000	8.0@2000	11.2@3000	21@2400	3.5/3.3	18:1	27.2	17.7	12.2	123.5
	TRD1-605	1	110	8.5@2000	13.7@3600	9.0@2000	14.9@3600	23@2400	3.7/3.3	18:1	27.2	17.7	12.2	125.7
	TRD1-655	2	119	7.9@2000	13.7@3600	8.4@2000	14.8@3600	20@2400	3.1/2.6	19:1				
	**TRD1-480S	1	87	5.3@2000	7.2@3000	5.5@2000	7.7@3000	14@2000	3.5/3.0	18.5:1	24.7	17.0	12.4	205.8
	**TRD2-655S	2	119	7.9@2000	11.8@3000	8.4@2000	12.6@3000	23@2400	3.1/2.6	19:1				
WISCONSIN ROBIN				**MAXIMUM H.P.**										
				LOW SPEED (HP@RPM)	HIGH SPEED (HP@RPM)									
	WRD1-300	1	55	3.3@1600	6.5@3600			11.3@2000	2.9/2.6	21:1	16.7	10.0	17.7	198.5
	WRD1-350	1	64	3[illegible]500	7.5[illegible]0			12.7@2200	3.2/2.6	21:1	16.7	10.0	17.7	202.9
	WRD1-410	1	75	5.5[illegible]2000	8.5@[illegible]00			14.8@2200	3.2/3.0	21:1	16.7	11.3	18.8	218.3
CONTINENTAL LIQUID COOLED														
R SERIES	RD16	4	97	19.2@1500	54@4800			73.0@2500	3.3/3.0	22:1	22.8	28.4	24.4	286.0
R SERIES	RD21	4	126	24.7@1500	62@4200			93.0@2000	3.6/4.0	21.5:1	22.6	23.1	24.8	352.0
OHV	TMD13	2	82	18.3@1600	29.5@3000			51.6@3000	3.6/4.0	20.5:1	19.8	21.7	26.8	421.0
OHV	TMD20	3	122	26.0@1500	47.1@3000			82.4@3000	3.6/4.0	20.5:1	23.9	22.0	26.8	521.0
OHV	TMD27	4	165	21.1@1000	66.5@3000			116.4@3000	3.6/4.0	20.5:1	27.9	22.0	26.7	532.0
TURBO CHARGED	TMDT27	4	165	46.0@1600	80.0@3000			159.4@2100	3.6/4.0	20.5:1	27.9	23.8	26.7	552.0

All Engines Are Air Cooled Except As Noted.
***"Super Silent"

TELEDYNE TOTAL POWER

Carefully machined engine parts are assembled with expertise and care to minimize friction and vibration which creates excessive wear. The result is engines from TELEDYNE TOTAL POWER which, even under the most adverse operating conditions, continue to perform at peak levels longer than most of their competitors—and with less "down time."

Diesels in all of the TELEDYNE TOTAL POWER lines are designed to function at optimal power levels with minimal fuel consumption. Higher "delivered-horsepower"/fuel consumption ratios are achieved through innovative design, superior materials, and conscientious workmanship.

Diesels from TELEDYNE TOTAL POWER have demonstrated their superior performance all over the world, in applications ranging from "personal" commercial equipment to heavy industrial construction and manufacturing operations. A major factor in that performance is the efficient horsepower/weight ratio which is a characteristic of all the diesel models.

committed to a policy of offering only engines of unmatched quality; engines which can meet rigorous standards of excellence in performance and durability. Before a new engine model is added to our lines it is subjected to extensive laboratory and field testing—and it must prove itself in actual work conditions, where *true* performance must always be judged.

We are proud that the engines in our product lines reflect the most innovative and highly-advanced techniques in design and manufacture, but we are more proud that their performance has earned us an enviable reputation for offering superior quality—in products and services—at competitive prices.

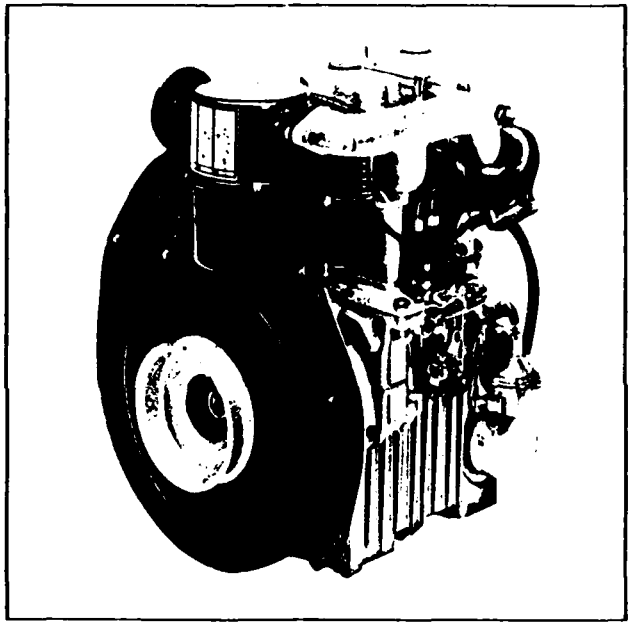
Engines from TELEDYNE TOTAL POWER. Offering the power you expect—for the performance you demand.

Teledyne Total Power backs its engines with a network of over 5000 engine distributors and service centers in over 90 countries. Experienced representatives are ready to help you with replacement engines, parts, servicing and repairs!

TTP00208

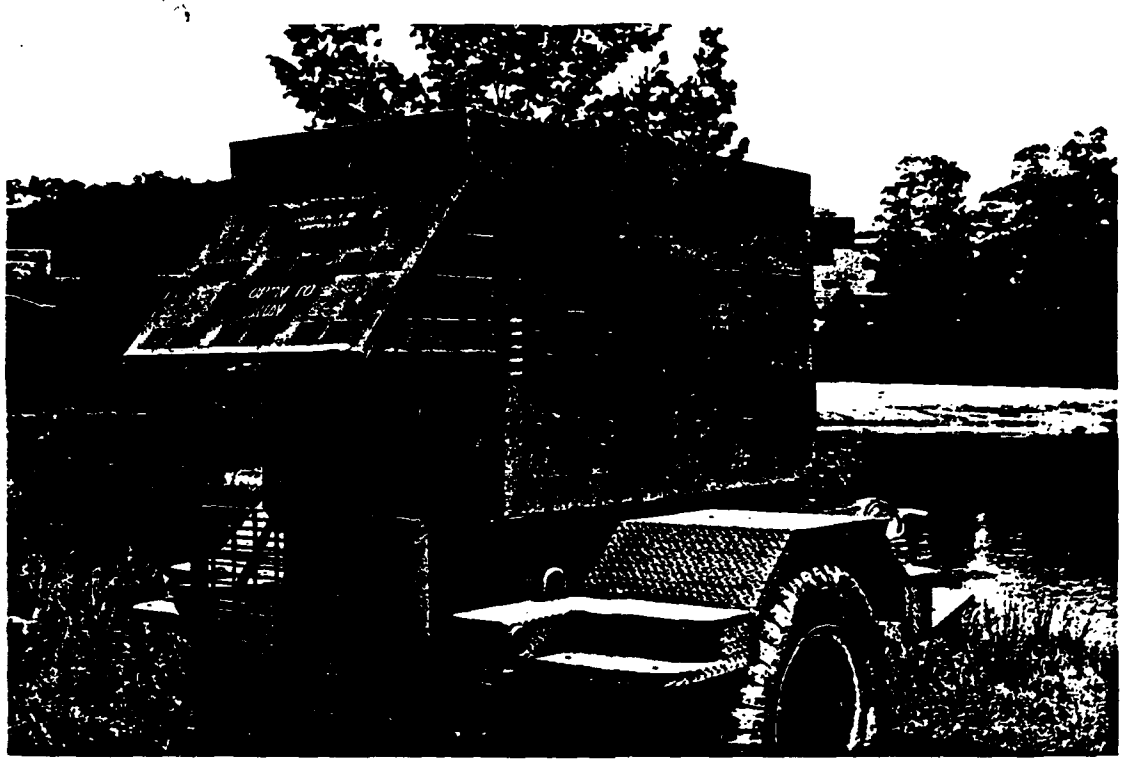
TELEDYNE TOTAL POWER

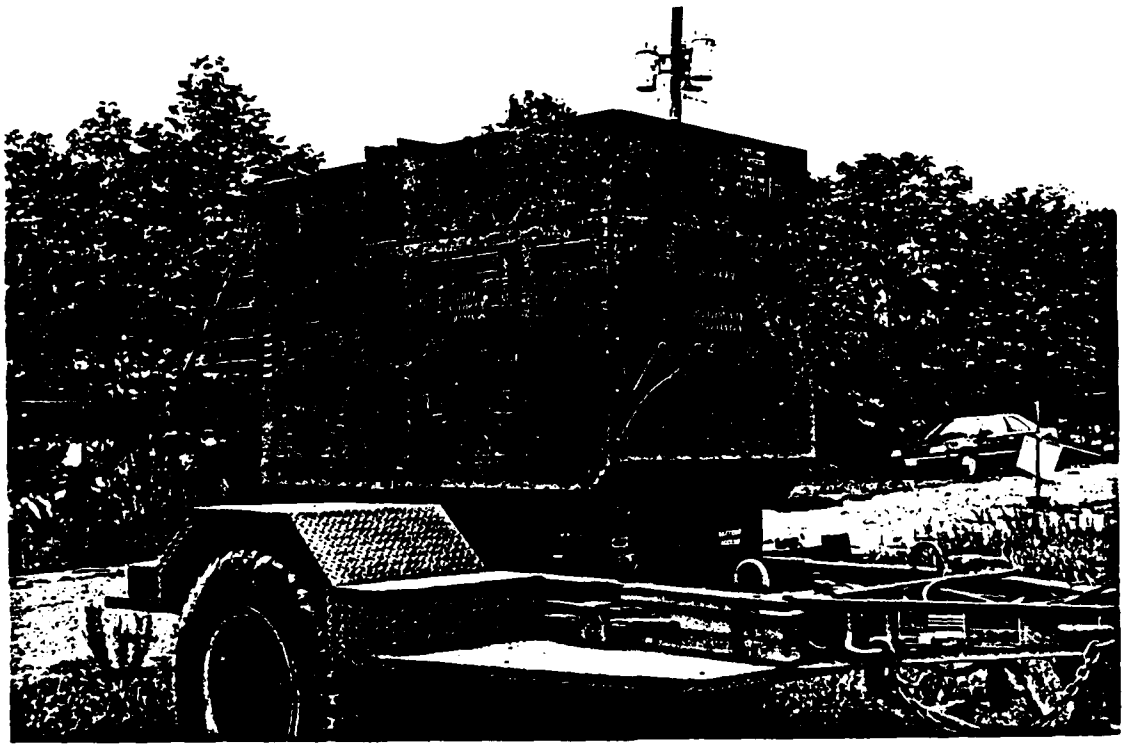
TELEDYNE TOTAL POWER

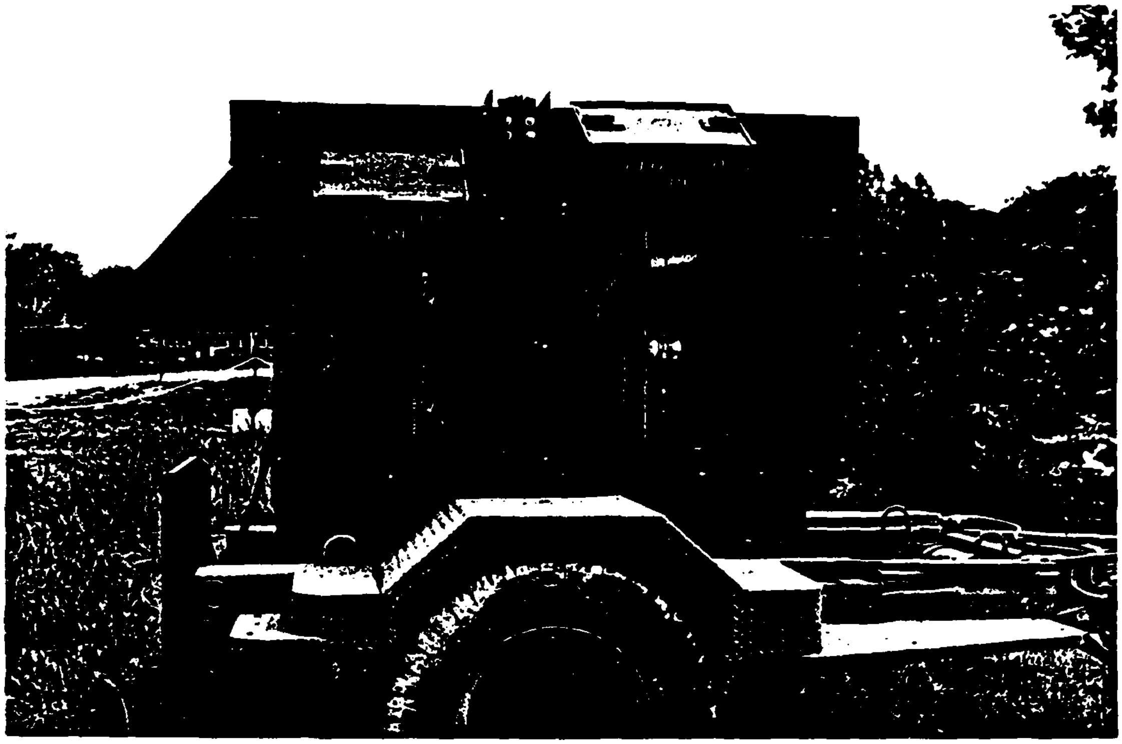


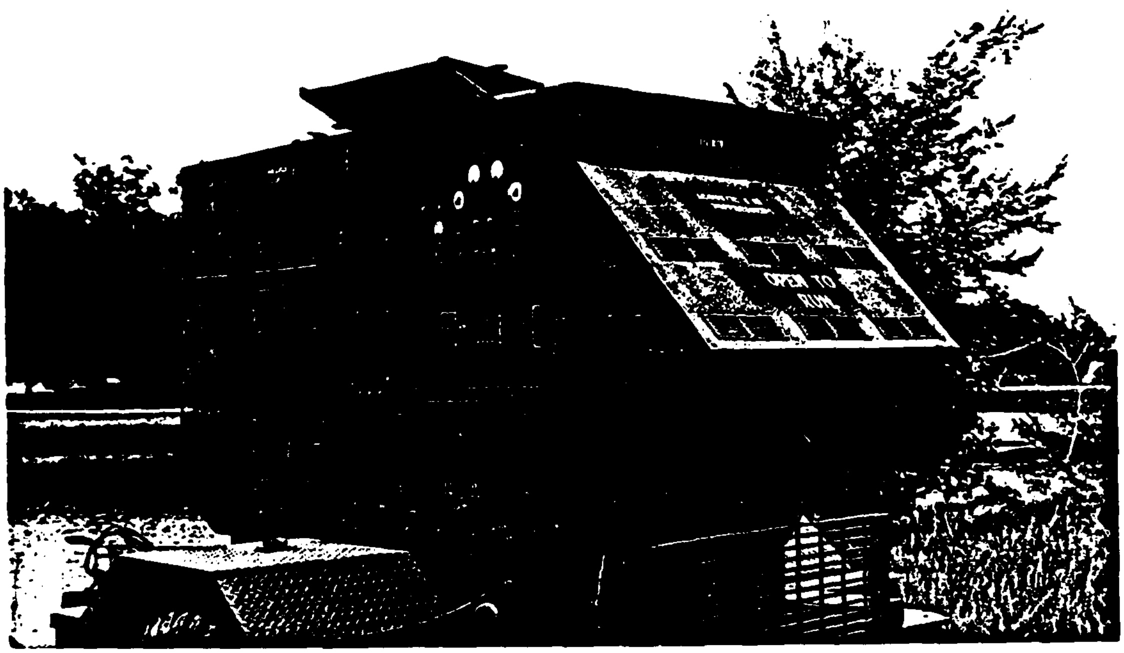
3409 Democrat Road
P.O. Box 181160
Memphis, Tennessee 38181-1160
Phone: (901) 365-3600
TELEX: 462-1058 (ITT)
CALL TOLL FREE: 1-800-932-2858

Rue Joseph Deflandre, 13
B-4920 Chaudfontaine
Liege, Belgium
Phone: (41) 67 53 20
TELEX: 42361 TDYCM B





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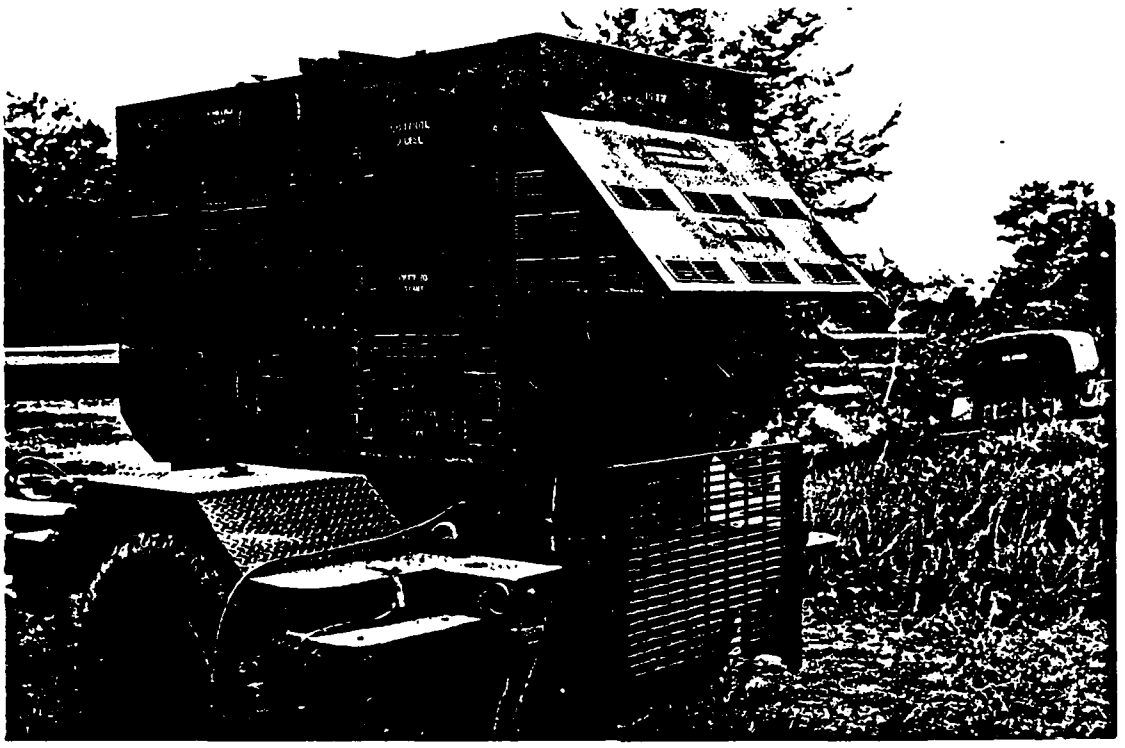
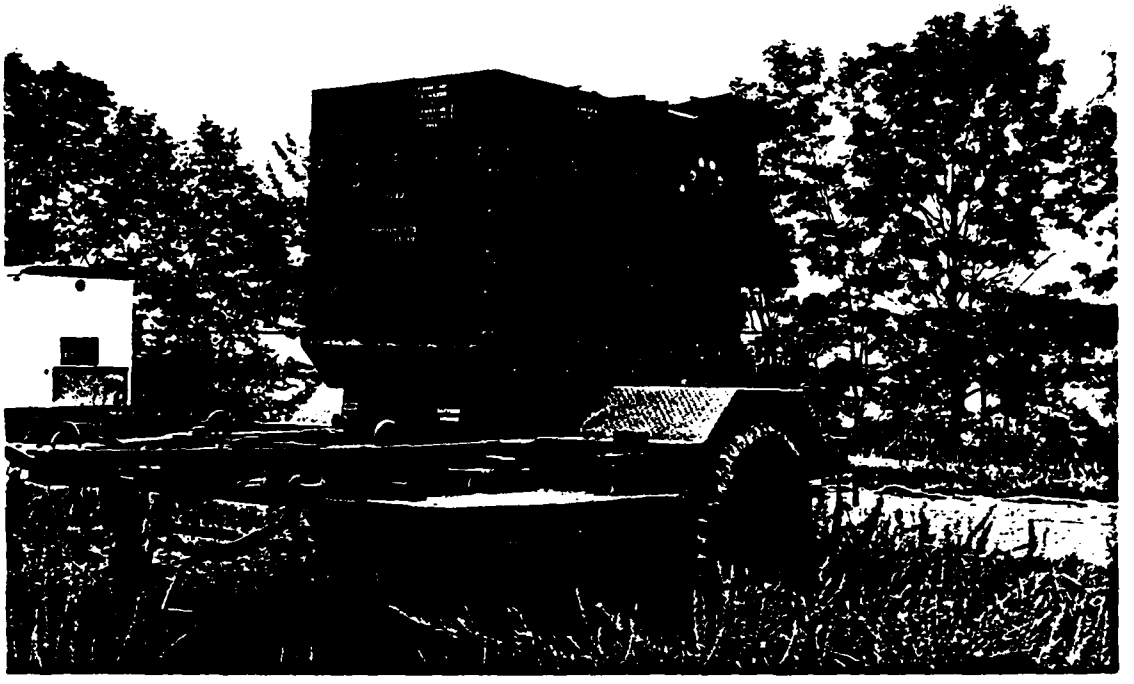
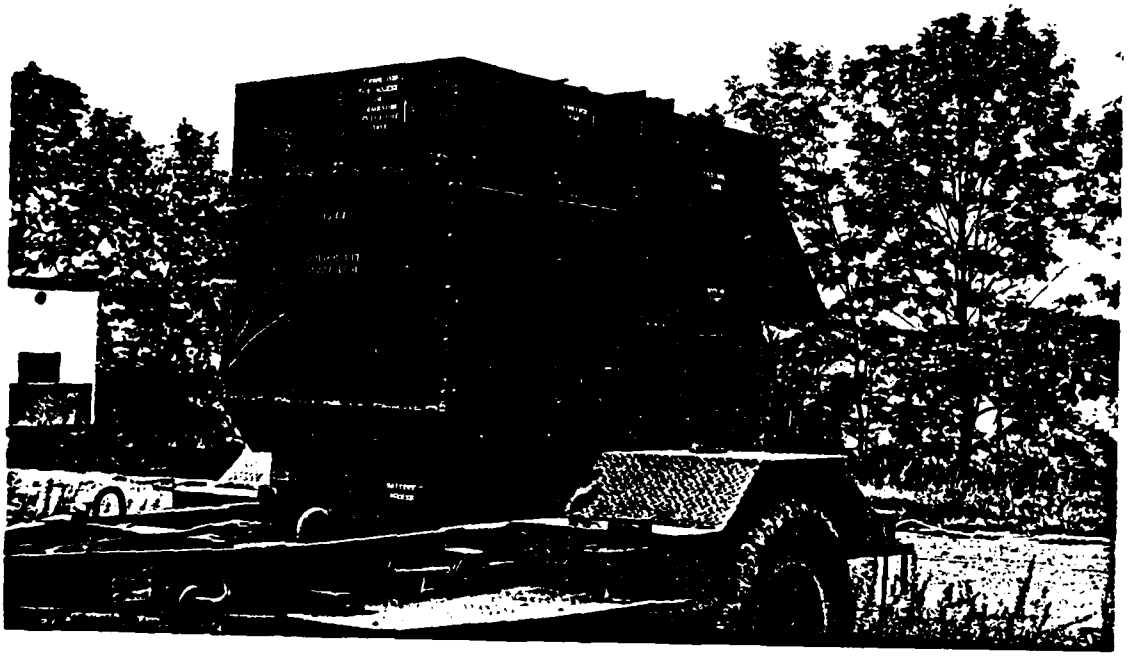
RUN







WHITE
ENGINES, INC.

P O BOX 6904
CANTON OHIO 44706
PHONE (216) 454-5631
TELEX-98-3439 WHTENGS CTN

March 11, 1987

Department of the Army
U. S. Army BRDEC
Attn: Power Generation Division
Mr. Noel Bishop
Ch, Power Equipment Support Team
Fort Belvoir, Virginia 22060-5606

Dear Noel:

The following comments are offered with response to your letter dated February 17 regarding improved reliability, IR and noise suppression:

White Engines has actively questioned, through the military organization and up to the Undersecretary of the Army, the reported unacceptable reliability on the DoD generator sets. We have offered to assist in evaluating the reliability problems to determine required product improvements to meet the Government's target objectives. (See attached information)

White Engines has also sponsored an NDI program to demonstrate how effectively the current 15 and 30 kW DoD generator sets can be noise and IR suppressed without major effect on interchangeability and field service support.

We have demonstrated this unit to many military personnel and would be most pleased to demonstrate the set at your facilities if it would benefit in meeting your overall objectives. I would very much appreciate the opportunity to visit your facility and discuss in further detail White Engines' recommendations and objectives for your overall program.

Yours truly,

WHITE ENGINES, INC.

Robert J. Holtgreive
Executive Vice President

/jb

Attachments

QUESTIONNAIRE

1. Are you a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets? Please describe. White Engines DISCER and DISCER engines are the std. for the 15 & 30 kW DoD Gen. sets.

If you manufacture other diesel engine driven equipment, what is the equipment? White Engines supplies diesel engines for most commercial and industrial applications.

2. What is an estimated average yearly usage for your equipment? _____

What is the estimated operating cycle of your equipment (8 hours per day, 5 days per week, etc.)? Please describe. _____

_____.

3. By what methods do you receive feedback from users on your equipment (application, engineering, sales, warranty replacements, etc.)? Please describe. White Engines receives feedback from OEMs by direct contact with the service managers who continually monitor their customers requirements.

4. If you are not a manufacturer, what is your position in the market place? Please furnish description. _____

_____.

5. The DoD generator sets, once in user hands, are operated outside, exposed to the elements in many parts of the world and are exposed to all climatic conditions. Their operating cycle may be around the clock, for extended periods, with short shut down intervals for servicing or they may sit idle, being operated only a few hours per month. The majority of our sets are trailer

mounted on open trailers and during some field exercises they are frequently transported over roads ranging from highways to open cross country terrain. The sets are typically operated by soldiers primarily trained to operate other equipment such as radios, radar, trucks, etc. Typically they are maintained by trained repairmen with limited experience. If you are interested in the reliability portion of the program, please consider the above, look at the attached reliability tree and answer the following questions:

a. Based on your experience, what part(s) of the tree do you think you can improve? White Engines can provide reliability improvements on the basic engine & all associated components. W.E. also has demonstrated experience in noise & IR suppression of the 15 and 30 kW sets.

b. How much improvement do you think you can provide? To be determined based on field evaluation.

c. Describe your approach for making the improvements. W.E. would incorporate latest technology into the mil. spec. which has been firm over the past 12 years. Product imporved engines could be assembled for reliability testing by the Govt. W. E. would also recommend a revised gen. set fuel system in conjunction with the updated engine.

d. Furnish a cost estimate for your program. Our program cost would depend on whether we incorporate noise & IR suppression or just product improvement.

6. The generator set described in the attached figure is a typical military liquid cooled diesel engine driven generator set. It is designed so that the engine fan pulls air through the generator end for cooling the electrical apparatus, as well as combustion air and cooling air for the engine. The air is discharged through thermostatically controlled louvers on the radiator end. The 120hp at 1800 RPM/6 cylinder turbocharged engine uses a 15hp standard four blade metal fan for moving the air. The engine muffler is located within the set housing and the engine exhaust is out the radiator end near the top. The generator is single bearing, four pole, with a synchronous speed of 1800 RPM.

The engine generator set assembly uses a three point mounting, two generator feet and an engine trunnion mount, and is mounted directly to the skid base. The present noise level of the set is 87dBA at a 7 meter distance from the set. The set has a metal housing, with all bolted construction. The present housing + muffler offers very little sound attenuation. Considering the above, please answer the questions applicable to your area of interest.

a. Please describe your general approach for lowering the noise emitted from the set in any direction to 70 dBA at 7 meters. White Engines would incorporate the demonstrated technology used on the 15 and 30 kW DoD gen. sets to reduce the noise level on the 60 kW set - See attached information.

b. What would be your guesstimation of the set weight and dimensional increase required for your sound attenuation effort? Height would increase approx. 10 to 12" - width 4 to 8". Overall the set would increase approx. 800 lbs.

c. Please describe your general approach for decreasing the infrared signature of the set. The same technology would be applied as demonstrated on the 15 and 30 kW set for total IR suppression. (See attached information)

d. What would be your guesstimation of the set weight and dimensional increase required for decreasing the infrared signature of the set? Same dimensions as specified under 6B

e. If you are interested in both the sound and infrared reduction efforts, how do you foresee their interrelation? White Engines design incorporates noise and IR suppression with the same design features. We do not foresee a problem in providing both IR and noise suppression or that it represents a major cost increase on a production basis.

f. What would be your guesstimate of the net set weight and dimensional increase for both efforts? The set size and weight would be consistent with 6B.

DEPARTMENT OF THE ARMY
DOD PROJECT MANAGER-MOBILE ELECTRIC POWER
7500 BACKLICK ROAD
SPRINGFIELD, VIRGINIA 22150

July 31, 1985

Mr. Robert J. Holtgreive
Executive Vice President
White Engine Company
P. O. Box 6904
Canton, Ohio 44706

Dear Mr. Holtgreive:

Thank you for your letter of July 16, 1985, regarding the Quiet Generator Set Program. Your comments and recommendations on quieting the 15 and 30 kW member of the DOD Standard Family of Generator Sets are timely and thought provoking. We are currently exploring a number of alternatives on how best to provide quiet generator sets to the Army in todays competitive environment. Your thoughts will contribute to this process.

I am also taking the liberty of forwarding a copy of your letter to Mr. Dick Sale at the Belvoir R&D Center for his review.

Sincerely,

David C. Hebden

CHARLES S. GREEN, JR.
Colonel, U. S. Army
Project Manager

Dick Sale - DRDME 514

Attachment #2

WHITE
ENGINES, INC.
CANTON OHIO 44707

ROBERT J. HOLTGREIVE
EXECUTIVE VICE PRESIDENT

July 17, 1985

Col. Charles Green, Jr.
Project Manager
Mobile Electric Power
7500 Backlick Road
Springfield, Virginia 22150

Dear Col. Green:

I was hoping to drop off this letter and discuss it with you during my trip to Washington on July 18. Unfortunately, you are on travel and unavailable for several days. I decided it was best to mail and request a meeting at your convenience for clarification and/or further information.

Our office will be closed for the next two weeks, but I will contact you as a follow-up.

Yours truly,

/jb

WHITE
ENGINES, INC.

P O BOX 6904
CANTON OHIO 44706
PHONE (216) 454-5631
TELEX 98-3439 WHTENGS CTN

July 16, 1985

Col. Charles Green, Jr.
Project Manager
Mobile Electric Power
7500 Backlick Road
Springfield, Virginia 22150

Dear Col. Green:

SUBJECT: Quiet Generator Set Program

At the recent Electrical Power Fair, you expressed an interest in having contractors provide you with comments and recommendations concerning military generator sets. It was also mentioned during this conference that the Project Manager's Office would be developing a specification for future procurement of quiet generator sets, based on test results of the Ft. Hood, Texas program.

As you are aware, White Engines, Inc. funded a development program to demonstrate that the current military standard DoD generator sets can be modified to meet noise and IR suppression, while retaining approximately 90% interchangeability of all current generator set components. Based on the successfully demonstrated results of our unit, White Engines, Inc. recommends that:

1) White Engines, Inc. consider funding a program to modify the military standard 15 kW DoD generator set using the same technology demonstrated on the 30 kW set.

2) The military conduct engineering tests on this modified 15 kw unit for compliance with military specification, similar to the tests conducted on the 30 kW unit. The 15 kW unit will be furnished to the Government for testing, on the same no-charge basis as was done on the 30 kW Signature Suppressed Generator Set.

3) White Engines provide the Project Manager's Office with all technical data from both the 15 and 30 kW generator sets.

4) The Project Manager's Office update the current DoD military standard bid packages to include noise, IR and thermal suppression for a competitive bid package.

5) The current production contract with Hollingsworth be modified to allocate a portion of production units with noise, IR and thermal capability.

6) New production be advertised on a competitive bid basis using the above released bid packages for both current and updated (noise, IR and thermal suppression) as determined for military application requirements.

7) The military procure retrofit packages for existing 15 kW and 30 kW units in the field.

The above recommendations provide the following:

1) The Government continues to control the complete design of the generator set and can purchase on a competitive bid basis for both standard and SSDED configuration.

2) No additional major components are added to the military supply system.

3) The SSDED specified generator sets can be obtained on a shorter program schedule by modifying current production contracts.

4) The Government risk factor for this program is low in that all major components have been tested and proven on production contracts since 1973.

5) The military has the opportunity to upgrade current generator sets by applying SSDED kits to units in the field.

6) The current bid package can be updated to include SSDED technology with minimum time and cost.

If the above recommendations are not consistent with the Project Manager's program plans, White Engines, Inc. requests, as a minimum, that any new required specifications for quiet generator sets not only include the noise reduction requirements, but take into consideration any additional benefits that can be offered by bidders to include IR suppression, thermal suppression, high degree of interchangeability, short program schedule with proven components to meet your requirements. It is requested that these additional features/items be favorably evaluated by the Project Manager's Office on any future procurement of quiet generator sets.

White Engines, Inc. appreciates the opportunity of testing the 30 kW modified set on the Ft. Hood, Texas program and at Ft. Belvoir, Va., and strongly encourages the military to take advantage of the currently available technology, as demonstrated, to meet future generator set requirements.

The above is submitted in response to your request at the Generator Fair for suggestions from industry to reduce system development time and cost. Please advise if we can be of further assistance in your program, and we welcome your comments.

Yours truly,

WHITE ENGINES, INC.

Robert J. Holtgreive
Executive Vice President

/jb

DEPARTMENT OF THE ARMY
HEADQUARTERS, U. S. ARMY MATERIEL COMMAND
5001 EISENHOWER AVENUE, ALEXANDRIA, VA 22333-0001

13 January 1987

cc: J. Scheetz
J. Lennon
E. Zembrzuski
G. Easterday
J. Tomsho
T. Bednar
M. Hritsko
D. Thompson
Carol Hall
Milton Beach

Mr. Robert J. Holtgreive
Executive Vice President
White Engine, Inc.
Canton, Ohio 44707

Dear Mr. Holtgreive:

This is in response to your letter of December 19, 1986 concerning 15 and 30kw DOD generator sets. Following our meeting with Congressman Regula on December 10, 1986, I discussed the points raised in great detail with U.S. Army Troop Support Command (TROSCOM) and PM Mobile Electric Power personnel.

Currently, TROSCOM is developing a master plan for the Army generator fleet of the future. Part of this total plan will be an effort to improve the reliability of military standard generator sets. TROSCOM will head up this effort and will include generator set manufacturers and major component vendors as part of an Army/Industry team.

I sincerely appreciate your offer to support us in this effort and you will be contacted with a request to participate along with other interested members of the mobile power generation industry. I believe that this combined team of Army and industry experts can effectively tackle the reliability improvemennt issue.

A successful outcome with cost effective improvements to the DoD generator fleet can have a big payoff in terms of reduced operating and support costs to the Army, which ultimately benefits each of us.

Sincerely,

Kenneth J. Oscar

Kenneth J. Oscar
Assistant Deputy Chief of Staff
for Development, Engineering and
Acquisition - Systems Management

Copies furnished:

Commander, U.S. Army Troop Support
Command, ATTN: AMSTR-G, 4300 Goodfellow
Blvd., St. Louis, Missouri 63120
DOD Project Manager, Mobile Electric Power
Bldg. 2089, 7500 Backlick Road,
Springfield, Virginia 22150-0001

WHITE
ENGINES, INC
[illegible]

[illegible]
[illegible]

December 19, 1990

Dr. Ken Oscar
Assistant Deputy Chief of Staff for
Development, Engineering & Acquisitions
Systems Management
Army Materiel Command
5001 Eisenhower Drive
Alexandria, VA 22333-0001

Dear Dr. Oscar:

During the meeting with Congressman Ralph Regula on the 15 and 30 kW DoD generator sets, you outlined various reliability problems and the resultant meantime between failure (MTBF). The military expressed an interest to resolve the problems and I volunteered White Engines' support.

Since the meeting I have contacted the generator set manufacturers and some major component suppliers and they also are willing to assist in improving the reliability of the military standard DoD generator sets.

I would like to suggest that if you desire industry support, that a meeting be arranged to outline the various tasks, establish goals, and program schedules.

If I can be of any further assistance, please feel free to call me at White Engines, A/C 216 438-1055.

I would like to wish you and your family a Merry Christmas and a Happy New Year.

Yours truly,

Robert J. Holtgreive

/jb

AREA THERM CORPORATION

7351-H LOCKPORT PLACE
LORTON, VIRGINIA 22079
(703) 339-8974/5

13 November 1985

White Engines, Inc.
101 Eleventh St., S. E.
Canton, Ohio 44707

Bob,

Enclosed is a test report on the White Engines' noise and thermal suppressed military standard 30 kW generator set. Test data indicates that the unit successfully meets target specifications.

Yours truly,

Ed

Dr. Edward Allard

Encl.

13 November 1985

ACOUSTIC & THERMAL INFRARED SUPPRESSION OF A 30KW, 60HZ DEPT OF DEFENSE (DOD) - DIESEL ENGINE DRIVEN (DED) GENERATOR SET

Test Report

1. Introduction

Area Therm Corporation has tested MIL-STD 30KW engine-generator sets which were altered to provide sound suppression and thermal suppression. The original housings of the sets were removed along with the fan, radiator and muffler. A new housing, a new radiator and a new muffler were integrated into each original set in a unique arrangement in order to achieve suppression. No electrical characteristics were changed, however, position of electrical outlets, control panel and hand frequency adjustor were changed.

2. Thermal Testing

There were two thermal tests. One test was to measure engine operating temperatures at various ambient air temperatures and the other was to measure or observe the surface temperature of the housing. Thermal testing of engine operation was necessary to measure any engine overheating. Testing of surface temperature was necessary to predict detection from thermal imaging devices.

2.1 Engine Operating Temperatures

The thermal design of the heat exchanger used for the suppressors were designed to trade off small volume for higher engine operating temperature. The White diesel engine can operate at a water temperature beyond 230°F but 230°F was selected as the highest

operating temperature for these particular heat exchanger designs. The heat exchangers were a two-pass system of such small size that engine operating temperatures were higher than normally observed for the MIL-STD 30KW. Area Therm Corporation does not have a room for high ambient temperature operation. However, ambient temperatures around 100°F were attainable with a plastic curtain enclosure. Many hours of testing proved that the present heat exchanger design held 32.3KW easily at ambients around 100°F. Extrapolation to an ambient of 125°F shows the design should just hold 32.3KW. Consider the following typical data:

right side ambient temperature	-	104°F
left side ambient temperature	-	99°F
cooling water high temperature	-	207°F
oil dip stick temperature	-	218°F

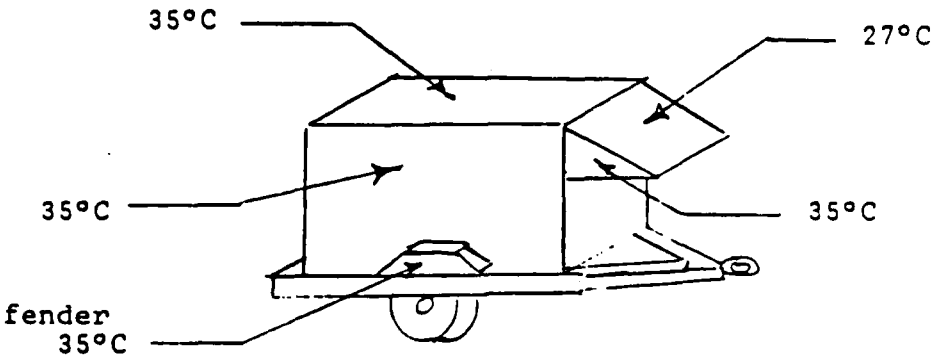
Assuming an average ambient temperature of 103°, the extrapolated ambient must increase by 22°F. Adding 22°F to 207°F would bring the engine water temperature up to 229°F which is below the goal of 230°F. This means that the heat exchanger should hold 32.3KW at 125°F. ATC recommends that the heat exchanger be built 20% larger in order to lower the hot water temperature. There is room in the 30KW for a larger design.

2.2 Surface Temperature

The detection range of a hot surface depends on the detection device itself, the range, and the difference in temperature between the surface and the ground surrounding the surface. One subject thermal suppressor was tested with a military Foward Looking Infrared (FLIR) device, which operated in the 8 to 12 micron region of the electromagnetic spectrum. At close range this device can resolve a temperature difference of less than 0.3C°. Data recorded on video tape revealed that the suppressor

had uniform temperature surfaces from a rear view, and views from both sides. The suppressor had a hood which hid the hot air and exhaust gases. A small area on the side of the hood was warmer than the sides. The temperature difference at night of this small area was 4C° above the rest of the set. This increase in temperature was caused from a heat leak which has been easily corrected. The front of the supppressor was cool except for a warm area under the hood. The hood was not long enough to hide this area. The temperature of this warm area was 4°C higher than the hood. The FLIR used to image the E-G set was so temperature sensitive that even warm spots appeared hot in the thermal image. A longer hood was built to hide this warm spot but thermal imagry was not taken.

Typical temperature data for surfaces in the sun follows.



black top 35°C
shade side temperatures - 27°C

From these data it is seen that the entire E-G set was no warmer than the ground temperatures under solar heating conditions.

3. Acoustical Testing

Acoustical measurements are affected by the environment surrounding a noise source. The tests performed by ATC used a standard

noise meter. The environment was a black top roadway with buildings on each side of the roadway. The E-G sets were tested in the middle of the roadway which was 60 feet wide. Measurements were taken at one meter and at 7 meters from the surfaces of each E-G set. The E-G sets were mounted on a military trailer.

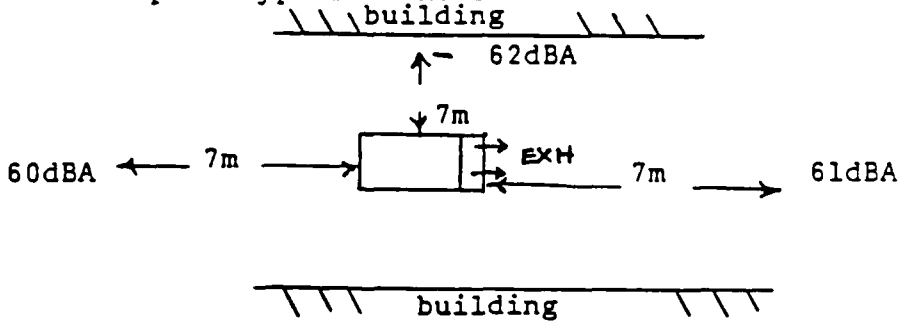
ATC measured two prototype suppressors. Suppressor#1, the first prototype, was designed to meet an average dBA level of 65dBA. This goal was met. With manufacturing costs in mind, the second prototype was built with a smaller heat exchanger and a slightly different acoustical design. The second prototype had an average dBA near 65dBA. Obviously, the first prototype design was better than the second from a noise viewpoint.

Data on prototype #2

		A	125	250	500	1K	2K	4K	8K
exhaust end	1m	79	95	83	69	66	64	58	48
exhaust end	7m	66	83	69	56	56	52	46	36
closed end	7m	62	74	64	56	57	54	48	38
closed end	1m	71	84	73	56	68	65	58	46

ambient sound 55 dBA

Data from prototype #1 - no load



Due to load bank problems this set was measured at no load. About 3dBA should be added for full load. About 2dBA should be subtracted due to the environment.

The noise data for an unsuppressed MIL-STD 30KW are on the following data sheet.

4. Results

1. The engine operating temperature, selected at 230°F maximum, will just hold 32KW at an ambient of 125°F.

2. The suppressor had surface temperatures no higher than background under solar heating conditions. At night only a very small area was warmer than background by about 4°C.

3. The average dBA reading of suppressed set #2 was around 64dBA at 7m. Background effects due to hard surfaces and buildings cause higher readings. At one meter the average was 75dBA measured at the ends. Prototype #1 had better sound suppression.

4. The average sound readings of the unsuppressed set were

97 dBA at 1m
86 dBA at 7m

measured at both ends.

5. Conclusions

1. The heat exchanger design was marginal for ambient operation at 125°F.

2. For the climatic test conditions, the suppressor completely suppressed the E-G set, except for a few small areas near the exhaust end. These areas have been suppressed on set #2.

3. The suppressors suppressed the noise 22dBA on the average.

6. Recommendations

1. A new heat exchanger should be designed into the system in order to easily meet the 125°F ambient operating requirement.

2. A correction to the exhaust suppression design should be incorporated in order to bring the noise level down to 62dBA or lower, if required.

Figure 1

30 KW Standard Set

		A	63	125	250	500	1K	2K	4K	8K
1M	1	92.5	95.0	99.5	97.0	86.0	85.5	85.5	81.0	70.0
	2	94.0	92.0	98.0	98.5	88.0	87.0	87.5	83.0	70.5
	3	97.5	97.5	103.5	101.0	93.0	92.0	91.0	86.5	80.5
	4	93.0	92.5	98.5	96.0	88.0	86.0	87.5	85.0	72.0
	5	92.0	91.5	96.5	95.5	86.5	85.0	86.5	83.0	71.5
	6	97.5	85.0	100.5	102.0	90.5	91.5	92.0	88.0	82.0
7M	1	87.5	84.0	96.0	96.5	79.5	76.5	76.0	70.5	61.0
	2	83.0	90.5	93.0	83.0	79.5	77.0	77.0	72.0	62.0
	3	82.5	83.5	90.5	89.0	78.0	75.0	74.0	67.0	61.0
	4	81.5	85.0	90.5	86.5	77.5	74.0	74.5	71.0	61.0
	5	81.5	86.5	93.0	91.0	77.0	73.0	74.5	72.0	62.0
	6	85.0	78.5	88.5	89.5	79.0	77.0	79.5	75.0	69.5

Data Positions:

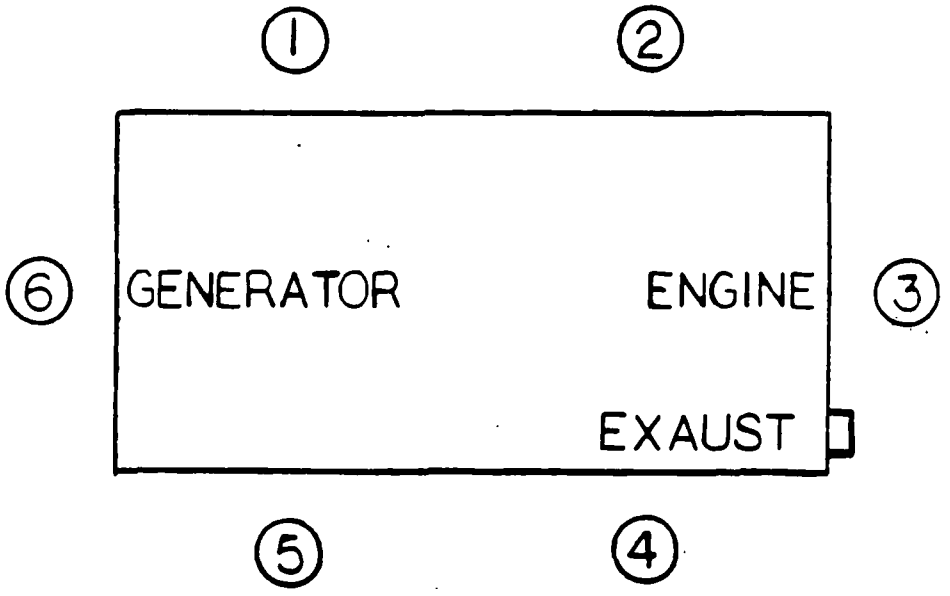


Figure 2

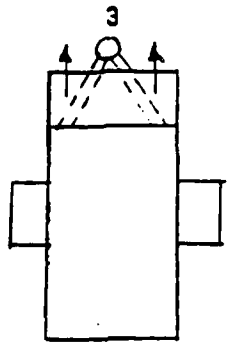
29 March 85

NOISE DATA

30KW GEN SET - White S/N 01

Trailer Mounted (Fort Hood set)

Data recorded
7 meters from
edge of set



Octave Bands	No Load Data* 1	2	3
63	71	75	69
125	73	77	70
250	67	69	68
500	51	53	55
1K	52	51	52
2K	50	49	50
4K	46	43	45
8K	31	35	30
dBA	60	62	61

* For load - Add 2 to 3 dBA
* For Hard Pavement - Subtract 2 to 3 dBA

DEPARTMENT OF THE ARMY
DOD PROJECT MANAGER-MOBILE ELECTRIC POWER
7500 BACKLICK ROAD
SPRINGFIELD, VIRGINIA 22150

15 July 1985

White Engines, Incorporated
ATTN: Mr. Robert J. Holtgreive
Canton, Ohio 44707

Dear Mr. Holtgreive:

I would like to thank you for participating in our highly successful joint industrial-government Electrical Power Fair activities. The Fair attracted over 1300 visitors, including the Under Secretary of the Army, a host of general officers and many senior corporate leaders. The Fair definitely indicated the strong support for improved communications and an awareness between industry and the military.

Your support and interest was even more evident based on your cooperation in allowing the attached photographs to be taken. These photographs portray the infrared signature of both military and participating commercial sets after operating approximately an hour without a load.

As you know, we are looking at the development cycle to see if there are low risk time savers we can take to develop the next generation of Department of Defense generators in the near future. These generators must be quieter and have a reduced infrared signature. I hope we can continually and collectively work together to reduce sound and infrared suppression on any new production generator sets.

Thank you again for your cooperation and a special thanks for your participation in the Fair. See you during the upcoming joint Electrical Power Interface Workshops.

Sincerely,

CHARLES S. GREEN, JR.
Colonel, U. S. Army
Project Manager

Enclosures

cc: J. Lennon
J. Scheetz
G. Easterday
G. Kandel
G. Smith
E. Hannum
T. Bednar

The photographs attached are in my possession if you care to see them.

Bob

INDEX

PHOTO 1 - Partial overview of outdoor display from the southwest.

PHOTO 2 - Approaching from the west end of the outdoor Fair grounds with White Engines in the foreground, Plessey Aerospace to the right, MIL STD 60 kW, Caterpillar Tractor and Hatz Diesel to the left.

PHOTO 3 - Approaching from the southwest with Kohler tent in the foreground, Hatz Diesel to the left and Fort Hood evaluation sets in the background.

PHOTO 4 - Approaching from the southwest, Tiernay in foreground, Stirling, with Caterpillar and Military EPP II with one 15 kW operating in the background.

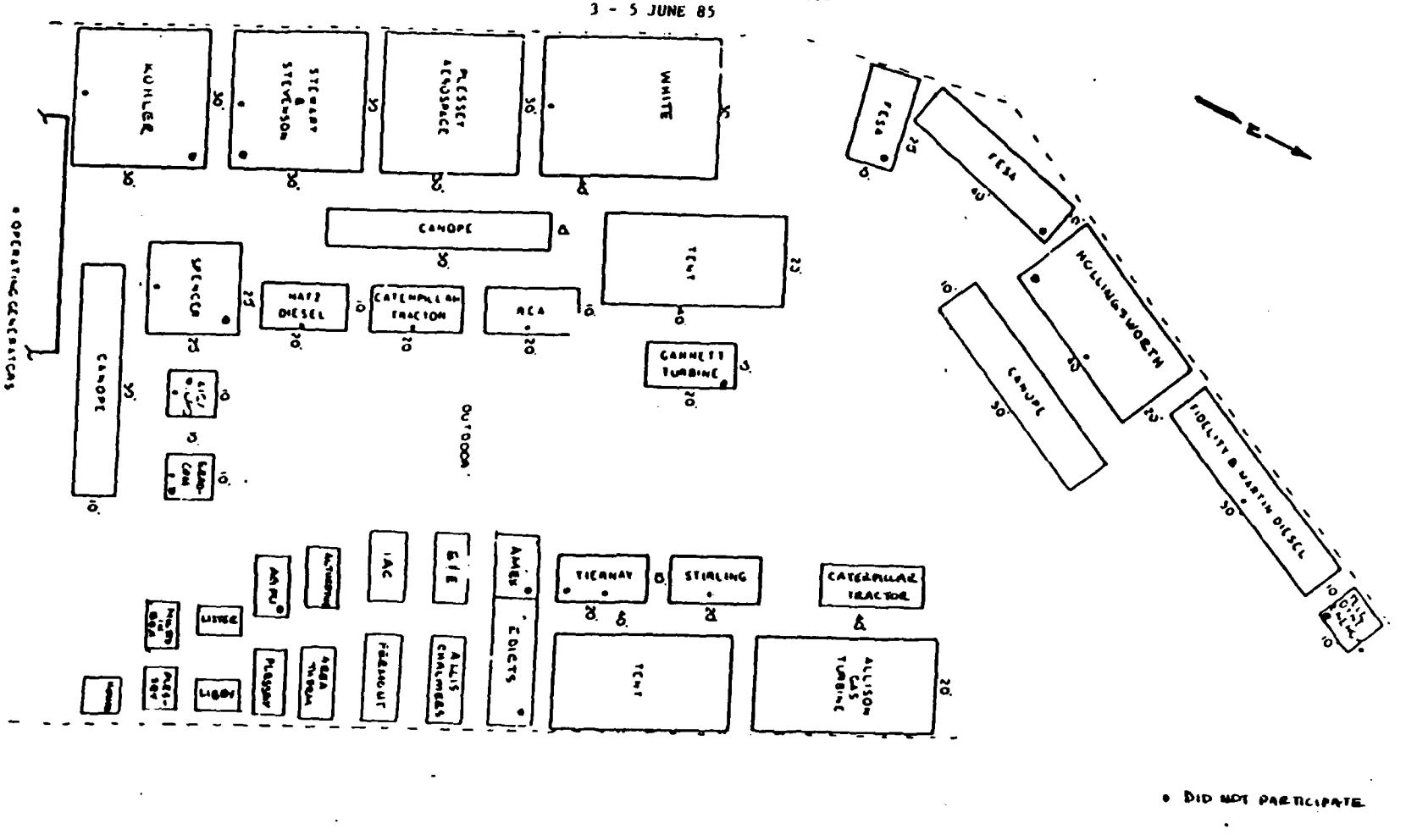
PHOTO 5 - Approaching from a northeasterly direction with Stirling (left foreground), Caterpillar (right foreground), White Engines (right), and Plessey on the right background.

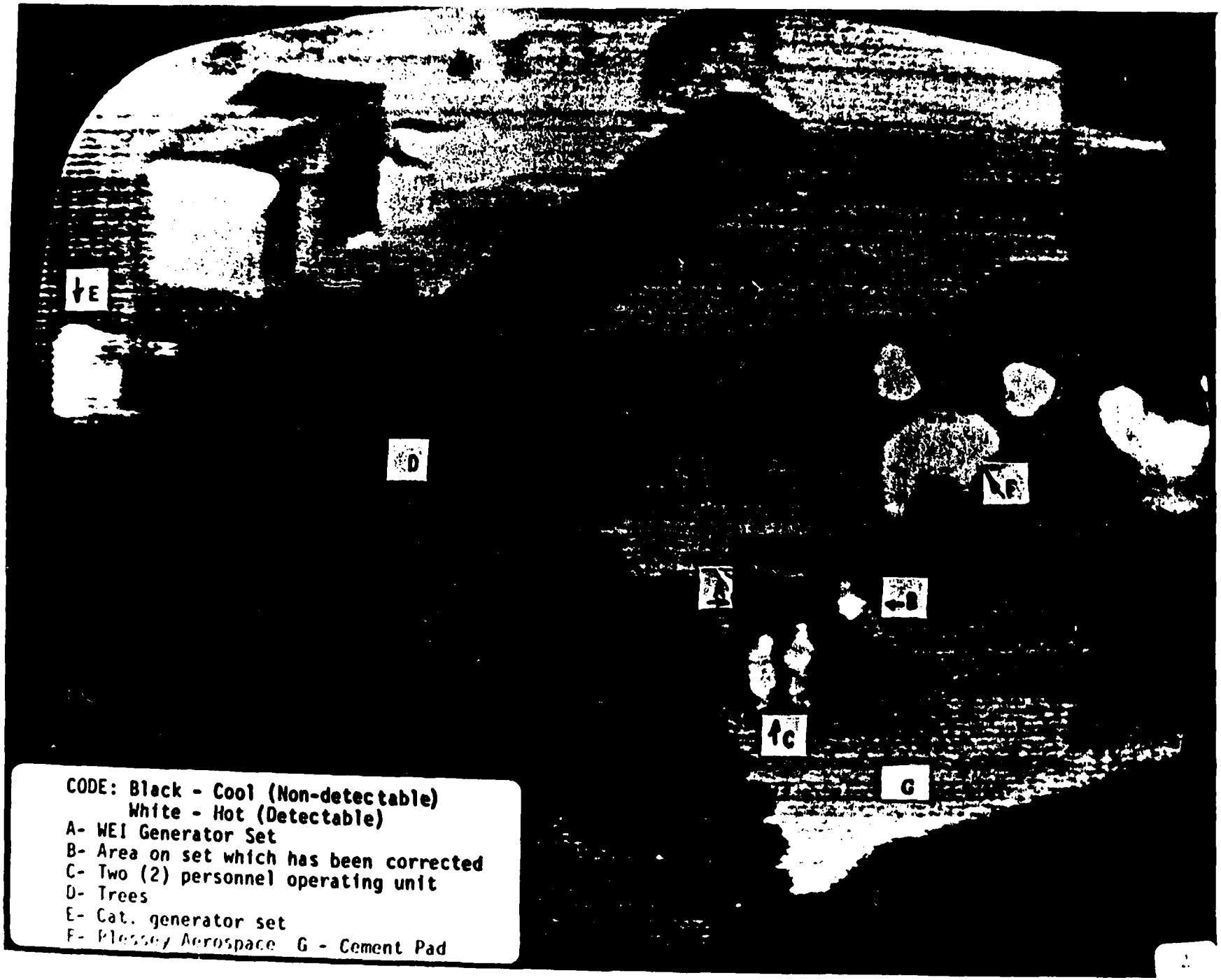
PHOTO 6 - Approaching from the northeast with Martin Diesel/Fidelity.

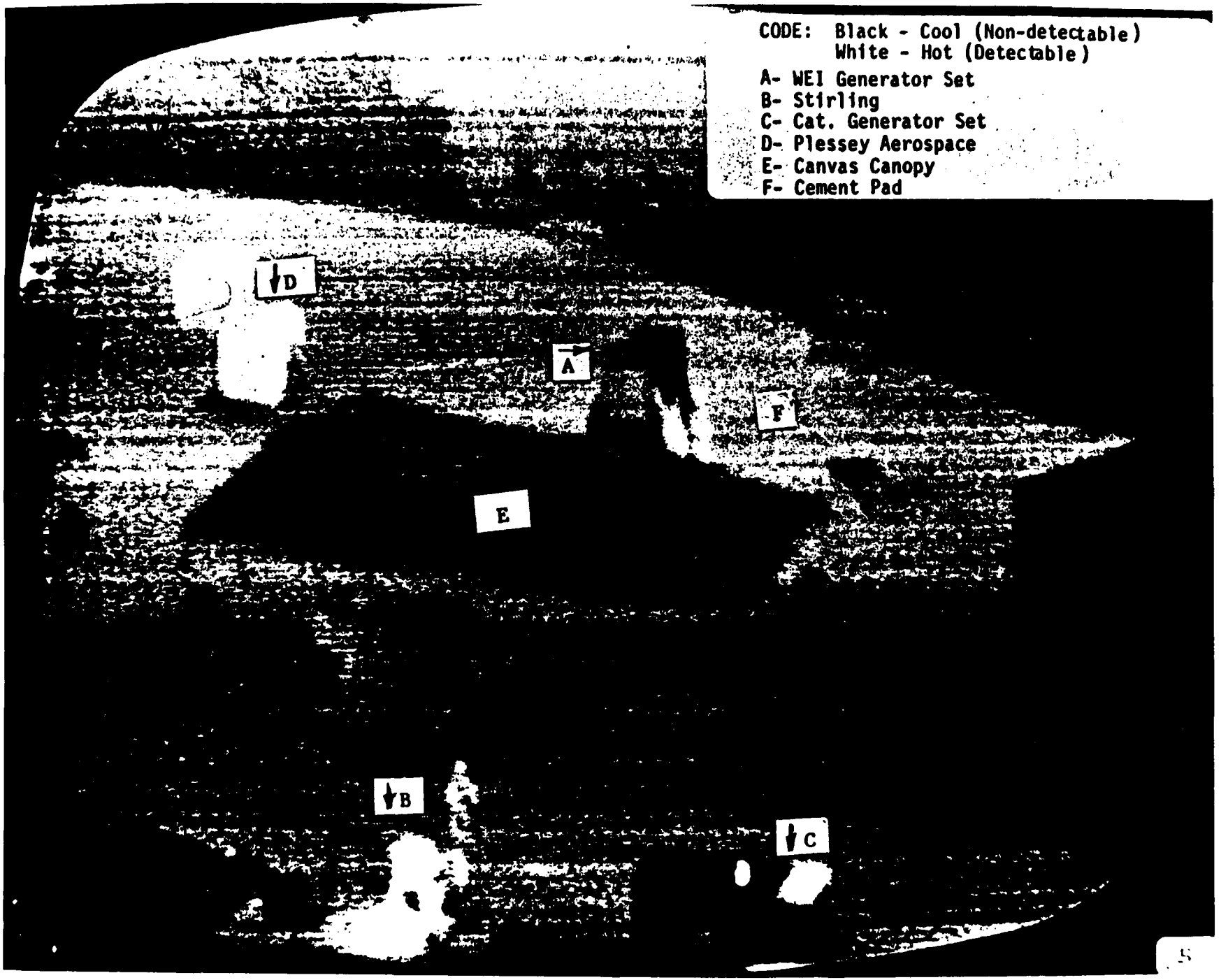
PHOTO 7 - Approaching from the southeast - overview of Fort Hood evaluation program sets in foreground with Stirling (on the left) in the background.

PHOTO 8 - Approaching from the northwest. A partial overview of the Fair with Military EPP II and Caterpillar on left foreground, Stirling in the middle, MIL STD 60 kW on the right along with Caterpillar and finally Fort Hood evaluation program in the background.

ELECTRICAL POWER FAIR OUTDOOR EXHIBITS
3 - 5 JUNE 85




E
D
C
C
G
CODE: Black - Cool (Non-detectable)
White - Hot (Detectable)
A- WEI Generator Set
B- Area on set which has been corrected
C- Two (2) personnel operating unit
D- Trees
E- Cat. generator set
F- Plessey Aerospace G - Cement Pad


CODE: Black - Cool (Non-detectable)
White - Hot (Detectable)
A- WEI Generator Set
B- Stirling
C- Cat. Generator Set
D- Plessey Aerospace
E- Canvas Canopy
F- Cement Pad
D
A
F
E
B
C

10 Moulton Street, Cambridge, MA 02238
Telephone 617 491-1850

BBN Laboratories Incorporated

13 March 1987

Mr. Noel D. Bishop
Chief, Power Equipment Support Team
Department of the Army
Belvoir Research, Development and Engineering Center
Ft. Belvoir, VA 22060-5606

Dear Mr. Bishop,

Enclosed is our response to your questionnaire on the U.S. Army's standard line of Diesel Engine Driven Generator sets, received here on March 6, 1987. Your questionnaire focuses on three areas: reliability, noise suppression and infra-red signature suppression. As our response indicates, we are primarily interested in two of those areas: noise suppression and infra-red signature suppression.

Should you have any questions concerning this response, please do not hesitate to contact the undersigned at 617-497-3240.

Sincerely,

BBN LABORATORIES INCORPORATED

Paul J Remington

Paul J. Remington
Principal Engineer

PJR/gac

encls.

QUESTIONNAIRE

1. Are you a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets? Please describe. NO

If you manufacture other diesel engine driven equipment, what is the equipment? NONE

2. What is an estimated average yearly usage for your equipment? NA

What is the estimated operating cycle of your equipment (8 hours per day, 5 days per week, etc.)? Please describe. NA

3. By what methods do you receive feedback from users on your equipment (application, engineering, sales, warranty replacements, etc.)? Please describe. NA

4. If you are not a manufacturer, what is your position in the market place? Please furnish description. RESEARCH DEVELOPMENT AND CONSULTING SERVICES TO INDUSTRY AND THE FEDERAL GOVERNMENT (SEE ATTACHMENT A)

5. The DoD generator sets, once in user hands, are operated outside, exposed to the elements in many parts of the world and are exposed to all climatic conditions. Their operating cycle may be around the clock, for extended periods, with short shut down intervals for servicing or they may sit idle, being operated only a few hours per month. The majority of our sets are trailer

mounted on open trailers and during some field exercises they are frequently transported over roads ranging from highways to open cross country terrain. The sets are typically operated by soldiers primarily trained to operate other equipment such as radios, radar, trucks, etc. Typically they are maintained by trained repairmen with limited experience. If you are interested in the reliability portion of the program, please consider the above, look at the attached reliability tree and answer the following questions:

a. Based on your experience, what part(s) of the tree do you think you can improve? NA

b. How much improvement do you think you can provide? NA

c. Describe your approach for making the improvements. NA

d. Furnish a cost estimate for your program. _____.

6. The generator set described in the attached figure is a typical military liquid cooled diesel engine driven generator set. It is designed so that the engine fan pulls air through the generator end for cooling the electrical apparatus, as well as combustion air and cooling air for the engine. The air is discharged through thermostatically controlled louvers on the radiator end. The 120hp at 1800 RPM/6 cylinder turbocharged engine uses a 15hp standard four blade metal fan for moving the air. The engine muffler is located within the set housing and the engine exhaust is out the radiator end near the top. The generator is single bearing, four pole, with a synchronous speed of 1800 RPM.

The engine generator set assembly uses a three point mounting, two generator feet and an engine trunnion mount, and is mounted directly to the skid base. The present noise level of the set is 87dBA at a 7 meter distance from the set. The set has a metal housing, with all bolted construction. The present housing & muffler offers very little sound attenuation. Considering the above, please answer the questions applicable to your area of interest.

a. Please describe your general approach for lowering the noise emitted from the set in any direction to 70 dBA at 7 meters. SEE ATTACHMENT B

b. What would be your guesstimation of the set weight and dimensional increase required for your sound attenuation effort? SEE ATTACHMENT B

c. Please describe your general approach for decreasing the infrared signature of the set. SEE ATTACHMENT C

d. What would be your guesstimation of the set weight and dimensional increase required for decreasing the infrared signature of the set? SEE ATTACHMENT C

e. If you are interested in both the sound and infrared reduction efforts, how do you foresee their interrelation? SEE ATTACHMENT C

f. What would be your guesstimate of the net set weight and dimensional increase for both efforts? SEE ATTACHMENT C

ATTACHMENT A

DESCRIPTION OF BBN LABORATORIES INC.

1. INTRODUCTION

BBN Laboratories is an engineering research, development and consulting company with specialized expertise in the physical sciences, computer sciences and information sciences. In our Physical Sciences Division we have over 200 scientists and engineers many of whom are expert in the application of the latest acoustic and noise and vibration control technology. A detailed description of BBN can be found in Sec. 2.

In Sec. 3 of this attachment are descriptions of four typical BBN projects that have dealt with the suppression of the acoustic signature of military generator sets. These projects have focused on the following generator sets:

- 1.5 KW gasoline powered generator set
- 15 KW diesel generator set
- 30 KW diesel generator set
- 60 KW gas turbine generator set

In two of these projects both infra-red and acoustic signature suppression were of concern and efforts were made to integrate the two requirements into the designs.

2. BBN LABORATORIES INCORPORATED

Bolt Beranek and Newman Inc. (BBN) has grown from an acoustic consulting partnership, formed in 1948, to a two-million-dollar corporation. In this process, BBN has earned an international reputation for innovative services and products related to acoustics and environmental technologies, information sciences, and computer and communication technologies.

Headquartered in Cambridge, MA, BBN now employs approximately 2200 people. Of these, approximately 1400 are scientists and engineers, a large number of whom hold advanced degrees. The corporation is organized into five wholly-owned subsidiaries: BBN Laboratories Incorporated, BBN Communications Corporation, BBN Software Products Corporation, BBN Advanced Computers Inc. and BBN Delta Graphics.

BBN Laboratories Incorporated performs the major research and development activities of the corporation. It consists of the Physical Sciences Division and the Computer and Information Sciences Division, the Architectural and Environmental Acoustics Division, and various administrative divisions. The Physical Sciences Division, which would lead any effort in generator signature suppression, conducts applied research and exploratory and advanced development and applications engineering in underwater and in-air acoustics; acoustic signal processing systems; noise and vibration analysis and control; and structural mechanics.

3. RELEVANT EXPERIENCE

Noise Control for 30 kW Diesel Generator

BBN Laboratories Incorporated has developed, under contract to the Belvoir Research Development and Engineering Center (BRDEC), a very effective acoustic signature reduction treatment for the U.S. Army standard 30 kW diesel generator. The treatment consists of a combination of specially designed silencers, cooling-fan drive modifications, sound absorption, vibration isolation and damping. The noise control package was designed to be retrofitable on existing Army generators, and to minimize size and weight increases or adverse impacts or performance, cooling and maintenance. Three prototype sets were fabricated and all currently reside at BRDEC.

The noise control treatments have been demonstrated to produce a 16-18 dBA reduction in the acoustic signature of Army standard 30 kW diesel generators with a negligible effect on cooling air flow. This reduction results in three-fold reduction in detection distance.

The noise control treatments developed by BBN for the 30 kW generator have been used under BBN's direction by BRDEC's Electric Systems Division in developing a similar package of treatments for the U.S. Army standard 15 kW diesel generator.

Noise Control for the 15 kW Diesel Generator

Working closely with the Belvoir Research Development and Engineering, BBN Laboratories Incorporated helped the Electric Systems Division apply the noise control treatments developed for the aforementioned 30 kW diesel generator to the standard U.S. Army 15 kW diesel generator. Essentially all of the treatments used on the 30 kW set were used on the 15 kW unit with some simplifications where possible because of the lighter weight and reduced heat rejection requirements of the smaller unit. BRDEC has recently completed a prototype that achieved 64 dBA at 7.5 meters, a noise level that is well below the agreed design goal of 70 dBA.

Noise Control for Ground Launch and Cruise Missile Systems

BBN is currently under contract to General Dynamics/Convair Division to develop a noise control package for the U.S. Air Force GLCM system. The objective of this project is to develop a series of noise control treatments that can be installed on existing equipment to reduce the acoustic signature, and thereby the detection distance. We will be developing treatments for two

primary areas: the 60 kW turbine generator and the environmental control system.

A detailed series of field tests was carried out to identify the primary sources of noise and the paths by which the noise from each source reaches the environment. Fifty source/path combinations were examined. It was determined that 22 noise control treatments would be required to achieve the desired reduction in detection distance. The weight penalty associated with these treatments was estimated to be about 1000 lbs. Plans are currently underway to implement the proposed treatments on a prototype GLCM Launch Control Center (LCC).

Noise Control of the 1.5 kW Gasoline Engine Driven Generator

Working with the Belvoir Research and Development Center, BBN Laboratories Incorporated designed and built a noise control kit for the U.S. Army standard 1.5 kW gasoline engine driven generator set. The intent was to reduce the acoustic detectability of the set in the jungle environment. The treatments consisted of an aluminum enclosure suitably lined with acoustic absorptive material; vibration isolation of the set from the enclosure, an improved muffler and acoustical plenum chambers at the inlet and discharge for cooling air. The final unit achieved a noise reduction of 23 dBA while still allowing the generator set to operate successfully over a temperature range of from -50°F to +125°F. In the final prototype, the generator set and all acoustic treatments weighed 217 lbs and had a total volume of 9.5 cubic feet. An assessment of the infra-red emissions from the set was also made and indicated that the treated set would be expected to be less detectable than the untreated set.

ATTACHMENT B

ACOUSTIC SIGNATURE SUPPRESSION OF THE 60 KW DIESEL GENERATOR SET

1. INTRODUCTION

Before the noise control treatments required to achieve a particular level of noise reduction can be defined it is necessary to obtain detailed source strength information for the unit. This involves determining the sound level contributed by each important source at each frequency at the measurement locations of interest around the set. Such information does not exist for the 60 KW generator set, and the first step in the design of a prototype noise suppression kit should be a series of diagnostic measurements to determine the source contributions.

Although the required source diagnostic information does not exist for the 60 KW generator, it does exist for its sister unit, the 30 KW generator. Figure 1 shows the results of a source diagnosis carried out by BBN on the 30 KW unit. Based on what we know about the 30 KW we can make a first order estimate of what will be required for the 60 KW unit.

2. NOISE SOURCES

We anticipate that the primary sources on the 60 KW diesel generator will be:

- the engine exhaust
- the engine combustion air intake
- cooling fan
- engine casing
- engine auxiliary equipment
- structureborne noise from the engine and generator radiated from the housing.

- generator cooling fan
- generator casing

Exhaust and cooling fan are probably the strongest sources. Engine intake is probably less important than on the 30 KW because the engine on the 60 KW is turbocharged. Turbocharging tends to reduce the severity of low frequency intake noise and may also improve exhaust noise. We know that in order to achieve 70 dBA or less at 7 meters that structureborne noise must be treated on both the 30 KW and the 15 KW. We infer from that information that structureborne noise will have to be treated on the 60 KW as well. Engine casing noise refers to the noise radiated from the engine block due to combustion and mechanical sources within the engine. It is typically a significant source with diesel engines and we see no reason to expect this engine to be different in that respect. Noise from the generator cooling fan and engine auxiliaries (alternator, injector pump, water pump, fuel pump, etc.) are generally over whelmed by the engine casing noise and generator casing noise is usually lumped with engine casing noise because the two are intimately connected together.

3. NOISE CONTROL TREATMENTS

Engine Intake and Exhaust

Once a source diagnosis has been performed, the noise reduction requirements (insertion loss) of the intake and exhaust silencers can be defined. Usually commercial silencers are available from a number of muffler manufacturers. If acceptable commercial silencers are not available due, for example, to size constraints, special silencers can be developed. The 60 kW unit will certainly require an improved exhaust silencer and most likely an intake silencer as well.

Cooling Fan

Cooling fan noise is especially sensitive to speed. A halving of fan speed, for example, would be expected to reduce fan noise by 18 dB. Consequently, the most productive approach to fan noise reduction would be to improve the air flow through the housing by increasing the intake opening area at the generator end of the set. Because this would reduce the air flow restriction, the air flow through the set would increase and the fan speed could then be reduced until the air flow returns to its original value. In the 30 KW diesel generator set we were able to achieve 8 to 10 dB of noise reduction in this manner while maintaining the maximum ambient temperature for the set at 125 degrees Fahrenheit. Since the fan is within the housing, additional noise reduction will be obtained from the acoustic treatments that are applied to the housing as will be described below.

Engine/generator Casing, Generator Cooling Fan and Engine Auxiliaries

To deal with the airborne noise from these sources one typically relies on the application of acoustic treatments to the housing of the set. These treatments include absorption (open cell foam or glass fiber mat suitably protected to prevent mechanical damage and absorption of flammable fluids) applied to the inner walls of the housing and silencers applied to the the cooling air openings at the front and back of the set. In the 30 KW generator these silencers were removable, weighed about 40 pounds and extended about 1 ft. from the housing.

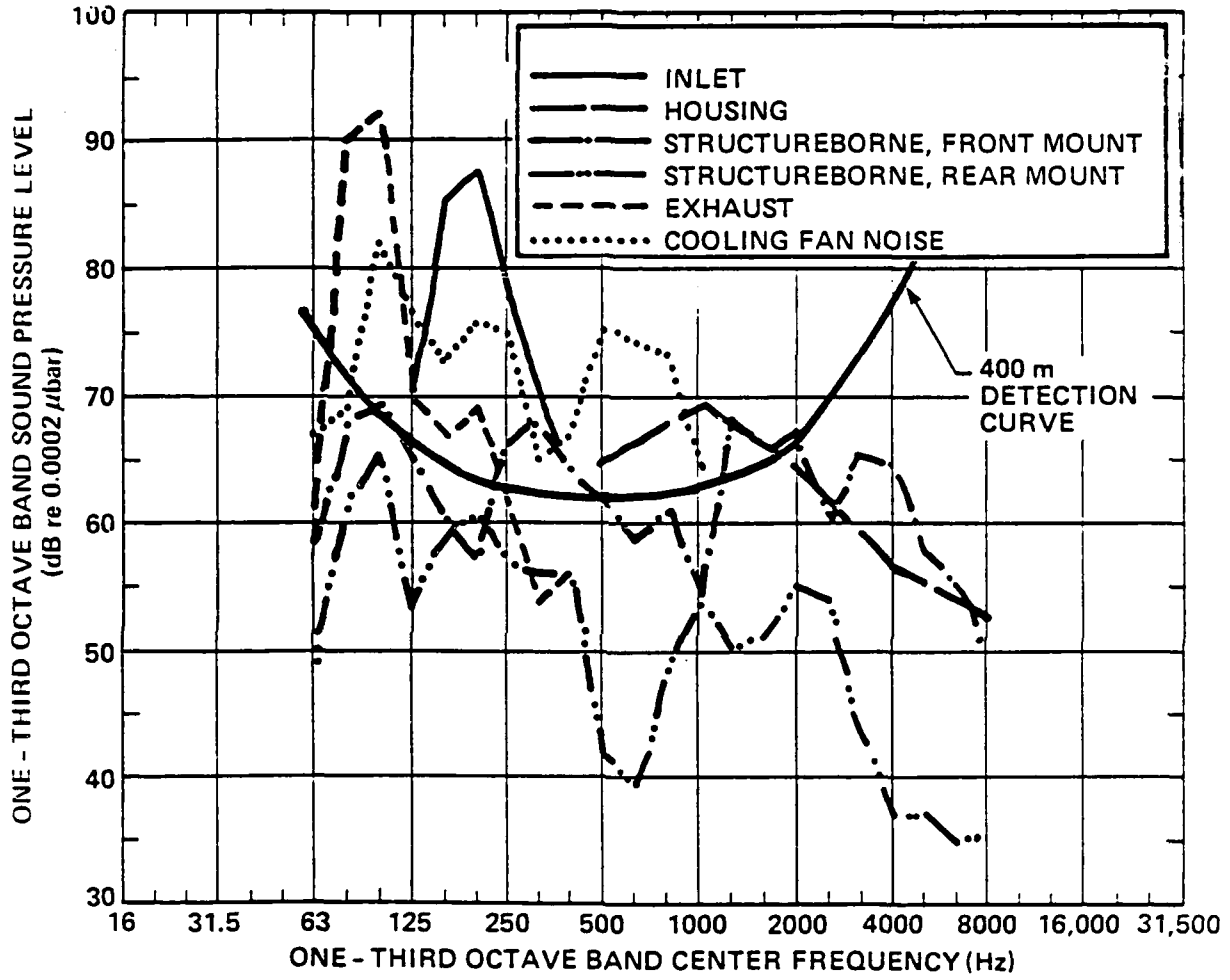


FIG. 1. SOURCE DIAGNOSIS FOR THE 30 KW DIESEL GENERATOR AT 7.5 METERS FROM THE RADIATOR DISCHARGE END.

Structureborne

It has generally been our experience that to achieve sound levels of 70 dBA or less at 7 meters structureborne noise treatments are necessary. The most effective treatment is the installation of resilient isolators (typically neoprene isolation mounts available from a number of suppliers). This is the approach that we took with the 30 KW and 15 KW generator sets. While this treatment has a high certainty of success it is often difficult to install on a retrofit basis since the entire generator must be removed from the housing and the mounting beams modified to accept the isolators. Another approach that would be easier to apply but with unknown weight penalties and less certainty of success is the application of damping treatment to the skid base and housing. This approach might prove to be adequate for the less ambitious goal of 70 dBA. Further noise reduction would most certainly require vibration isolation.

4. INCREASES IN WEIGHT AND VOLUME

Applying treatments as described above we achieved 67 dBA at 7.5 meters with the 30 KW generator set. Figure 2 shows a photograph and Fig. 3 shows a schematic drawing of the treated 30 KW set. We have fabricated three prototype quieted 30 KW units, all of which currently reside at BRDEC. The increase in weight was approximately 400 lbs. The increase in volume was due to the cooling air intake and discharge silencers which projected 1 ft. from the front and rear of the set and to raising the roof of the set approximately 1 ft. to allow for space for the exhaust and intake silencers and additional cooling air intake area. We anticipate approximately the same increase in volume for the 60 KW unit with a similar weight increase.

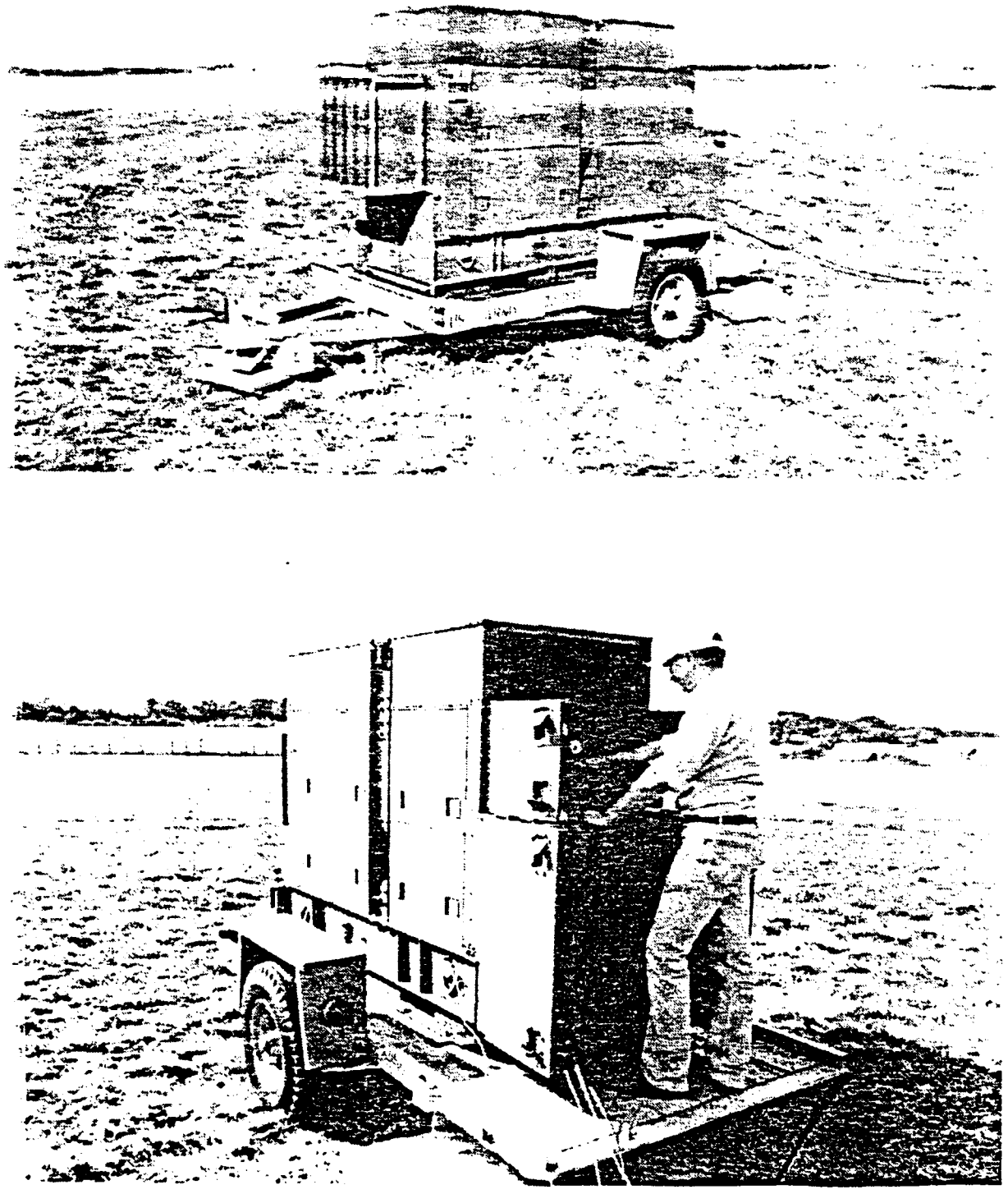


FIG. 2. PHOTOGRAPH OF THE FULLY TREATED 30 KW DIESEL GENERATOR SET.

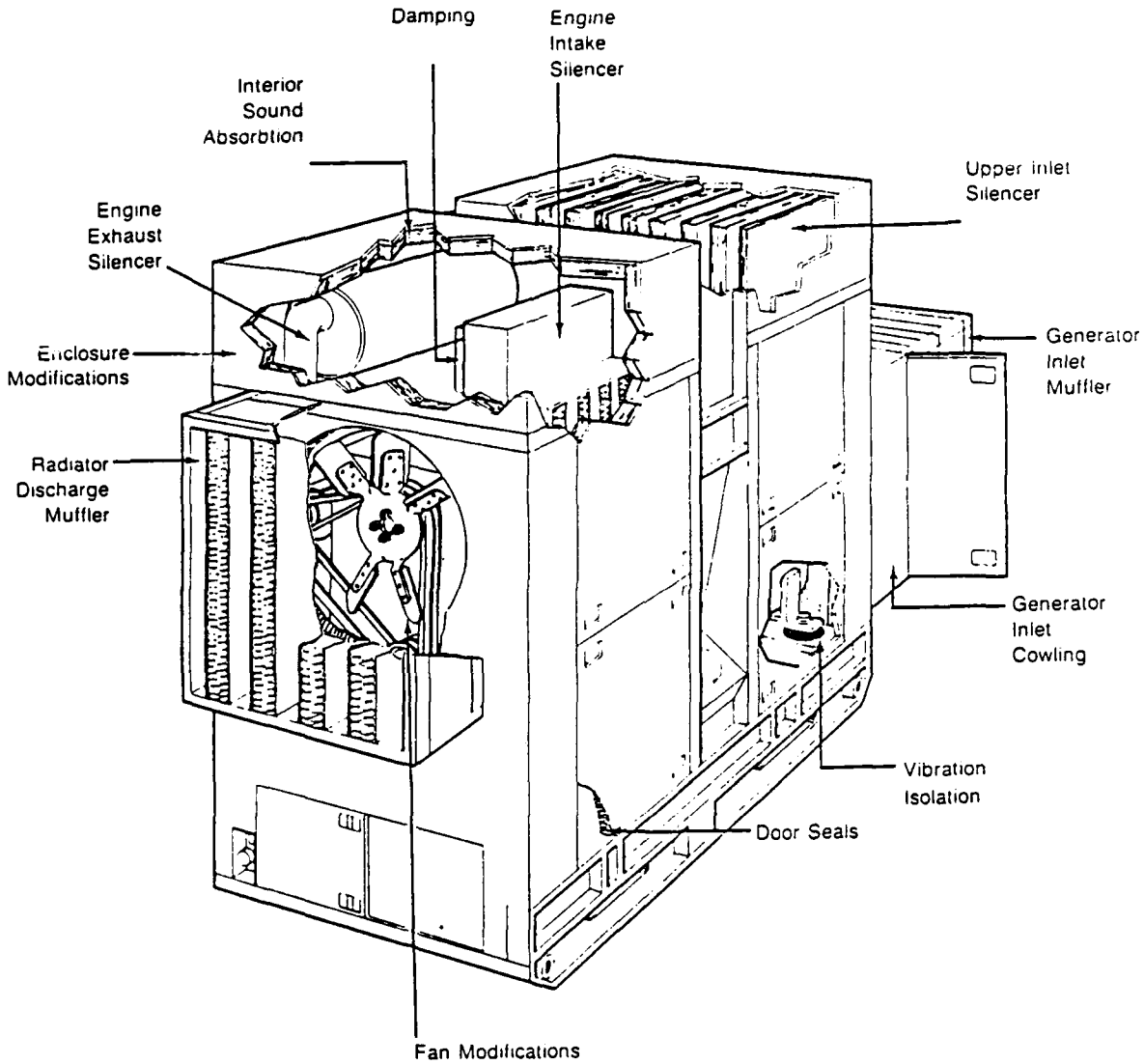


FIG. 3. SCHEMATIC DRAWING OF THE TREATMENTS INSTALLED ON THE 30 KW DIESEL GENERATOR SET.

ATTACHMENT C

INFRA-RED SIGNATURE SUPPRESSION

1. INTRODUCTION

The type of infra-red signature suppression treatments required for the 60 KW set will be determined by the suppression specification, i.e., the number of degrees of above ambient that the skin of the set is allowed to be and possibly the maximum temperature in the exhaust and cooling air discharge plume. If the infra-red signature suppression requirements are not too stringent, then, only slight modifications of the acoustic suppression kit may be required. In many ways treatments required for acoustic signature suppression are also helpful in achieving infra-red signature suppression. For example, the material used for acoustic absorption on the inner walls of the housing is also a thermal insulator. Consequently, for modest infra-red signature suppression only slight modification of the acoustic suppression treatments described in Attachment B will be required. For more stringent infra-red suppression requirements more heroic means may be necessary, e.g., double walled enclosures.

2. TREATMENTS

For modest reduction of the infra-red signature of the set and for those cases where no increase in the acoustic signature is allowed but acoustic suppression is not required, a promising approach would be as follows. First, one would increase the cooling air inlet area. That would reduce the flow restriction and result in increased cooling air flow with no increase in fan speed. If in conjunction with this thermal insulation material were applied to the walls of the housing, decreases in the skin temperature of the housing would most certainly occur. Other treatments might include diverting the engine exhaust into the

cooling air discharge air flow to reduce the exhaust plume temperature, use of flow vanes to eliminate stagnation regions where temperatures might build up, use of low pressure drop vanes in the cooling air intake and discharge openings to prevent line of sight into the interior of the housing, etc.

If modest infra-red signature suppression is required in conjunction with acoustic signature suppression, then the acoustic suppression treatments discussed in Attachment B would be used as the starting point. The acoustic absorption treatments used on the walls of the housing are in themselves thermal insulators. If additional thermal insulation is used to ensure that all surfaces of the housing are thermally insulated and flow vanes are used to eliminate stagnation regions, reductions in housing skin temperature will result. As above the engine exhaust gases could be injected into the cooling air discharge if necessary to reduce the exhaust plume temperature.

If dramatic reductions in infra-red signature are required, then, the approach that offers the highest certainty of success is the use of double wall construction. With both walls covered with thermal insulation and sufficient ambient air flow through the gap between the two walls, exterior wall temperatures can approach ambient temperatures. The difficulty with this approach is that it can be heavy and increase the size of the set substantially, since, essentially, a second larger housing is placed over the existing housing. The pressure drop due to air flowing through the gap between the two walls may be substantial, requiring that the axial flow fan currently in the sets be replaced by fans that are more tolerant to larger pressure drops, e.g., a centrifugal fan.

3. INCREASES IN WEIGHT AND VOLUME

For modest reductions in infra-red signatures either with or without acoustic signature suppression, the increase in weight and volume would be essentially the same as for the acoustic signature reduction kit alone. When dramatic reductions in infra-red signature are sought using the double wall approach, significant increases in weight and volume can result. Our best estimate is that the weight and volume increase would be approximately twice what those increases would be for acoustic signature suppression alone.

Deutz Corporation

KHD DEUTZ

March 16, 1987

Commander
U. S. Army Belvoir Research, Development and Engineering Center
Attention: Mr. Noel D. Bishop
Chief, Power Equipment Support Team
Logistics Support Directorate
Ft. Belvoir, Virginia 22060-5606

RE: DOD diesel Engine Driven Generator Sets
Industry Solicitation/Questionnaire, Dated Feb. 17, 1987.

Dear Mr. Bishop:

The following is submitted in response to your recent industry survey. We have completed the questionaire and provided attachments to support some of our answers, In addition, we have included a number of articles and publications addressing the Deutz Air Cooled Diesel.

Please contact us should you wish to discuss our response in greater depth.

Regards,
DEUTZ CORPORATION

R. O. Barton
Manager, Government Programs

ROB:jef

Enclosures

cc: W. Hertz, W. Laubner, W. Steinbuechel

7585 Ponce de Leon Circle, Atlanta, Georgia 30340, Tel (404) 449-6140, Telex: 6827025 DEUTZATL UW

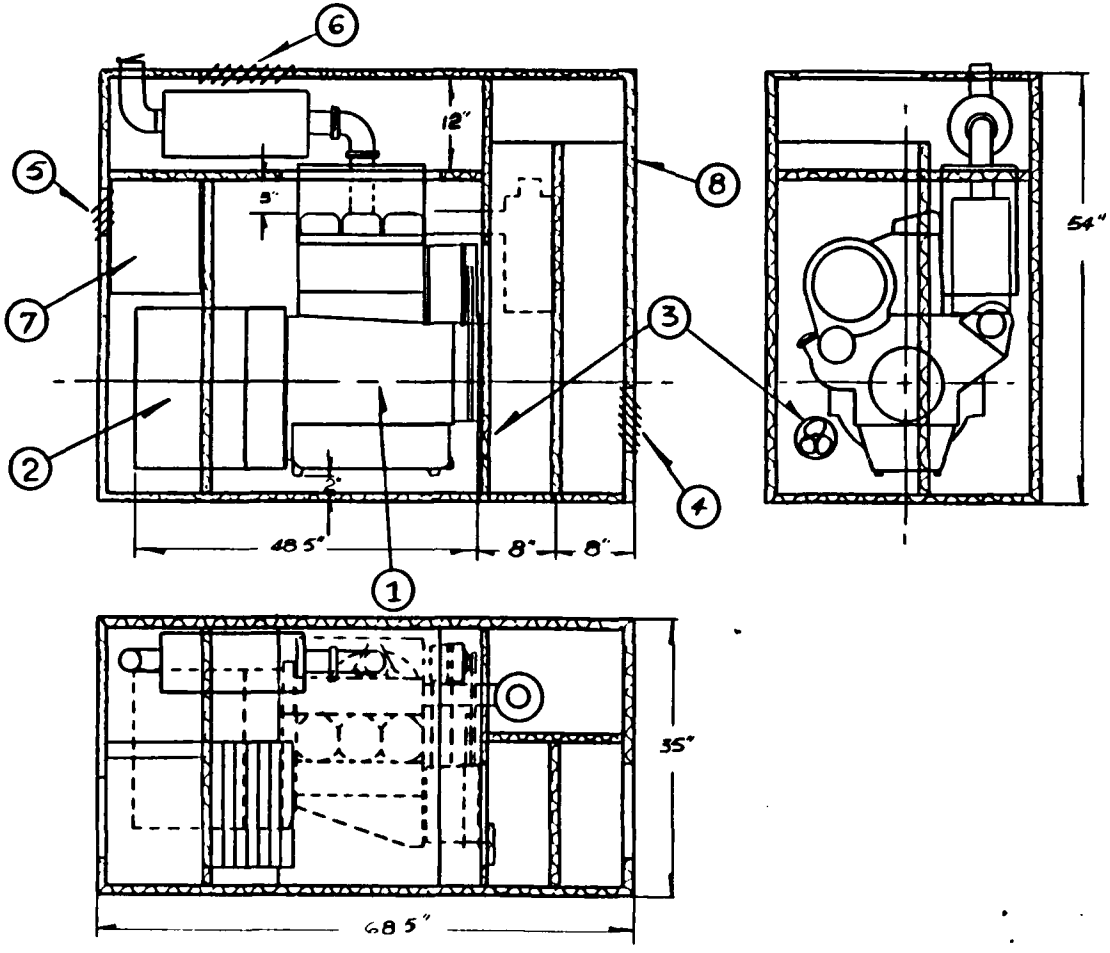
U.S.ARMY/DOD
60 KW GENERATOR SET
ENGINE COMPARISON

	ALLIS CHALMERS 670 T		DEUTZ BF6L 913
No. of Cyl.	6		6
Displacement (in ^{3})	426		374
Bore/Stroke (in)	4.25/5.00		4.06/4.92
Turbocharger	Yes		Yes
Net weight w/o cooling system	1425		—
Net weight with cooling system	1575		1070
Gross gen set rating (kW)	91 @1800 RPM		—
Net gen set rating (kW)	84.5 @1800 RPM		88 @1800
Fuel consumption lbs/HP h	.425		.348
Fuel consumption for 10 hrs. of operation, 60 kW gen set (η = .88) US Gal.	57.1		46.7
Height (in)	49.75	*	36.45
Width	33.84		28.22
Length	58.19		43.29

* w/o cooler

KHD DEUTZ

U. S. ARMY/DOD
INSTALLATION SUGGESTIONS

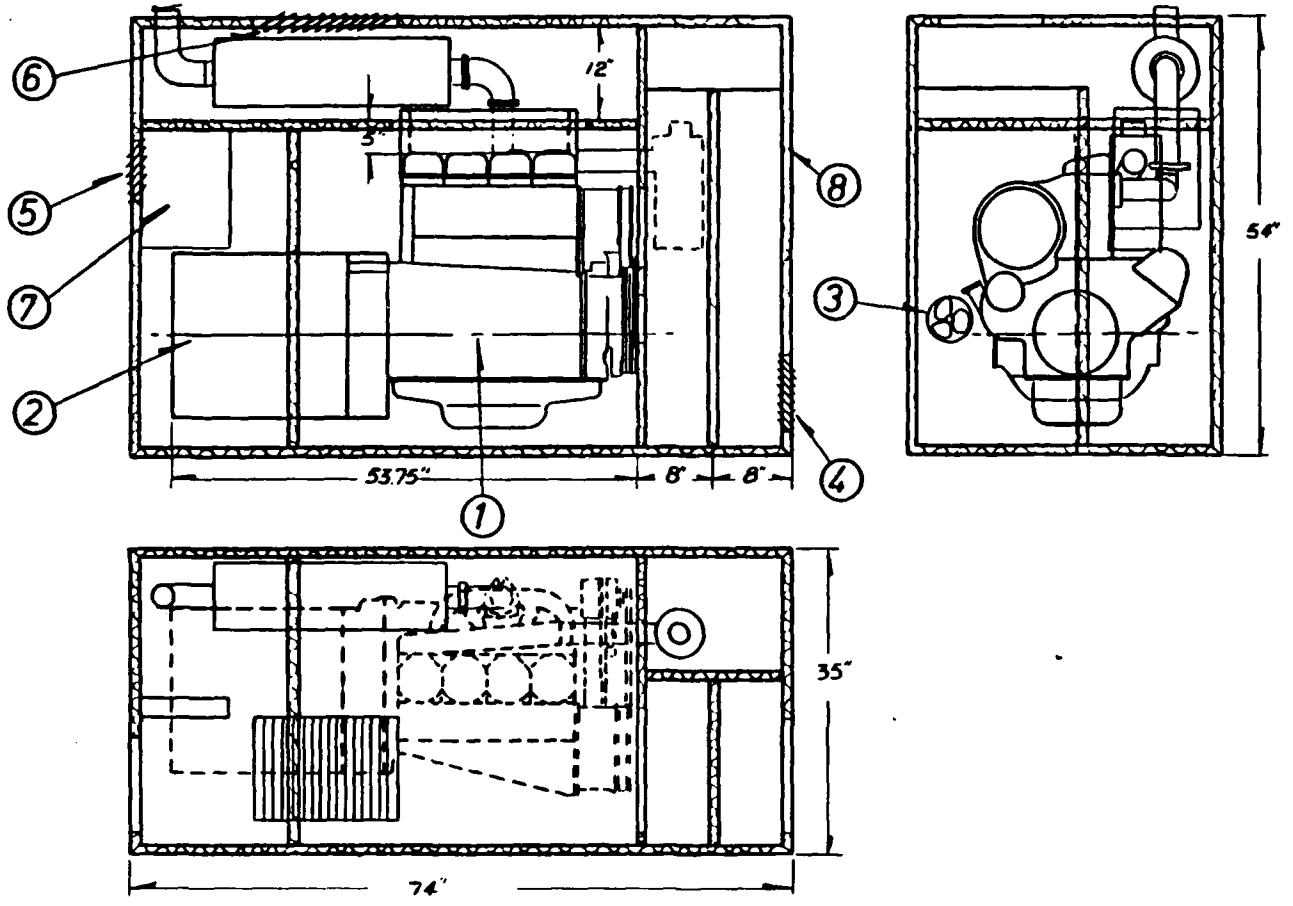


1. F3L 913 DEUTZ DIESEL 30 KW @ 1800 RPM
2. GENERATOR
3. ENG. COMP. VENT. FAN
4. ENG. COOLING & COMB. AIR INTAKE
5. GENERATOR COOLING AIR INTAKE
6. HOT AIR DISCHARGE
7. INSTRUMENT PANEL
8. 1" FOAM INSULATION

15 KW GEN SET
SOUND SUPPRESSED
60 - 65 dB(A) 7m

2/86

U. S. ARMY/DOD
INSTALLATION SUGGESTIONS

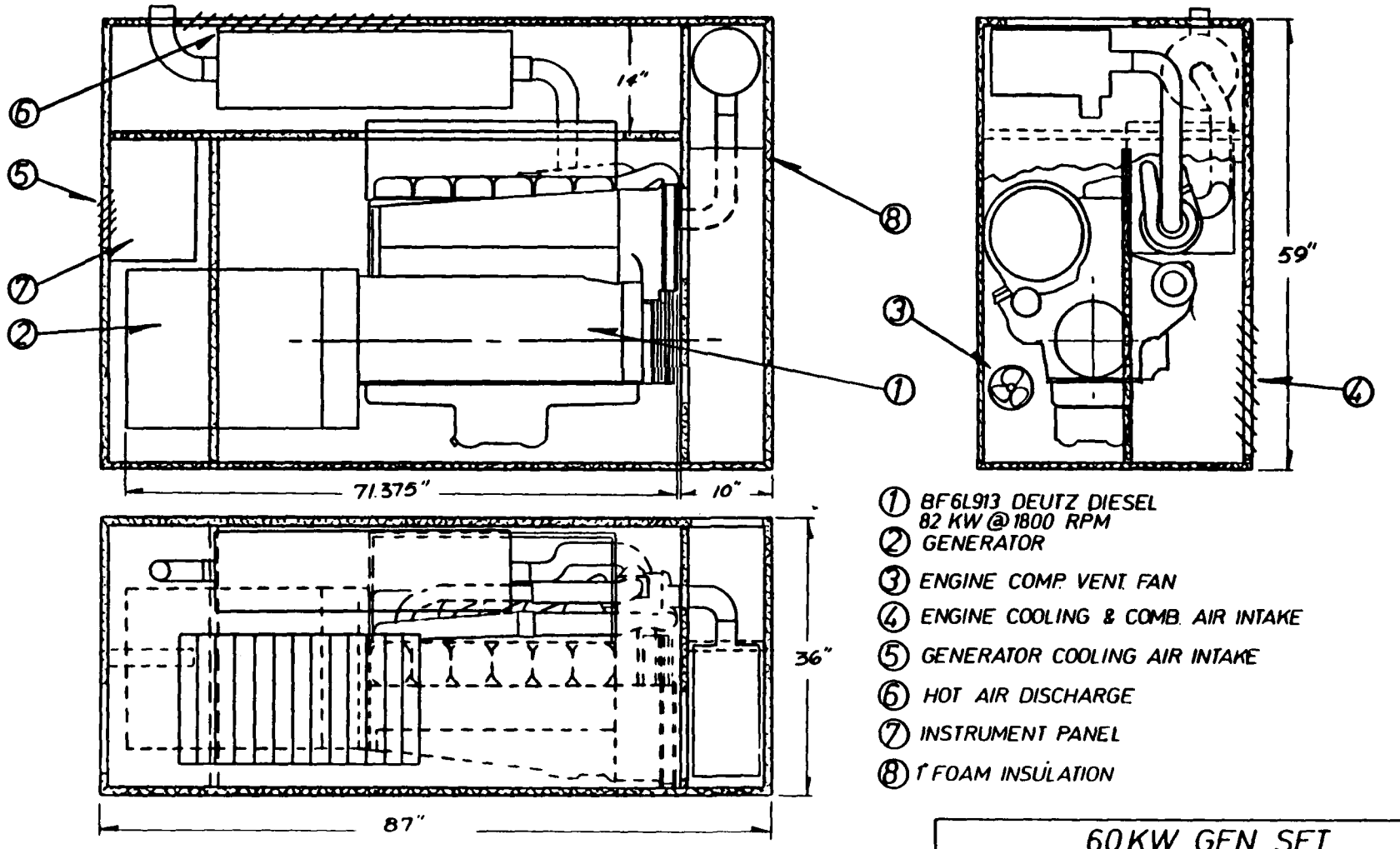


1. F4L913 DEUTZ DIESEL 41 KW @ 1800 R.P.M.
2. GENERATOR
3. ENG. COMP. VENT. FAN
4. ENG. COOLING & COMB. AIR INTAKE
5. GENERATOR COOLING AIR INTAKE
6. HOT AIR DISCHARGE
7. INSTRUMENT PANEL
8. 1" FOAM INSULATION

2/86

30 KW GEN. SET
SOUND SUPPRESSED
60-65 dB(A) 7m

U. S. ARMY/DOD
INSTALLATION SUGGESTIONS



1. BF6L913 DEUTZ DIESEL 82 KW @ 1800 RPM
2. GENERATOR
3. ENGINE COMP. VENT. FAN
4. ENGINE COOLING & COMB. AIR INTAKE
5. GENERATOR COOLING AIR INTAKE
6. HOT AIR DISCHARGE
7. INSTRUMENT PANEL
8. 1" FOAM INSULATION

60 KW GEN. SET
SOUND SUPPRESSED 65-69dB(A) 7m

2/86

DEUTZ CORPORATION
7585 PONCE DE LEON CIRCLE
ATLANTA, GEORGIA 30340

QUESTIONNAIRE

1. Are you a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets? Please describe. Air cooled diesel engines 3 - 386 kW.

If you manufacture other diesel engine driven equipment, what is the equipment? see attached brochure

2. What is an estimated average yearly usage for your equipment? What is the estimated operating cycle of your equipment (8 hours per day, 5 days per week, etc.)? Please describe. Approximately 1,200 hrs/year average approximately 65% continuous duty 7 hr. avg. day, 35% intermittent duty.

3. By what methods do you receive feedback from users on your equipment (application, engineering, sales, warranty replacements, etc.)? Please describe. Warranty claims, parts surveys, reports from regional service managers, meetings with customers & distributors. (The results on the attached 'tree' are not consistent with our experience).

4. If you are not a manufacturer, what is your position in the market place? Please furnish description. not applicable.

5. The DoD generator sets, once in user hands, are operated outside, exposed to the elements in many parts of the world and are exposed to all climatic conditions. Their operating cycle may be around the clock, for extended periods, with short shut down intervals for servicing or they may sit idle, being operated only a few hours per month. The majority of our sets are trailer

mounted on open trailers and during some field exercises they are frequently transported over roads ranging from highways to open cross country terrain. The sets are typically operated by soldiers primarily trained to operate other equipment such as radios, radar, trucks, etc. Typically they are maintained by trained repairmen with limited experience. If you are interested in the reliability portion of the program, please consider the above, look at the attached reliability tree and answer the following questions:

a. Based on your experience, what part(s) of the tree do you think you can improve? item 04A, 04B

b. How much improvement do you think you can provide? Difficult to say; however, our experience consistently suports 40% of engine failures attributable to the cooling system.

c. Describe your approach for making the improvements. An air cooled diesel engine installation, properly engineered, will result in fewer parts. Furthermore, those items eliminated are of low reliability

d. Furnish a cost estimate for your program. *See page 4

6. The generator set described in the attached figure is a typical military liquid cooled diesel engine driven generator set. It is designed so that the engine fan pulls air through the generator end for cooling the electrical apparatus, as well as combustion air and cooling air for the engine. The air is discharged through thermostatically controlled louvers on the radiator end. The 120hp at 1800 RPM/6 cylinder turbocharged engine uses a 15hp standard four blade metal fan for moving the air. The engine muffler is located within the set housing and the engine exhaust is out the radiator end near the top. The generator is single bearing, four pole, with a synchronous speed of 1800 RPM.

The engine generator set assembly uses a three point mounting, two generator feet and an engine trunnion mount, and is mounted directly to the skid base. The present noise level of the set is 87dBA at a 7 meter distance from the set. The set has a metal housing, with all bolted construction. The present housing + muffler offers very little sound attenuation. Considering the above, please answer the questions applicable to your area of interest.

a. Please describe your general approach for lowering the noise emitted from the set in any direction to 70 dBA at 7 meters. See attached sketches for general concepts and ideas.

b. What would be your guesstimation of the set weight and dimensional increase required for your sound attenuation effort? See attached summary

c. Please describe your general approach for decreasing the infrared signature of the set. Not qualified to provide any ideas in this area, however, during the SSDED competition in late 1983, we were consistently informed that the air cooled engine was easier to I-R suppress because of its smaller areas of concentrated heat.

d. What would be your guesstimation of the set weight and dimensional increase required for decreasing the infrared signature of the set? unknown

e. If you are interested in both the sound and infrared reduction efforts, how do you foresee their interrelation? Extremely interrelated.

f. What would be your guesstimate of the net set weight and dimensional increase for both efforts? Unknown

* We estimate a cost of $20-$25,000 and 2-3 months effort to re-engine an existing DOD 60 kW set for prototype evaluation. This unit will be noise attenuated to 70 dB(A) at 7 meters.

Onan

Onan Corporation
1400 73rd Avenue N.E.
Minneapolis, MN 55432
(612) 574-5000
Telex 29-0476 TWX 910-576-2833

March 24, 1987

Mr. Noel Bishop, Chief
Power Equipment Support Team
U.S. Army Belvoir R, D & E Center
Ft. Belvoir, VA 22060-5606

Re: IMS Questionnaire

Dear Mr. Bishop:

Onan's response to the IMS Questionnaire is offered as a general overview of our approach to improving reliability and non-detectability of current diesel powered MEP sets. The assumption is that the existing engine, generator and control would not change; only related components would be changed to improve reliability. It is assumed that non-detectability would be improved by add-ons in a kit concept. Kits, however, increase set size and weight and may not be allowed.

An exception might be the 5 and 10kW MEP sets where a kit could be added to the trailer, leaving the existing sets basically in their present configuration (better mufflers, etc.). We would need additional time to fully evaluate alternatives for the 5 and 10kW sets.

Please let us know if we can be of further assistance.

Sincerely,

ONAN CORPORATION
Electrical Products Division

Thomas K. Rose, Manager
Government Business Group

TR:lj

IMS QUESTIONNAIRE - ONAN CORPORATION RESPONSE

Onan Diesel Products:

1. Onan is a manufacturer of Diesel engine driven generator sets and related equipment from 3 - 1,000kW. We also market Diesel engines from 10-120Hp for use in OEM applications such as truck refrigeration, front end loaders, aircraft ground support equipment, and light trucks.

Generator Set Use:

2. Generator set applications in the U.S. fall into four primary power use categories: standby, prime (including co-generation), mobile and portable. Sets above 10kW are 90-95% standby applications with about 2 hr/wk of operation. Very few Onan sets fall into the 24 hr/day stationary prime power category. The mobile category includes all sets permanently integrated with trailers, boats, or vehicles. Use is considered prime power and mobile diesel sets, including rental units, are expected to run about 1,000 hr/yr with a first rebuild after 8 years. The mobile category most nearly matches the military generator set application. Few diesel sets meet the man portable criteria for portable sets because of weight. Portable contractor sets are used 500-1,000 hr/year.

Feed back:

3. Onan has a world-wide distributor organization which feeds back application information to the factory on an ongoing basis. Information is channelled back to the plant through Area Offices where Onan employees provide direct assistance to the independently owned distributor organizations. We also hold technical seminars for consulting engineers who specify electrical equipment involving national, state and local building codes. Warranty information is collected and processed from the field under highly developed procedures. Our OEM customers, such as builders of recreation vehicles, provide immediate feedback on high volume products. Onan has a large field service organization who investigate major problems on site plus provide service training to our distributor/dealer organization. Onan also provides extensive application engineering and product support to assure correct product use. Established in-house quality audit programs on new products also help minimize problems in the field.

4. N/A

5. Reliability:

a. Items To Improve

Onan has the expertise necessary to provide improvements to all parts of the Reliability Tree. However, we believe it to be in the best interest of the government and ourselves to address those areas of the Reliability Tree which have relatively high numbers of failures. An exception would be an area with minimal failures where examination makes it obvious that a fix can be made with a minimum of effort.

We are specifically interested in the 5 & 10 KW units because we currently manufacture the engine-generator assembly for them. To make the most of our improvement efforts we would need a Reliability Tree and other reliability information for these units. We are presuming that this would be supplied by the government.

b. Quantity of Improvement

We feel that we can cut the number of design related failures approximately in half. We realize that it is possible to make a greater improvement, however, this is the most cost effective balance of failure reduction and cost. This is based on assumption that there are 3 or at the most 4 areas that comprise a major share of the failures. Therefore fixing these would improve the reliability greatly. However, as previously expressed, Onan will need detailed information used to develop the Reliability Tree.

c. Approach

Using the reliability tree provided in the questionnaire as an example, we would prioritize the failures and emphasize those specific areas with the greatest number of problems. To do this we would arrange the failures in a different manner under the major topics as illustrated below:

Generator Control System	(36%)	105 failures
Control Cubical Assembly		50 failures
Electrical Governor Control		13 failures
Status Ex and Voltage Regulator		9 failures
Fault Indicator and D.C. Circuit Board		9 failures
Engine Electrical System	(27%)	78 failures
Battery Installation		57 failures
Battery Charging System		14 failures
Power Plant	(18%)	50 failures
Engine Assembly		32 failures
Cooling System		14 failures

c. Approach (Cont.)

Engine Fuel System	(13%)	45 failures
Fuel Injection System		17 failures
Fuel Filtration		7 failures
Fuel Tank Assembly		7 failures

It becomes apparent that the priorities should be assigned as follows:

Battery Installation
Control Cubical Assembly
Engine Assembly
Fuel Injection System

Assuming that these failures are representative of those for the 5 and 10 KW, we would act on them in the above order. We would determine what was at fault with the battery, determine what corrective action should be taken, test it, and implement it.

d. Cost Estimate

Based on the Reliability Tree furnished, we estimate that 3,000 MH at a cost of $165,000 is required. The estimate assumes that the majority of failures are attributed to 3 or 4 items.

6. Sound Attenuation and Infra-red Signature Suppression:

a. Noise Emissions - General Approach

To lower the noise emitted from the 60kW unit specified to 70dBA at 7 meters in all directions we would take the following steps:

° Determine the noise level at all locations around the set as it currently exists.

- This would determine those areas needing the highest level of effort.

° Investigate the areas where the highest sound level exists. These would probably include:

- Muffler
- Air intake
- Cooling air inlet
- Cooling air discharge

° Evaluate adequacy of engine generator isolation.

° Work with muffler and intake filter-silencer vendors to reduce the noise level.

° Develop air flow paths such that there was not a direct line of sight from the outside to inside the set.

° Investigate using both damped panels and/or panels with sound attenuating material attached to them.

a. (Cont.)

Specifically for the 5 and 10kW units this would require designing, developing, testing and building a housing. There currently is none. When doing this a balance must be maintained to achieve adequate air flow for cooling along with satisfactory sound attenuation. At this time we feel the best solution would be a housing that mounted directly to the trailer yet completely enclosed the set.

If the sound attenuating housing were mounted directly to the skid it would require increasing the length, width and height of the package. Also the underside of the skid base would have to be treated to prevent noise from escaping through this path. The result would be a unit of essentially the same size.

b. Noise Emissions - Size and Weight

For the 60kW unit specified we estimate that to achieve this level of sound attenuation would require a weight increase of 500 lbs and dimensional increases of 3 inches in length, width and height.

We estimate that to achieve this level of sound attenuation for the 5 and 10kW units would require a weight increase of 300 lbs. The minimum dimensional increase would be 3 inches each for width and height and 6 inches in length. These are subject to change based on the balance of sound attenuation and cooling air passage size requirement.

c. Infra-red Signature Suppression - General Approach

The general approach to decreasing the infra-red signature for the 60kW unit specified, or for any unit, is to suppress the highest temperature or temperatures. Typically the highest temperatures are on the exhaust manifold and muffler. Then it is desired to decrease the total area of high temperature. The amount of decrease desired determines the level of effort required. For instance to treat just the worst one or two areas would require one level of effort. To treat the entire unit as Onan did for the 15, 30 and 60kW SSDED sets would require a much higher level of effort. This would, however, result in a greater decrease in the IR signature.

Onan has developed a system for decreasing the infra-red signature of the 15, 30 and 60kW SDED sets. The technology could be transferred to the 5 and 10kW sets in a major development program. It would be easier to integrate this into the total set design rather than make it an add on package.

d. IR Suppression - Size and Weight

The best estimate of size and weight increases for the 60kW unit specified are broken down per the discussion in c above. To treat the worst areas only would require 100 lbs with no dimensional increase. To treat the entire unit would require 600 lbs and increase all dimensions (LxWxH) by 3 inches.

d. (Cont.)

The best estimate of weight and dimensional increase required to decrease the infra-red signature for the 5 and 10kW sets is 300 lbs. weight and 3 inches each for width and height. The length would increase by 6 inches.

e. Interrelation Noise and IR Suppression

Both sound and infra-red reduction efforts could be accomplished simultaneously. Onan has proven this with their design of an active system for the 15, 30 and 60kW SSDED sets.

We feel that an effort to lower the sound level may or may not affect the infra-red (IR) signature. However, any successful IR suppression could easily be made to lower the noise emissions.

This can further be explained this way. The exterior of a housing for a sound attentuated unit might typically be 50°F above ambient. This constitutes a large area at elevated temperatures. Without the housing there is a smaller area (muffler and manifold for instance) at the higher temperature differential. Therefore the larger area of the housing might well be more easily detected by I.R. sensors than a smaller area at higher temperature.

For an active I.R. suppression system Onan would use panels containing integral air flow passages. These would be noise barriers in themselves. Sound absorbing foam could easily be added. I.R. suppression requires ducting air into and out of the enclosure. These ducts could readily be configured to aid in noise attenuation.

f. Noise and IR Suppression - Size and Weight

For the 60kW unit specified the best estimate of weight and dimensional increase required to decrease both the IR signature and sound level is 650 lbs weight, 3 inches each for length, width and height. This would treat the entire unit. To treat just the area of highest IR signature but to lower the noise level it is estimated, would add 350 lbs and add change the dimensions 3 inches in each direction.

To treat both the IR signature and sound level of the 5 and 10 kW sets would require 300 lbs and dimensional increases of 3 inches in width and height and 6 inches in length for minimal IR suppression. For total IR suppression the weight changes to 400 lbs, dimensions remain the same.

UNITED TECHNOLOGIES AUTOMOTIVE

United Technologies Automotive, Inc.
Components Division

Diesel Systems
P.O. Box 85
One Diesel Drive
Columbia, South Carolina 29202
803/735-1400

March 10, 1987

Department of the Army
U.S. Army Research Development
and Engineering Center
Power Generation Division
Fort Belvoir, Virginia 22060-5606
Attn: Mr. Noel D. Bishop
Chief, Power Equipment Support Team
Logistics Support Directorate

Dear Mr. Bishop:

Enclosed is the questionnaire attached to your February 17, 1987 letter with the applicable portions completed. As a manufacturer of Engine Governing Systems (electric governors) my contribution would be toward reliability rather than noise and infrared suppression.

Thank you for the opportunity to contribute our thoughts concerning your program.

Very truly yours,

David H. Derrick
Product Support Representative
Engine Governing Systems

DHD/bt

Enclosure

cc: M. Krosney
W. Martin
C. Mastroianni

QUESTIONNAIRE

1. Are you a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets? Please describe. Manufacturer of electric governors for precise engine speed.

If you manufacture other diesel engine driven equipment, what is the equipment?

2. What is an estimated average yearly usage for your equipment? _____ What is the estimated operating cycle of your equipment (8 hours per day, 5 days per week, etc.)? Please describe. Equipment is used for prime power (24 hrs./day - 7 days/wk.) and standby power (intermittent usage).

3. By what methods do you receive feedback from users on your equipment (application, engineering, sales, warranty replacements, etc.)? Please describe. Feedback is received by all of the methods listed. Warranty and repair records and application assistance to customer engineering are primary sources

4. If you are not a manufacturer, what is your position in the market place? Please furnish description.

5. The DoD generator sets, once in user hands, are operated outside, exposed to the elements in many parts of the world and are exposed to all climatic conditions. Their operating cycle may be around the clock, for extended periods, with short shut down intervals for servicing or they may sit idle, being operated only a few hours per month. The majority of our sets are trailer

mounted on open trailers and during some field exercises they are frequently transported over roads ranging from highways to open cross country terrain. The sets are typically operated by soldiers primarily trained to operate other equipment such as radios, radar, trucks, etc. Typically they are maintained by trained repairmen with limited experience. If you are interested in the reliability portion of the program, please consider the above, look at the attached reliability tree and answer the following questions:

a. Based on your experience, what part(s) of the tree do you think you can improve? Generator Control System - 05B and/or 05N.

b. How much improvement do you think you can provide? At least 30% improvement in reliability.

c. Describe your approach for making the improvements. By development of digital circuitry to replace the present analog circuitry. Components part could be cut in half.

d. Furnish a cost estimate for your program. $75,000 - $100,000.

6. The generator set described in the attached figure is a typical military liquid cooled diesel engine driven generator set. It is designed so that the engine fan pulls air through the generator end for cooling the electrical apparatus, as well as combustion air and cooling air for the engine. The air is discharged through thermostatically controlled louvers on the radiator end. The 120hp at 1800 RPM/6 cylinder turbocharged engine uses a 15hp standard four blade metal fan for moving the air. The engine muffler is located within the set housing and the engine exhaust is out the radiator end near the top. The generator is single bearing, four pole, with a synchronous speed of 1800 RPM.

The engine generator set assembly uses a three point mounting, two generator feet and an engine trunnion mount, and is mounted directly to the skid base. The present noise level of the set is 87dBA at a 7 meter distance from the set. The set has a metal housing, with all bolted construction. The present housing + muffler offers very little sound attenuation. Considering the above, please answer the questions applicable to your area of interest.

a. Please describe your general approach for lowering the noise emitted from the set in any direction to 70 dBA at 7 meters. _____

_____

_____

_____.

b. What would be your guesstimation of the set weight and dimensional increase required for your sound attenuation effort? _____

_____

c. Please describe your general approach for decreasing the infrared signature of the set. _____

_____

_____.

d. What would be your guesstimation of the set weight and dimensional increase required for decreasing the infrared signature of the set? _____

_____

_____.

e. If you are interested in both the sound and infrared reduction efforts, how do you foresee their interrelation? _____

_____

_____.

f. What would be your guesstimate of the net set weight and dimensional increase for both efforts? _____

_____.

QUESTIONNAIRE

1. Are you a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets? Please describe. Cummins manufacturers diesel engines, a major component for generator sets ranging from 15-1200 KW.

If you manufacture other diesel engine driven equipment, what is the equipment? Not applicable.

2. What is an estimated average yearly usage for your equipment? Estimated usage varies dependant on type of application (standby or prime). Usage rg. 100-300 Hrs. What is the estimated operating cycle of your equipment (8 hours per day, 5 days per week, etc.)? Please describe. Standby Applications: 1 Hr/Wk

Prime Power Applications: 8-24 Hrs/Day; 5 days/week.

3. By what methods do you receive feedback from users on your equipment (application, engineering, sales, warranty replacements, etc.)? Please describe. Warranty claims, engineering and application assistance requests, service inquiries from end users.

4. If you are not a manufacturer, what is your position in the market place? Please furnish description. Not applicable.

5. The DoD generator sets, once in user hands, are operated outside, exposed to the elements in many parts of the world and are exposed to all climatic conditions. Their operating cycle may be around the clock, for extended periods, with short shut down intervals for servicing or they may sit idle, being operated only a few hours per month. The majority of our sets are trailer

mounted on open trailers and during some field exercises they are frequently transported over roads ranging from highways to open cross country terrain. The sets are typically operated by soldiers primarily trained to operate other equipment such as radios, radar, trucks, etc. Typically they are maintained by trained repairmen with limited experience. If you are interested in the reliability portion of the program, please consider the above, look at the attached reliability tree and answer the following questions:

a. Based on your experience, what part(s) of the tree do you think you can improve? (See Attachment)

b. How much improvement do you think you can provide? (See Attachment)

c. Describe your approach for making the improvements. (See Attachment).

d. Furnish a cost estimate for your program.

6. The generator set described in the attached figure is a typical military liquid cooled diesel engine driven generator set. It is designed so that the engine fan pulls air through the generator end for cooling the electrical apparatus, as well as combustion air and cooling air for the engine. The air is discharged through thermostatically controlled louvers on the radiator end. The 120hp at 1800 RPM/6 cylinder turbocharged engine uses a 15hp standard four blade metal fan for moving the air. The engine muffler is located within the set housing and the engine exhaust is out the radiator end near the top. The generator is single bearing, four pole, with a synchronous speed of 1800 RPM.

The engine generator set assembly uses a three point mounting, two generator feet and an engine trunnion mount, and is mounted directly to the skid base. The present noise level of the set is 87d8A at a 7 meter distance from the set. The set has a metal housing, with all bolted construction. The present housing + muffler offers very little sound attenuation. Considering the above, please answer the questions applicable to your area of interest.

a. Please describe your general approach for lowering the noise emitted from the set in any direction to 70 dBA at 7 meters. Not applicable.

b. What would be your guesstimation of the set weight and dimensional increase required for your sound attenuation effort? Not applicable.

c. Please describe your general approach for decreasing the infrared signature of the set. Not applicable.

d. What would be your guesstimation of the set weight and dimensional increase required for decreasing the infrared signature of the set? Not applicable.

e. If you are interested in both the sound and infrared reduction efforts, how do you foresee their interrelation? Not applicable.

f. What would be your guesstimate of the net set weight and dimensional increase for both efforts? Not applicable.

5. ENGINE RELIABILITY

The engineering staff at Cummins monitors and develops engine reliability through product development tests and customer feedback on installations in service. Design changes are implemented as required for performance improvements. Many government projects are contracted over extended periods. The generator set manufacturer tends to be locked in on original specifications. Design changes implemented during the life of the contract are generally rejected by the generator set manufacturer and never presented to the government for review. Design changes that do not effect form, fit and function should be encouraged if the full benefit of product improvements are to be realized. Cost benefits vary depending on the changes but it should be noted that we constantly look for ways to improve and reduce the cost of our engines.

Fermont
Division
Dynamics Corporation of America
141 North Avenue
Bridgeport, CT 06606
Telephone (203) 366-5211
*Telex: FERMONTEXP BGT-964365

March 16, 1987

U.S. Army, Belvoir R, D & E Center
Fort Belvoir, VA 22060-5606

Attention: Noel D. Bishop, Power Generation Div.

Dear Noel:

Attached are our best thoughts on your questionnaire.

Sincerely,

FERMONT DIVISION

C. M. Colt

Charles M. Colt
Manager, Military Sales & Contracts

Enclosure
pb

*PLEASE NOTE OUR NEW TELEX NUMBER IS: 4971108 FERMONT

VERMONT DIVISION
DYNAMICS CORP. OF AMERICA
[illegible]
[illegible] 05606

QUESTIONNAIRE

1. Are you a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets? Please describe. Mfr. DED gen sets

If you manufacture other diesel engine driven equipment, what is the equipment?

N/A

2. What is an estimated average yearly usage for your equipment? varies

What is the estimated operating cycle of your equipment (8 hours per day, 5 days per week, etc.)? Please describe. Varies from 24 hrs/day to standby use

3. By what methods do you receive feedback from users on your equipment (application, engineering, sales, warranty replacements, etc.)? Please describe. Sales, warranty replacement parts

4. If you are not a manufacturer, what is your position in the market place? Please furnish description. N/A

5. The DoD generator sets, once in user hands, are operated outside, exposed to the elements in many parts of the world and are exposed to all climatic conditions. Their operating cycle may be around the clock, for extended periods, with short shut down intervals for servicing or they may sit idle, being operated only a few hours per month. The majority of our sets are trailer

mounted on open trailers and during some field exercises they are frequently transported over roads ranging from highways to open cross country terrain. The sets are typically operated by soldiers primarily trained to operate other equipment such as radios, radar, trucks, etc. Typically they are maintained by trained repairmen with limited experience. If you are interested in the reliability portion of the program, please consider the above, look at the attached reliability tree and answer the following questions:

a. Based on your experience, what part(s) of the tree do you think you can improve? -03, -04, -05.

b. How much improvement do you think you can provide? est. 50%.

c. Describe your approach for making the improvements. component selection & mounting.

d. Furnish a cost estimate for your program. not available.

6. The generator set described in the attached figure is a typical military liquid cooled diesel engine driven generator set. It is designed so that the engine fan pulls air through the generator end for cooling the electrical apparatus, as well as combustion air and cooling air for the engine. The air is discharged through thermostatically controlled louvers on the radiator end. The 120hp at 1800 RPM/6 cylinder turbocharged engine uses a 15hp standard four blade metal fan for moving the air. The engine muffler is located within the set housing and the engine exhaust is out the radiator end near the top. The generator is single bearing, four pole, with a synchronous speed of 1800 RPM.

The engine generator set assembly uses a three point mounting, two generator feet and an engine trunnion mount, and is mounted directly to the skid base. The present noise level of the set is 87dBA at a 7 meter distance from the set. The set has a metal housing, with all bolted construction. The present housing + muffler offers very little sound attenuation. Considering the above, please answer the questions applicable to your area of interest.

a. Please describe your general approach for lowering the noise emitted from the set in any direction to 70 dBA at 7 meters. Housing lined with sound insulation - Inlet and outlet cooling air noise baffles & ducting - larger muffler and noise attenuating techniques.

b. What would be your guesstimation of the set weight and dimensional increase required for your sound attenuation effort? 600-800 lbs. approx. 1 ft. all sides and top

c. Please describe your general approach for decreasing the infrared signature of the set. Mixing ambient air with cooling & exhaust air. Also integrate sound attenuation and IR signature measures.

d. What would be your guesstimation of the set weight and dimensional increase required for decreasing the infrared signature of the set? Less than 12 in. all around set. Approx. 600 lbs.

e. If you are interested in both the sound and infrared reduction efforts, how do you foresee their interrelation? Very interrelated. Probably most cost effective.

f. What would be your guesstimate of the net set weight and dimensional increase for both efforts? Approx. same as for either sound or IR signature design plus 200-300 lbs.

LCE

5722-87-02-030
March 12, 1987

Mr. Noel D. Bishop
Chief, Power Equipment Support Team
Logistics Support Directorate
Department of the Army
U.S. Army Belvoir Research, Development
and Engineering Center
Fort Belvoir, VA 22060-5606

Dear Mr. Bishop:

Life Cycle Engineering, Inc. (LCE) is pleased to provide this response to the questionnaire you provided concerning resolution of the operational problems being experienced with the current standard family of DOD Diesel Engine Driven Generator Sets.

LCE is excited about the prospect of working for the U.S. Army and sincerely believes that we can provide invaluable assistance in this effort.

If we may be of any further assistance, please call me.

Sincerely,

Douglas R. Stevens

Douglas R. Stevens
Executive Vice President

WL/lf

Enclosure

LIFE CYCLE ENGINEERING, INC.
1 POSTON ROAD, SUITE 300 – P.O. BOX 300001 – CHARLESTON, SOUTH CAROLINA 29417-3000
TELEPHONE (803) 556-7110 TELEX 755698 LIFE CYCLE UD

Responses to U.S. Army Belvoir Research, Development and Engineering Center, Fort Belvoir, VA, Power Generation Division Questionnaire

The following answers are given in response to a questionnaire delivered to Life Cycle Engineering, Inc. (LCE) under the signature of Mr. Noel D. Bishop, Chief, Power Equipment Support Team, Logistics Support Directorate:

1. LCE is not a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets. Nor does LCE manufacture other diesel driven equipment.

2. Since LCE is not an equipment manufacturer, the questions regarding annual usage rate and estimated operating cycle are not applicable.

3. Since LCE is not an equipment manufacturer the question regarding method of feedback is not applicable.

4. LCE's position in the market place is that of providing maintenance and reliability engineering services. These services include design improvement, preventive and performance monitoring maintenance procedures and plans development, troubleshooting and repair of failed drive and generator components and the development of procedures for making, and for some customers performing, material condition assessment and failure mode and effects analysis evaluations of mechanical and electrical rotating equipment.

5. LCE has considerable prior experience with diesel engine installation designs, reliability and maintenance procedures for the U.S. Army Corps of Engineers, U.S. Navy, Commercial and Oil Drilling industry in all parts of the world. The following comments pertain to questions 5.a. through d. in the questionnaire:

   a. LCE can improve upon all parts of the reliability tree specifically in block area's 01A/02A/03A, 03B, 05A-05B and 03C through a combination of design review, improved maintenance and operating procedures and improved set-up/start-up procedures.

   b. Significant improvement can be made. Development of proper maintenance techniques and improvements in equipment design on equipments with similar application have resulted in achievement of up to a 75% reduction in equipment failures. LCE operating and maintenance procedures are written in enough specific and technical detail that minimally trained and experienced repair/service/personnel can operate and maintain the equipment without the necessity for additional training.

   c. LCE preventive and performance monitoring maintenance programs are used by the oil drilling industry on the north shore of Alaska and off-shore oil drilling rigs to identify component degradation modes and implement the appropriate maintenance actions to prevent component failures. A failure mode and effects analysis for each deficiency noted in the reliability tree would be conducted. An acoustic emission monitoring program can be used to detect brinelling of generator bearing surfaces caused by rough and harsh actions during transportation of generator sets. Where practical and cost effective, design improvements would be developed to enhance component and equipment reliability. An example of the maintenance requirements

developed by LCE for an AC Diesel Generator Set used on an oil drilling platform is enclosed. The maintenance requirements are provided on a laminated "T-card" which is stored in a rack for easy reference. The laminated card is carried by the craftsman performing the maintenance action and the other card remains in the rack for record purposes.

d. The estimated cost for this program would be $60,000. A final cost quote can be provided once detailed requirements are obtained.

6. The following comments pertain to questions 6.a. through f. in the questionnaire:

a. LCE has considerable technological experience in submarine noise reduction and anechoic sound damping. Infrared thermographic imaging is used in our preventive, predictive and performance monitoring program for the military and commercial industry. Our approach to reduce vibration and noise would be to evaluate the following areas: 1) design of housing construction to reduce the number of bolts, 2) fewer panels with gasketed joints, 3) thermal insulation integral to the housing, 4) improved design of engine exhaust and muffling system through muffler baffling and cooling air injection, 5) alignment of generator to engine and, 6) the use of an anti-brinelling device for generator bearings. LCE would not limit the scope of its efforts to these areas. If adequate improvement could not be achieved through implementation of the conventional methods, LCE would explore other means of achieving the desired reduction in emitted noise levels.

b. It is estimated that the weight of the example 60kW diesel generator set would be increased 3 to 5%. The dimensional increase would be on the order of 10 to 15%.

c. LCE's approach for suppressing the infrared signature would be through improved cooling system design, air injection and thermal insulation of exhaust system and improved thermal insulating materials for the housing enclosure.

d. The estimate of increase in weight and dimensions as reflected in 6.b. above takes into account the combined modifications to improve emitted noise levels and to suppress the infrared signature.

e. Insulation added to reduce emitted heat and, therefore, the infrared signature would provide the added benefit of reducing to some degree the emitted noise level. Additionally, the diesel exhaust would be a primary source of both emitted noise and heat. A diesel exhaust design improvement effort aimed at lowering both of these levels would be required. The noise and infrared emission problems are inexorably interrelated.

f. As noted in 6.d., LCE's estimate of weight and dimensional changes given in 6.b. are combined for the envisioned noise and infrared emission modifications.

EQUIPMENT: AC Diesel Generator Sets
M.R. NUMBER: 206-1-1-R4 FREQUENCY: 2,000 HRS
TITLE: Set Exhaust and Inlet Valve Clearances

SPECIAL TOOLS/EQUIPMENT:
1. Feeler gauge set 2. Engine turning bar

DESCRIPTION

NOTE: Accomplish this MR every 2,000 operating hours.

Preliminary
1. Ensure diesel engine is stopped.

A. Set Exhaust and Inlet Valve Clearances
1. Remove the flywheel housing and timing access cover.
2. Remove valve covers.

NOTE: Bar the flywheel in the direction of engine rotation (CCW) until the TDC 1-15" timing mark aligns with the timing pointer on the flywheel.

3. Check both inlet and exhaust valve rockers on No. 1 cylinder. If they can be moved freely, No. 1 piston is on the compression stroke.
4. Check the bridge adjustment screw and lock nut for tightness.
5. Set valve clearances by loosening valve lash adjuster lock nut. Tighten or loosen lash adjuster to attain the desired clearance between the rocker arm and valve stem when measured with a feeler gauge.
6. Exhaust valve lash is 0.035". Inlet valve lash is 0.015".
7. With No. 1 piston at TDC on compression, adjust exhaust valves, 1, 2, 3, 4, 5, 6, 7, 8, 9 and inlet valves 1, 2, 7, 8, 11, 12, 13, 14.

NOTE: Bar over engine one complete revolution until timing mark TDC 1-15" aligns again with the timing pointer on the flywheel. No. 1 piston will be on the exhaust stroke and only the inlet valve rocker will move freely.

8. With No. 1 piston at TDC on exhaust stroke, adjust exhaust valves 10, 11, 12, 13, 14, 15, 16 and inlet valves 3, 4, 5, 6, 9, 10, 15, 16.
9. Remove the engine turning tool and the timing bolt from the flywheel.
10. Start engine.
11. Watch the cam followers. Each cam follower should slowly rotate while the engine is running.

LCE

EQUIPMENT: AC Diesel Generator Sets
M.R. NUMBER: 206-1-1-R4 FREQUENCY: 2,000 HRS
TITLE: Set Exhaust and Inlet Valve Clearances

DF

SPECIAL TOOLS/EQUIPMENT:
1. Feeler gauge set 2. Engine turning bar

DESCRIPTION

NOTE: Accomplish this MR every 2,000 operating hours.

Preliminary
1. Ensure diesel engine is stopped.

A. Set Exhaust and Inlet Valve Clearances
1. Remove the flywheel housing and timing access cover.
2. Remove valve covers.

NOTE: Bar the flywheel in the direction of engine rotation (CCW) until the TDC 1-15" timing mark aligns with the timing pointer on the flywheel.

3. Check both inlet and exhaust valve rockers on No. 1 cylinder. If they can be moved freely, No. 1 piston is on the compression stroke.
4. Check the bridge adjustment screw and lock nut for tightness.
5. Set valve clearances by loosening valve lash adjuster lock nut. Tighten or loosen lash adjuster to attain the desired clearance between the rocker arm and valve stem when measured with a feeler gauge.
6. Exhaust valve lash is 0.035". Inlet valve lash is 0.015".
7. With No. 1 piston at TDC on compression, adjust exhaust valves, 1, 2, 3, 4, 5, 6, 7, 8, 9 and inlet valves 1, 2, 7, 8, 11, 12, 13, 14.

NOTE: Bar over engine one complete revolution until timing mark TDC 1-15" aligns again with the timing pointer on the flywheel. No. 1 piston will be on the exhaust stroke and only the inlet valve rocker will move freely.

8. With No. 1 piston at TDC on exhaust stroke, adjust exhaust valves 10, 11, 12, 13, 14, 15, 16 and inlet valves 3, 4, 5, 6, 9, 10, 15, 16.
9. Remove the engine turning tool and the timing bolt from the flywheel.
10. Start engine.
11. Watch the cam followers. Each cam follower should slowly rotate while the engine is running.

12. Stop engine, check valve cover gaskets. Renew, if necessary.
13. Install valv covers and timing cover.
14. Start engine and place under load and check for proper operation.
15. Return engine to normal operation.

No. 1 _____ No. 2 _____

Completed By _____ Date _____

12. Stop engine, check valve cover gaskets. Renew, if necessary.
13. Install valve covers and timing cover.
14. Start engine and place under load and check for proper operation.
15. Return engine to normal operation.

No. 1 _____ No. 2 _____

Completed By _____ Date _____

MAR 1987

ALTURDYNE

8050 Armour Street
San Diego, California 92111-3788
619-565-2131
TWX 910-335-2000

March 4, 1987

DEPARTMENT OF THE ARMY
US Army Belvoir Research,
Development and Engineering Center
Fort Belvoir, Virginia 22060-5606

Attention: Noel D. Bishop
Chief, Power Equipment Support Team
Logistics Support Directorate
Power Generation Division

REFERENCE: Your Questionnaire of February 17, 1987

Gentlemen:

We have filled out the questionnaire and are sending it back to you. We have supplied signature suppressed, acoustically treated generator sets to various government agencies. The Army purchased nine of our standard quiet "movie type" units for the 1985 Power Fair demo.

We plan to be in the 1987 Fair and would like to participate in your program. Mr. Don Kearns will contact you shortly.

Sincerely yours,

Frank G. Verbeke
President

bja

CC: Mr. Don Kearns, P.O. Box 2567, West Springfield, VA 22152 (703)451-4260
Mr. Mark Gramlich, Alturdyne, San Diego, CA
Mr. Jim Scull, Alturdyne, San Diego, CA

Enclosure

DEPARTMENT OF THE ARMY
US ARMY BELVOIR RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
FORT BELVOIR, VIRGINIA 22060-5606

February 17, 1987

REPLY TO
ATTENTION OF

Power Generation Division

Mr. Frank G. Verbeke
Alturdyne
8050 Armour Street
San Diego, California 92111-3788

Dear Mr. Verbeke:

The Army is planning a program to build improved prototypes of our current standard family of DoD Diesel Engine Driven Generator Sets in sizes 5kW, 10kW, 15kW, 30kW, 60kW and 100kW. Our primary areas of interest are reliability, noise and infrared suppression.

The purpose of this questionnaire is to solicit industry input for resolving operational problems of the DoD generator set fleet. Completion and return of the questionnaire and any additional information you may wish to furnish, is appreciated. The information thus furnished may be the basis for procurement of services and material for purposes of experimentation, and for eventual incorporation into the improved generator set fleet. In the interest of protecting your company's technology, it is requested that any information furnished at this time be of a non-proprietary nature; furthermore, it must be understood that any information furnished as a result of this questionnaire is without obligation to the Government. Your information is requested by March 16, 1987.

Please contact me if you have any questions at (703) 664-5596.

Sincerely,

Noel D. Bishop
Chief, Power Equipment Support Team
Logistics Support Directorate

Attachments

ALTURDYNE
8050 ARMOUR
SAN DIEGO, CA 92111-3783
(619) 565-2131

QUESTIONNAIRE

1. Are you a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets? Please describe. We manufacture commercial and military gen sets - see data sheets EMV-36E ETC

If you manufacture other diesel engine driven equipment, what is the equipment? engine pumps, compressors and rotary product.

2. What is an estimated average yearly usage for your equipment? 3,000,000

What is the estimated operating cycle of your equipment (8 hours per day, 5 days per week, etc.)? Please describe. Standby - 1 hr/week
Move - 10 hrs/day govt @ 40 hrs/week.

3. By what methods do you receive feedback from users on your equipment (application, engineering, sales, warranty replacements, etc.)? Please describe. direct sales and engineering contact with customer.

4. If you are not a manufacturer, what is your position in the market place? Please furnish description. _____

_____.

5. The DoD generator sets, once in user hands, are operated outside, exposed to the elements in many parts of the world and are exposed to all climatic conditions. Their operating cycle may be around the clock, for extended periods, with short shut down intervals for servicing or they may sit idle, being operated only a few hours per month. The majority of our sets are trailer

mounted on open trailers and during some field exercises they are frequently transported over roads ranging from highways to open cross country terrain. The sets are typically operated by soldiers primarily trained to operate other equipment such as radios, radar, trucks, etc. Typically they are maintained by trained repairmen with limited experience. If you are interested in the reliability portion of the program, please consider the above, look at the attached reliability tree and answer the following questions:

a. Based on your experience, what part(s) of the tree do you think you can improve? simplify the controls, fuel system and packaging.

b. How much improvement do you think you can provide? 4 X.

c. Describe your approach for making the improvements. eliminate some mil spec requirements. Integrate electrical controls.

d. Furnish a cost estimate for your program. $250,000/per sys

6. The generator set described in the attached figure is a typical military liquid cooled diesel engine driven generator set. It is designed so that the engine fan pulls air through the generator end for cooling the electrical apparatus, as well as combustion air and cooling air for the engine. The air is discharged through thermostatically controlled louvers on the radiator end. The 120hp at 1800 RPM/6 cylinder turbocharged engine uses a 15hp standard four blade metal fan for moving the air. The engine muffler is located within the set housing and the engine exhaust is out the radiator end near the top. The generator is single bearing, four pole, with a synchronous speed of 1800 RPM.

The engine generator set assembly uses a three point mounting, two generator feet and an engine trunnion mount, and is mounted directly to the skid base. The present noise level of the set is 87dBA at a 7 meter distance from the set. The set has a metal housing, with all bolted construction. The present housing + muffler offers very little sound attenuation. Considering the above, please answer the questions applicable to your area of interest.

a. Please describe your general approach for lowering the noise emitted from the set in any direction to 70 dBA at 7 meters. Softer mount, and more of them - better wall insulation - Trap sound of air in and discharge. Better muffler.

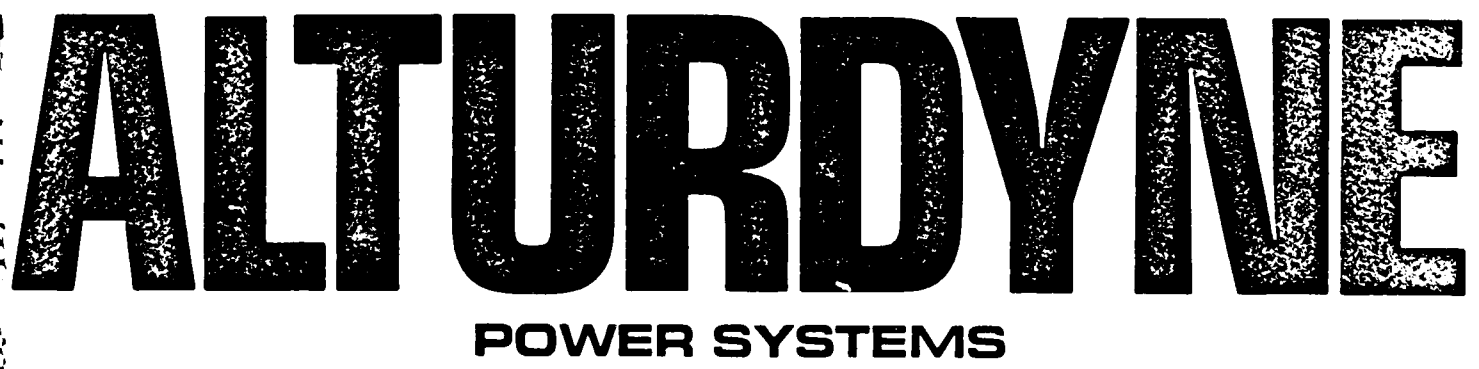
b. What would be your guesstimation of the set weight and dimensional increase required for your sound attenuation effort? adds 500# and $3000 to package

c. Please describe your general approach for decreasing the infrared signature of the set. To what level? We achieved within + 4° of ambient on a turbine - Need a black hole suppresor system - no hot metal - extra air

d. What would be your guesstimation of the set weight and dimensional increase required for decreasing the infrared signature of the set? + 250# adds 6" to set

e. If you are interested in both the sound and infrared reduction efforts, how do you foresee their interrelation? They must be integrated and we're interested. We did this for AF GLCM program.

f. What would be your guesstimate of the net set weight and dimensional increase for both efforts? 1000 # + 6" to package size all dimensions.



POWER SYSTEMS

ALTURDYNE

Alturdyne was founded in 1971 to package small gas turbine systems for the commercial and governmental marketplaces. Hundreds of these packages are now in operation nationally and internationally. Since 1971 Alturdyne has expanded its staff to nearly 100 people operating at three San Diego area facilities. Their expertise extends to reciprocating engine systems, sound attenuation and many related packaging and engineering fields for stationary, portable and airborne applications.

Specializing in custom and engineered systems, Alturdyne has the unique capability to assist its customers in selecting and applying the optimum prime mover for each application.

Alturdyne has the proven capability to package gas turbine, rotary, and reciprocating engines for a wide variety of applications: Generator Sets, Compressors, Hydraulic Start Systems, High-Speed Reduction Drives, Air-Bleed Systems, Fluid Pumpers, Fan Drives, Mechanical Drives, Ground Power Units and Air-Transportable Power Systems.

Alturdyne is committed to the advancement of the state-of-the-art in power systems packaging and application and to making this technology available to new areas of industry, commerce, and government.

Consulting and A&E services are provided for commercial turnkey installations. Infrared-suppressed, nuclear-hardened, and electromagnetic-pulse-suppressed generator sets are becoming an Alturdyne specialty for government agencies.

FRANK VERBEKE
President

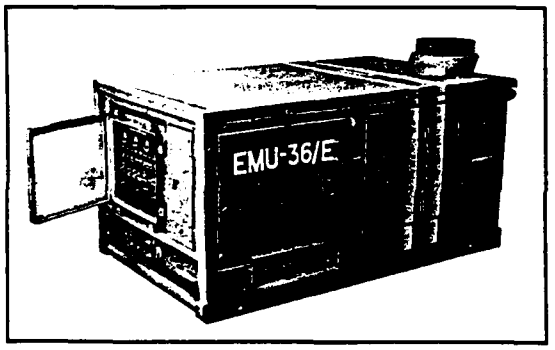
ALTURDYNE

GOVERNMENT AND MILITARY POWER SYSTEMS

ALTURDYNE

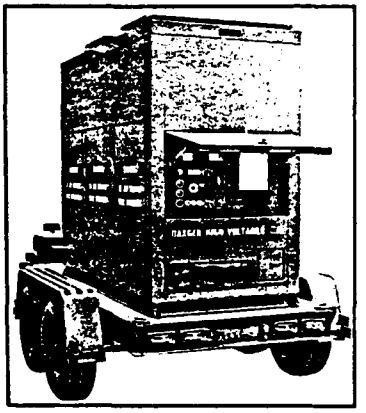
Alturdyne specializes in custom and production packaging of gas turbine, rotary and reciprocating engines for the military for a wide variety of applications. These applications include Quiet/Reliable Generator Sets, Compressors, Hydraulic Start Systems, High-Speed Reduction Drives, Air-Bleed Systems, Fluid Pumpers, Fan Drives, Mechanical Drives, Ground Power Units and Air-Transportable Power Systems. Alturdyne's experience and expertise extend to sound attenuation, achieving multiple outputs from a single prime mover and infrared-suppressed, nuclear-hardened, electromagnetic-pulse-suppressed generator sets.

Alturdyne is committed to the advancement of state-of-the-art power systems packaging and application and to making this technology work for the military and the government.



EMU-36/E

The EMU-36/E is a 60 kW, 400 Hz generator developed as a high reliability and maintainable set for the U.S. Air Force's Ground Launch Cruise Missile System. These units feature a weatherproof/sound attenuated enclosure, multi-fuel capability, multiple outputs, nuclear hardening, infrared suppression, remote operation, precise power, bite-analog diagnostics and a simplified control panel. In addition, they are *parallelable, lightweight, compact* (60" × 35.25" × 29.5"H), and may be air-lifted and operated in extreme environmental conditions.



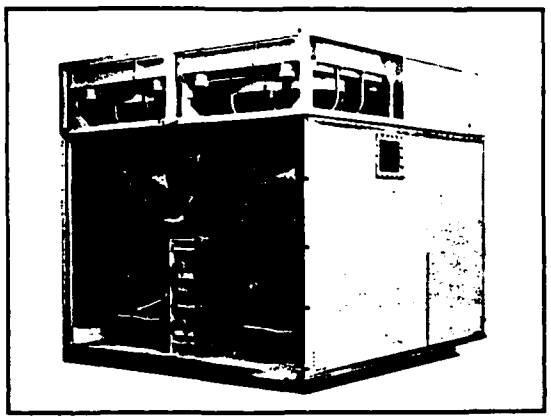
QUIET/RELIABLE ARMY TRAILER

Quiet generator sets are a specialty at Alturdyne. This is one of nine quiet, trailer-mounted, diesel engine generator sets purchased by the U.S. Army for evaluation of commercial-type mobile power systems. These sets were produced in 60 kW models using a turbocharged, six-cylinder, in-line diesel engine and 125 kW models using a turbocharged, V-8 diesel engine. Noise level performance for these sets demonstrated a remarkable 65 dBA at 25 feet. These units are fully self-contained and incorporate a 100-gallon fuel tank mounted in the trailer.

LACV-30

The LACV-30 (Lighter, Amphibian, Air Cushion Vehicle—30 ton payload) is a fully amphibious, high-speed cargo carrier developed for the U.S. Army. It is primarily used to move cargo from ship to shore and inland when port facilities are not available.

Alturdyne designed and built, under contract to Bell Aerospace Textron, gas turbine auxiliary power units used on this craft. The gas turbine engines used in the auxiliary power units are coupled to an Alturdyne dual-output reduction gearbox. One output rotates at 3600 rpm supplying 85 hp to a shaft-driven fan for the Air Management Filtration System. This system provides forced air through the filter system to feed the main turbine powerplants fresh intake air. The other output rotates at 6000 rpm and supplies 45 hp to drive a 400 Hz generator.



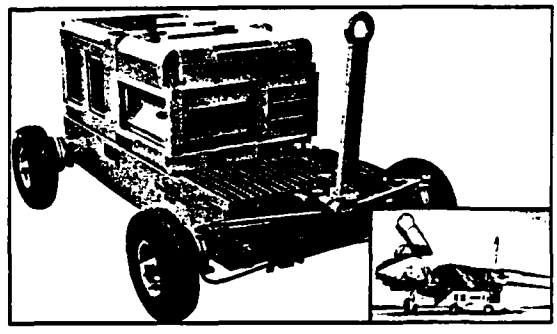
DIESEL PGU

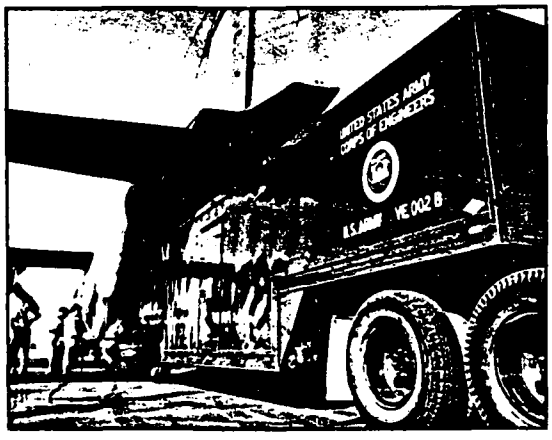
This unit is a sound attenuated, nuclear hardened, continuous duty power generation system used by the U.S. Air Force for communications and strategic surveillance purposes. These self-contained units are rated at 125 kW and can be operated continuously for 2000 hour intervals utilizing an automatic oil feed system. They are powered by twin Detroit Diesel 4-71T turbocharged diesel engines which operate independently of each other. For fast maintenance and overhaul, all systems have quick-disconnect components to provide minimum down time.

JASU (JET AIRCRAFT START UNIT)

JASU is a gas turbine/load compressor used for main engine starting on jet aircraft. It was designed and packaged by Alturdyne under contract to Turbomach for the U.S. Navy.

To keep production costs to a minimum and provide maximum reliability, 90 percent of the components used are current "off the shelf" production items which have been proven in similar applications in the past. It is powered by a gas turbine capable of over 300 horsepower, and produces 150 ppm of airflow at a delivery pressure of 60 psig at sea level, 60°F.





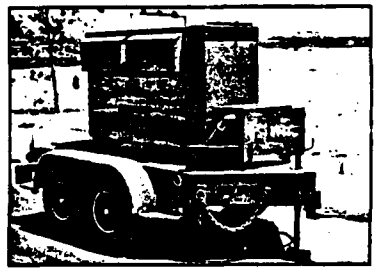
MEP-409A/750 kW AIR-TRANSPORTABLE TRAILER

Alturdyne subcontracted to design and package these semi-trailer mounted 750 kW air-transportable gas turbine generator sets for the U.S. Army. These units are special low-profile, self-contained sets that have a unique cargo handling system, enabling loading and unloading on C-130 aircraft without special ground support equipment in less than four hours by as few as two men. This can be done quickly in remote areas that may not have machinery for hauling and lifting.

The generator sets provide 4160 volts at 60 Hz or 3460 volts at 50 Hz operation. The highway-legal trailers (40' long and 8' wide) contain all equipment necessary to provide electrical power as soon as cables are connected to the output panel. A soundproof room is located at the rear of the trailer for the operator and contains the control console, power switchgear, station power transformer, telephone jack, desk, lights and ventilation. The unit also comes with a remote desk-top control panel for operating two or more units from a central remote control station. A 500-gallon day tank provides enough fuel to operate the set for up to seven hours.

FAA TRAILERS

These self-contained 60 kW, 60 Hz gas turbine generator systems were manufactured for the Federal Aviation Administration to provide emergency power at FAA facilities during maintenance and repair of stationary engines. The trailers include integral fuel tanks, voltage selection and on-board automatic transfer switches.



ALTURDYNE

Home Office:

8050 Armour Street
San Diego, CA 92111-3788
(619) 565-2131
TWX 910-335-2000

Branch Offices:

Connecticut, Florida, Houston,
Los Angeles, Northern California,
Michigan, Washington DC,
Chicago, Dallas, Ohio

DS—16/2M 10/85

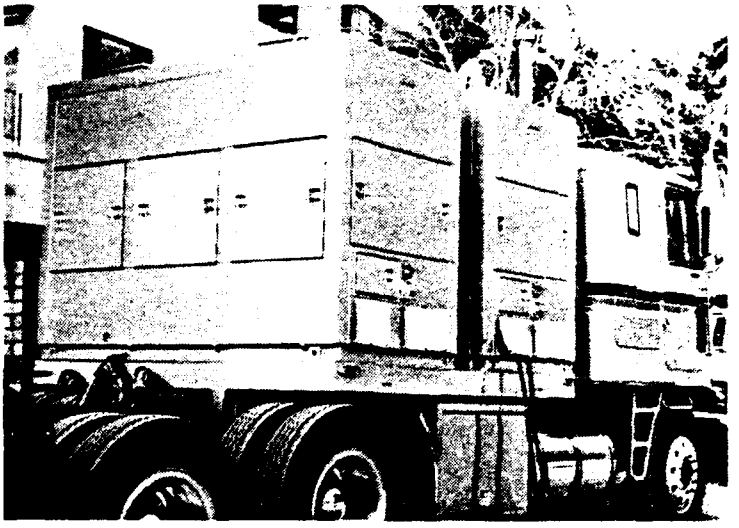
ALTURDYNE

MOTION PICTURE LIGHTING GENERATOR SETS

200 TO 1000 AMPS

Alturdyne's Motion Picture Lighting Generator Sets are expertly engineered and manufactured to meet the exacting requirements of motion picture lighting. Inherent in the design are:

- Quiet operation
- Precise voltage and frequency regulation
- Power for flicker-free metal halide (HMI) lighting
- D.C. and/or A.C. output
- Maximum reliability
- Ease of maintenance
- Minimum size and weight
- Long life
- Diesel or gasoline
- Remote or on-set controls
- Mounting flexibility — *fits tractor or trailer*



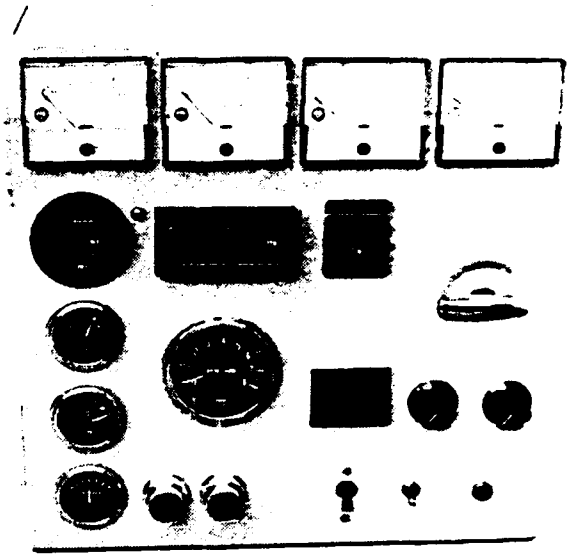
Now available in ratings from 200 to 1000 amps, Alturdyne Motion Picture Lighting Generator Sets powered by both diesel and gasoline engines have accumulated thousands of hours of service reliably powering critical motion picture and video lighting loads. Standard units from 25 to 125 kW are offered as well as special units to customer specifications.

STANDARD EQUIPMENT

•Heavy-duty industrial engine • Electronic governor • Brushless AC generator • Solid-state voltage regulator • Heavy-duty rectifier/filter section for close-regulated, ripple-free DC output (when ordered) • Protective devices for engine and electrical system • Sound-attenuating and weather resistant aluminum enclosure • Removable access doors • Control panel • Battery • Battery charging alternator • Convenience outlet • Output bus bars

STANDARD OPTIONAL EQUIPMENT

• Diesel engine • Gasoline engine • AC only • DC only • Concurrent AC with DC • Reconnectible AC or DC • 48, 50 and/or 60 Hz • Base fuel tank • Remote control • Jacket water heater • Water separator/fuel filter • Special paint • Cold weather start kit • Heavy-duty trailer with integral fuel tank



PERFORMANCE

AC VOLTAGES

120 — single-phase, 2-wire
120/240 — single phase, 3-wire
120/208 — three phase, 4-wire
120 — three phase, 3-wire

STANDARD kW RATINGS*

25 to 125

OPTIONAL FREQUENCIES

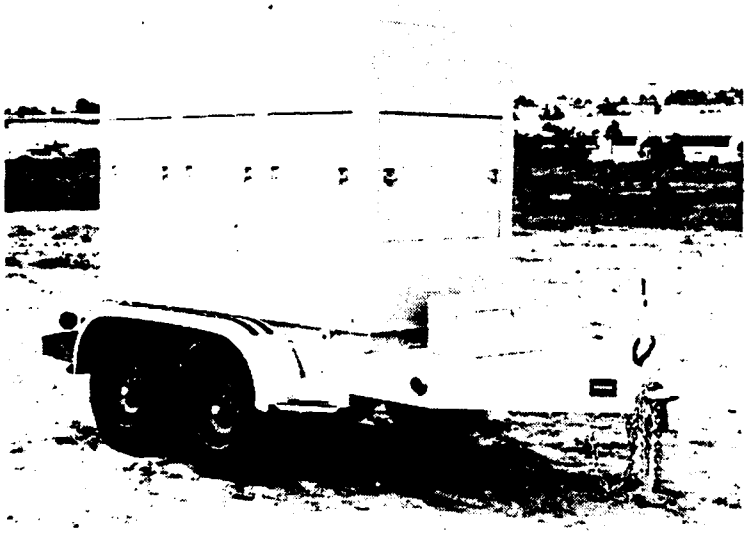
48, 50, 60 Hz

DC VOLTAGE

120, 2-wire

STANDARD AMPERE RATINGS*

200 to 1000



DIMENSIONS

Length	Width	Height
94″	45″	78″

*Consult factory for kW and ampere ratings for specific units

Specifications and dimensions are subject to change without notice.

ALTURDYNE

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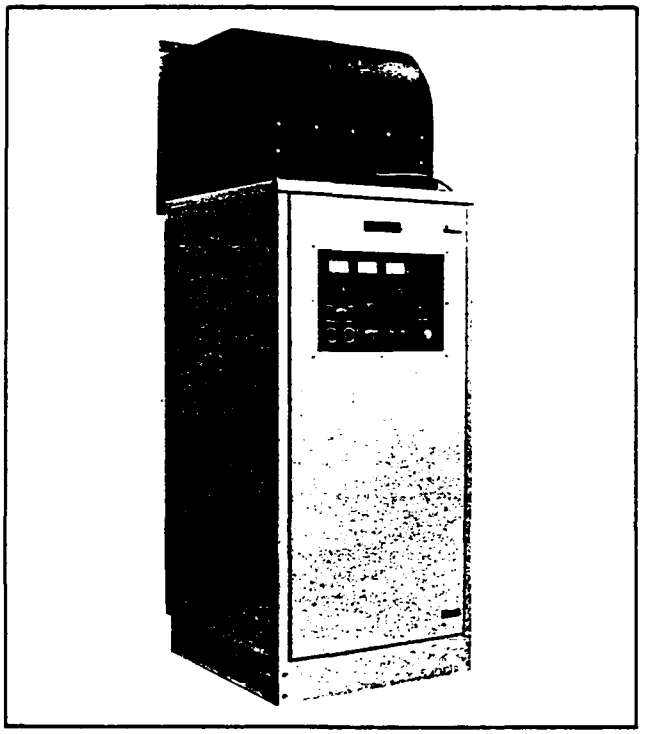
(619) 565-2131
TWX 910-335-2000

BRANCH OFFICES
Dallas, Los Angeles
Chicago, Washington DC
San Francisco, Florida
Michigan, Conneticut

DS-7/1M 6/84

ALTURDYNE

30kW TO 60kW VERTICAL DIESEL ENGINE EMERGENCY GENERATOR SETS



Alturdyne is pleased to announce the expansion to our line of Vertical Emergency Generator Sets. The new 40 kW and 60 kW Vertical Diesel Engine Emergency Generator Sets compliment the hundreds of 30 kW and 45 kW models which have been in service for the past several years. All of these units offer outstanding features, dependability, and the performance of Volkswagen's four or six-cylinder industrial diesel engine. Whether you choose a naturally aspirated 30 kW or 45 kW model or one of our new 40 kW or 60 kW turbocharged models, you've chosen a true performer.

Initially developed for the telecommunications industry's emergency power needs, these units established new standards for size, weight, sound level, performance, and ease of installation. The engine, generator, radiator, controls, battery and battery charger, and muffler are housed within a sound attenuating enclosure. These packages are ideally suited for applications where space is at a premium and do not require a separate engine room. Two openings in the wall for air intake and exhaust are the only building modifications normally required.

In addition to the 30, 40, 45 and 60 kW Vertical Diesel Engine units, Alturdyne also produces 90 kW and 125 kW Vertical Gas Turbine-powered generator sets and custom generator sets to conform to our customers' individual needs and power requirements. A 90 kW Vertical V8 Diesel Engine-driven unit is currently being developed.

For more information regarding any of these unique generator systems or a custom set to suit your needs, please contact the Alturdyne office nearest you.

ENGINE SPECIFICATIONS/NOMINAL PERFORMANCE*

kW RATING:	30 kW	40 kW	45 kW	60 kW
ENGINE:	Naturally Aspirated 4-Cylinder VW	Turbocharged 4-Cylinder VW	Naturally Aspirated 6-Cylinder VW	Turbocharged 6-Cylinder VW
BORE & STROKE:	3.01 x 3.40 in. (76.5 x 86.4 mm)	3.01 x 3.40 in. (76.5 x 86.4 mm)	3.01 x 3.40 in. (76.5 x 86.4 mm)	3.01 x 3.40 in. (76.5 x 86.4 mm)
DISPLACEMENT:	97 cu. in. (1588 cc)	97 cu. in. (1588 cc)	145 cu. in. (2383 cc)	145 cu. in. (2383 cc)
COMPRESSION RATIO:	23:1	23:1	23:1	23:1
HORSEPOWER:	47 @ 3600 rpm	74 @ 3600 rpm	70 @ 3600 rpm	95 @ 3600 rpm
OUTPUT:	30 kW @ 60 Hz 25 kW @ 50 Hz	40 kW @ 60 Hz 33 kW @ 50 Hz	45 kW @ 60 Hz 37 kW @ 50 Hz	60 kW @ 60 Hz 50 kw @ 50 Hz
VOLTAGE REGULATION:	2%	2%	2%	2%
FREQUENCY REGULATION:	Droop or Isochronous	Droop or Isochronous	Droop or Isochronous	Droop or Isochronous
FUEL COMSUMPTION AT FULL LOAD:	3.2 gph (12 l/hr)	3.5 gph (13.3 l/hr)	4.4 gph (16.6 l/hr)	4.9 gph (18.5 l/hr)

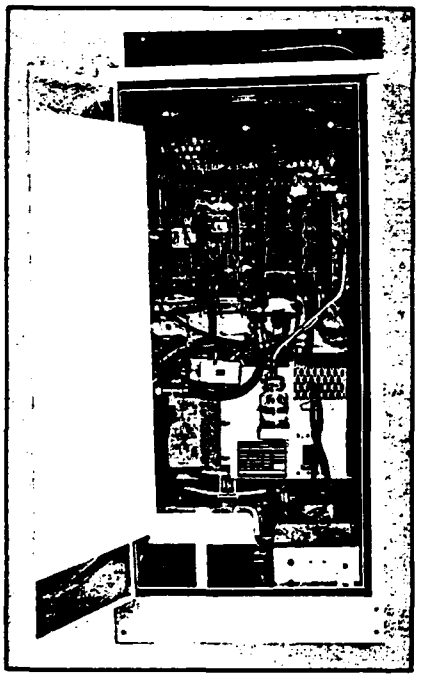
*Ratings based on sea level, 68°F ambient

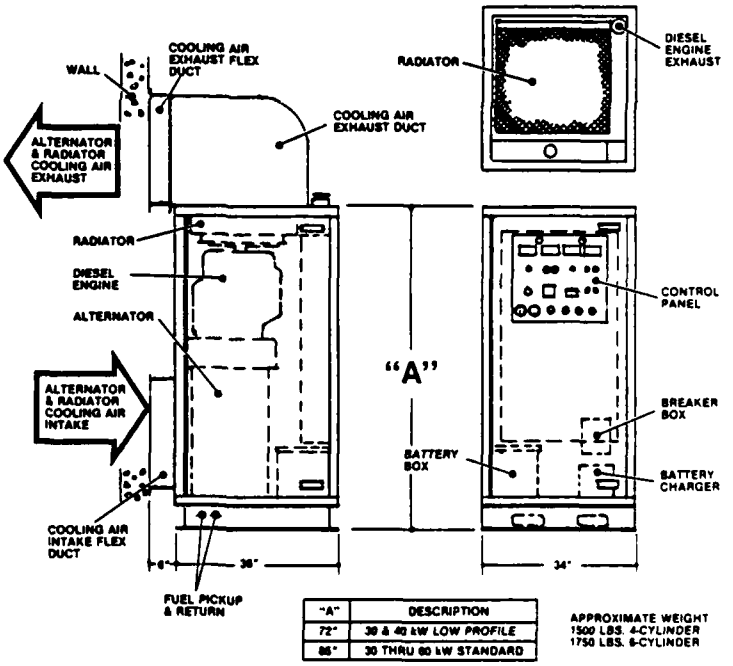
STANDARD EQUIPMENT

- Industrial Diesel Engine
- Brushless Generator
- Solid-state Voltage Regulator
- Voltage/Phase Ratings:
  - — 120/240 Volts, Single-phase
  - — 120/208 Volts, Three-phase
  - — 277/480 Volts, Three-phase
- Sound Attenuating Enclosure
- Radiator and Fan
- Electronic Governor
- Automatic Pre-lube System
- Glow Plug Pre-heating System
- Automatic Start
- Fuel/Water Separator
- Control Panel Featuring:
  - — Oil Pressure Gauge
  - — Water Temperature Gauge
  - — AC Ammeter
  - — AC Voltmeter
  - — Frequency Meter
  - — Operation Selector Switch
  - — Ammeter/Voltmeter Selector
  - — Emergency Stop Switch
  - — Malfunction Indicators
  - — AC and DC Circuit Breakers
- High Lift Fuel Boost Pump
- Automatic Shutdown Protection and Control Panel Indicators For:
  - — Overspeed
  - — Overcrank
  - — Low Oil Pressure
  - — High Water Temperature
  - — Low Water Level
  - — Rectifier Fail (battery charger)
  - — Malfunction (summary)
- Remote Contacts For:
  - — Start
  - — Stop
  - — Engine Run
  - — Major Malfunction
  - — Battery Charger Failure
- Output Circuit Breakers
- DC Ammeter (charging system)
- DC Voltmeter (charging system)
- Turbocharger Boost Pressure Gauge
- Jacket Water Heater
- Muffler
- Maintenance-Free Battery
- Battery Charger with 7 Amp Float
- Flexible Intake and Exhaust Ducts with Flanges
- 72 Hour Continuous Operation Oil Sump Capacity

OPTIONAL EQUIPMENT

- kW Meter with Transducer
- Tachometer (auto logic only)
- Paralleling
- Fuel Tanks
- Automatic (Bell System) Transfer Logic
- Automatic Transfer Switch
- Remote Emergency Stop Switch
- Hand Priming Pump System
- Mechanical Governor (deduct option)
- Remote Control Panel
- Special Acoustic Enclosure
- Outdoor Walk-in Module
- Unit Mounted 6 kW Load Bank
- Outside Duct Arrangements:
  - — Snow Protection (standard)
  - — Acoustic (68 dBA)
  - — Maximum Attenuation (50 dBA)
- Intake/Exhaust Outside Louvers
- Additional Monitoring, Malfunction, Protection, Annunciation, Controls, and Remote Contacts tailcred to customer application





"A"	DESCRIPTION
72"	30 & 40 kW LOW PROFILE
86"	30 THRU 60 kW STANDARD

APPROXIMATE WEIGHT
1500 LBS. 4-CYLINDER
1750 LBS. 6-CYLINDER

*Design and specifications subject to change without notice.

ALTURDYNE

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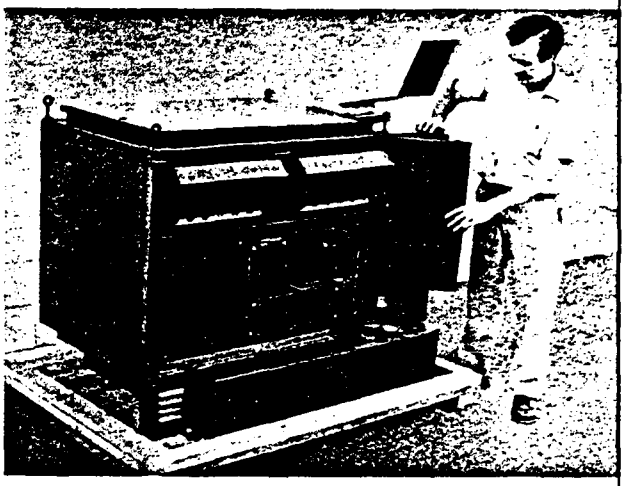
DS-6/2M 6/85

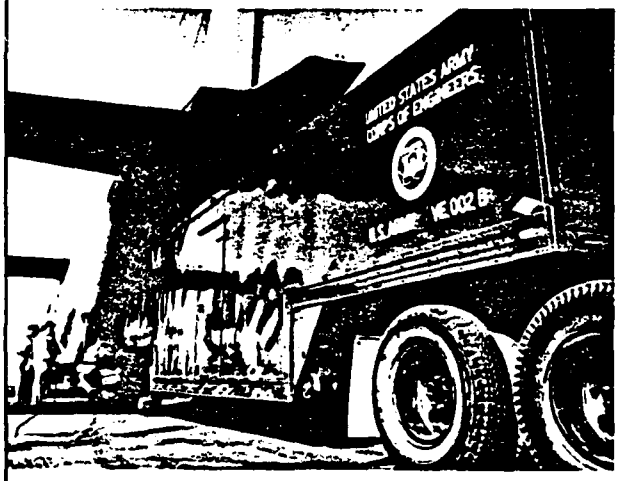
Communications

Alturdyne gas turbine and diesel engine-powered emergency generator sets are in service worldwide, protecting vital telephone and communications installations. Alturdyne "Verti-Pacs" are unsurpassed where space is at a premium. Gas-turbine-powered sets are available to 225 kW and new diesel engine-powered sets extend this packaging philosophy to units as small as 10 kW.



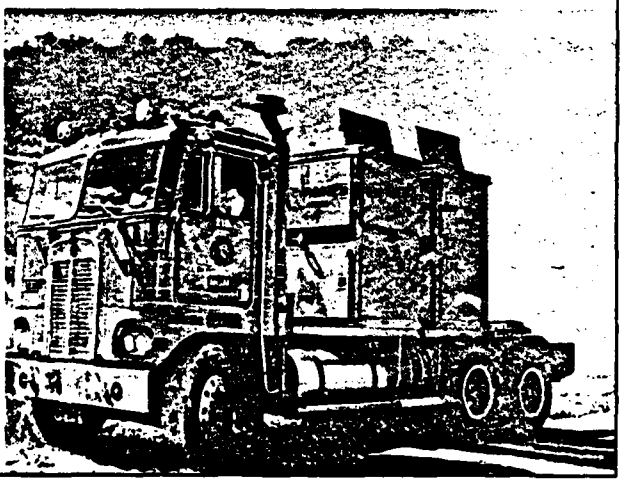
Government and Industry

Specialized turbine and reciprocating engine systems packages are regularly delivered to a wide variety of customers. Alturdyne gas turbine auxiliary and prime power units, for instance, have been developed to supply multiple outputs from a single prime-mover. Combinations of 400 Hz, 60 Hz, and DC electrical power; hydraulic power; shaft power and compressed air are possible.



Packaging

Alturdyne's capabilities include custom and production packaging of many different types and sizes of reciprocating and gas turbine power systems. Experience includes enclosures, silencers, equipment skids, single-lift modules, power vans and trailers for systems to 7000 kW, with physical sizes of 40' x 10' x 10' and 40,000# being common. A complete metal fabricating facility permits custom assemblies to be designed and fabricated quickly and economically.



Acoustical

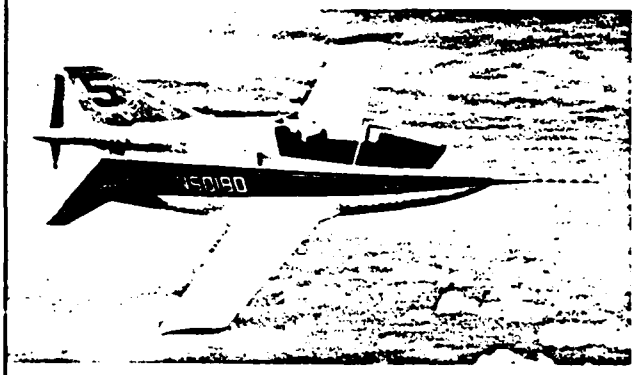
Alturdyne's experience in the acoustical treatment of gas-turbine and reciprocating engine packages has been applied to a variety of successful applications including AC/DC power units for the motion picture industry, acoustical modules and enclosures, and special intake and exhaust silencer systems designed to meet unique customer criteria.

Transportation

MARINE Alturdyne units supply ship's service and emergency power on high performance ferries, hydrofoils and research vessels.

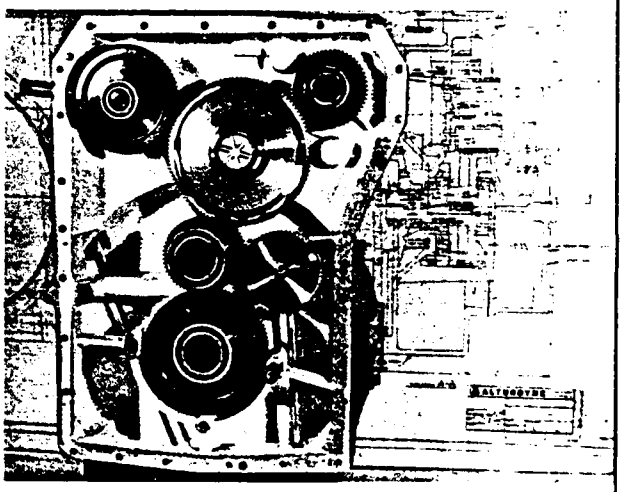
VEHICULAR APU's for tracked vehicles and battery charging units for electrical vehicles.

AVIATION Pod-mounted auxiliary power units for special aircraft applications, ground power carts for aircraft service and support.



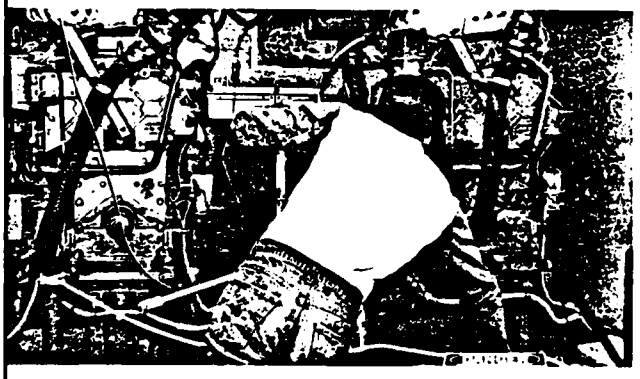
Alturair

An aircraft products subsidiary offering FAA-PMA certified parts for light aircraft. Installation and modification services for various STC's presently held for the Swift are performed.



Research and Development

Alturdyne's research and development activities are centered around advancements in prime mover applications. High-speed reduction gearboxes, direct-driven turbine load compressors, prototype hardware for electric vehicles and other energy research projects are some of the programs in which we are engaged. Military programs include preparation of DOD-D-1000 and DOD-STD-100 drawings, and completion of other DOD data requirements.



Product Support

A full-service organization provides installation consultation and contracting, emergency repairs, preventive and corrective maintenance, spare parts, publications, and equipment modification and modernization.

For additional information, write or call:

ALTURDYNE

8050 ARMOUR STREET,
SAN DIEGO, CA. 92111
(619) 565-2131 • TWX #910-335-2000 • ALTURDYNE SDG

Branch offices in Los Angeles, San Francisco, Detroit, Washington, D.C., Orlando, Houston, and Fairfield, Conn.

KOHLER CO KOHLER, WISCONSIN 53044 PHONE 4 4 [illegible] TELEX [illegible]

KOHLER

12 March 1987

Department of the Army
U.S. Army Belvoir Research
Development & Engineering Center
Attn: Mr. Noel D. Bishop
Chief, Power Equipment Support Team
Logistics Support Directorate
Fort Belvoir, VA 22060-5606

REFERENCE: QUESTIONNAIRE - IMPROVED PROTOTYPES FOR CURRENT STANDARD DOD GENERATOR SETS

Dear Mr. Bishop:

We have reviewed your letter of 17 February 1987 requesting industry input for resolving operational difficulties on the present DOD standard family generator sets. Pursuant to my telephone conversation with you on 9 March 1987, we have enclosed herewith Kohler Co.'s response to your questionnaire.

As per the guidance provided in your letter, you will note that our response to your queries has been intentionally general, and we have tried to furnish an approach only to solving the issues at hand. Please review this information and if you need to discuss it further, we will avail ourselves to meet with you at any time convenient to you.

Very truly yours,

D. K. Dhir
Manager-Defense Projects
Generator Division

DKD/njw

Enclosure

KOHLER CO KOHLER WISCONSIN 53044 PHONE [illegible]

KOHLER

RESPONSE TO QUESTIONNAIRE

1. Kohler Co. is a leading manufacturer of electrical power systems including generator sets, automatic transfer switches, switchgear, and accessories for the standby, prime power, marine, portable, and recreation vehicle markets. The generator sets range in size from 500 watts to 1,200 kW.

   In addition to the commercial end of our business, we have actively participated in the U.S. Department of Defense generator set development programs. Most noteworthy to mention is the latest building of 15, 30, and 60 kW; 50/60 Hertz; SSDED prototypes for U.S. Army which are presently undergoing qualification testing at various Army Depots.

2. The yearly usage on Kohler generator sets vary widely due to numerous applications involved coupled with the kW size of the units in question. In more general terms we would estimate that the generator sets in the range of 15 to 200 kW accumulate roughly 4,000 to 5,000 hours annually on prime applications versus about 100 hours on standby use.

3. Over the years Kohler has built an excellent network of distributors, both in the U.S. and internationally. Our 45 distributors in North American and 40 international firms are authorized to sell and service Kohler electrical power products. These distributors combined with original equipment manufacturers (OEM's) that use our sets provide a constant flow of parts/service and warranty data to our Service and Reliability Department. The data received is tabulated by product mix and analyzed.

The analyses of the service and reliability data is crucial not only in improving our designs but also to keep the warranty costs in check for the products in production. We essentially break down the total system failures in three broad categories - Engine, Alternator, and Controls. Since commonality of major components is critical for a company like Kohler with a diversified product line, any design improvement is applied throughout the system as applicable.

In addition to receiving service data from sources outside of Kohler Co., our Reliability Department is responsible for conducting an ongoing test and endurance program under actual environment and site conditions to generate information for Design Engineering critical to product performance.

4. Since Kohler Co. is a major manufacturer of generator sets and accessories as described above, this question is not applicable to us.

5a. From the reliability information provided for the typical DOD generator set,
5b. it appears that roughly 60% of the failures are engine related while 40% are control system related with a MTBF of 350 hours. These are ominous numbers and warrants close scrutiny to determine specifics of the failure followed by a detailed failure analysis.

Albeit it may be beyond the scope of your work, we believe that the overall set MTBF can be raised to 800, possibly even 1,000 hours, by selecting new engines that are state of the art with proven MTBF of 20,926 and dependable service life of over 9,000 hours before requiring overhaul in generator set applications. Cummins diesel engines are uniquely qualified for the DOD sets in the range of 15 through 200 kW.

Using microprocessor controls system in lieu of electromechanical devices, you can further enhance the reliability of the DOD sets by substantially reducing the part count thereby significantly providing increased space within the generator set enclosure for additional items, such as insulating materials and attenuators for acoustic and infrared suppression treatment. From tests run at Kohler with microprocessor controls, the reliability prediction for the control system is 1,900 hours MTBF.

5c. After study of the failed parts and the failure analysis, the availability of alternative components will be explored and (or) a redesign of the failed component will be recommended. Failed assemblies must be redesigned by statistical methods in order to minimize the possibility of a new failure.

5d. In order to present a meaningful cost estimate, DOD should first define the statement of work (SOW).

6a. Prerequisite to any noise reduction is the efficient attenuation of intake and exhaust noise emissions. A typical muffler size would be several cubic feet of double-wrapped exhaust silencer. As a second step, the internal surface of the housing must be lined with a thick acoustic foam in order to absorb the mechanical noise radiated through the engine housing. In a third step, there must be efficient attenuators installed at the cooling air entry and at the cooling air exit behind the radiator.

Kohler has been successful in applying above techniques on several sets in the range of 15 through 60 kW for both SSDED and Modified Commercial prototypes and has demonstrated lowering the noise levels to 65 to 68 dB(A) at 7 meters in any direction.

6b. We estimate the weight will increase by approximately 15%, while a typical 60 kW DOD set size will increase as follows, while the current footprint of the set being maintained.

- 6 inches wider
- 36 inches longer
- 16 inches higher

The increased set size is predicated upon the assumption that no changes will be made to current DOD engine, alternator, and control system components.

6c. Temperature reduction of the housing walls will be achieved by applying acoustic insulation to the walls. The exhaust pipe can be shielded from the hot exhaust gases by applying our proven exhaust ejector. The radiator would have to be extensively shielded or housed in a special enclosure with a cooling air circuit totally separated from the housing.

6d. The set weight and dimensional changes would not exceed as noted above under item 6b. Both acoustic and infrared suppression would be accommodated concurrently.

6e. Since acoustic and infrared suppression should be treated simultaneously, we would be interested in both tasks. At this time many of our designs are considered proprietary information and cannot be discussed in specific terms. We can only state that acoustic and infrared treatment require closely interwoven solutions.

6f. The weight and dimensional increase for both acoustic and infrared suppression are estimated under item 6b. on the previous page.

DKD/njw
R-Resp (DOD)

Michigan Technological University

Houghton, Michigan 49931

Division of Research
Keweenaw Research Center 906/487-2750

March 9, 1987

Noel D. Bishop
Power Generation Division
US Army Belvoir RD&E Center
Fort Belvoir, VA 22060-5606

Dear Mr. Bishop:

Enclosed please find the Keweenaw Research Center's response to the Power Generation Division's product improvement questionnaire for generator sets. KRC's interests are directed towards the signature suppression problem and, as you will notice, we've responded correspondingly.

We have taken the liberty to expand our reply on these areas and an additional attachment is included.

Please direct any questions concerning this questionnaire to our staff point-of-contact: Mr. Gary Howard (906) 487-2750.

Sincerely,

S. M. Lee

Sung M. Lee, Director
Keweenaw Research Center

SML/vs

QUESTIONNAIRE

1. Are you a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets? Please describe. No

If you manufacture other diesel engine driven equipment, what is the equipment?

None

2. What is an estimated average yearly usage for your equipment? N/A

What is the estimated operating cycle of your equipment (8 hours per day, 5 days per week, etc.)? Please describe. N/A

3. By what methods do you receive feedback from users on your equipment (application, engineering, sales, warranty replacements, etc.)? Please describe. N/A

4. If you are not a manufacturer, what is your position in the market place? Please furnish description. Multi-Spectral Countermeasure Design & Analysis

5. The DoD generator sets, once in user hands, are operated outside, exposed to the elements in many parts of the world and are exposed to all climatic conditions. Their operating cycle may be around the clock, for extended periods, with short shut down intervals for servicing or they may sit idle, being operated only a few hours per month. The majority of our sets are trailer

mounted on open trailers and during some field exercises they are frequently transported over roads ranging from highways to open cross country terrain. The sets are typically operated by soldiers primarily trained to operate other equipment such as radios, radar, trucks, etc. Typically they are maintained by trained repairmen with limited experience. If you are interested in the reliability portion of the program, please consider the above, look at the attached reliability tree and answer the following questions:

a. Based on your experience, what part(s) of the tree do you think you can improve? N/A.

b. How much improvement do you think you can provide? N/A.

c. Describe your approach for making the improvements. N/A.

d. Furnish a cost estimate for your program. N/A.

6. The generator set described in the attached figure is a typical military liquid cooled diesel engine driven generator set. It is designed so that the engine fan pulls air through the generator end for cooling the electrical apparatus, as well as combustion air and cooling air for the engine. The air is discharged through thermostatically controlled louvers on the radiator end. The 120hp at 1800 RPM/6 cylinder turbocharged engine uses a 15hp standard four blade metal fan for moving the air. The engine muffler is located within the set housing and the engine exhaust is out the radiator end near the top. The generator is single bearing, four pole, with a synchronous speed of 1800 RPM.

See Attachment

The engine generator set assembly uses a three point mounting, two generator feet and an engine trunnion mount, and is mounted directly to the skid base. The present noise level of the set is 87dBA at a 7 meter distance from the set. The set has a metal housing, with all bolted construction. The present housing + muffler offers very little sound attenuation. Considering the above, please answer the questions applicable to your area of interest.

a. Please describe your general approach for lowering the noise emitted from the set in any direction to 70 dBA at 7 meters. _____

_____

_____

_____.

b. What would be your guesstimation of the set weight and dimensional increase required for your sound attenuation effort? _____

_____

c. Please describe your general approach for decreasing the infrared signature of the set. _____

_____

_____.

d. What would be your guesstimation of the set weight and dimensional increase required for decreasing the infrared signature of the set? _____

_____

_____.

See Attachment

e. If you are interested in both the sound and infrared reduction efforts, how do you foresee their interrelation? _____

_____

_____

f. What would be your guesstimate of the net set weight and dimensional increase for both efforts? _____

_____

Questionnaire Continued

Question 6.

If both an acoustic signature and infrared signature suppression effort is required, it is proposed that this effort be approached as a single countermeasure issue. The reduction needed in either spectral area can only be efficiently accomplished by using a coordinated countermeasure design.

ACOUSTICS:

There are three main areas of design concentration:

1. Housing. The walls of a newly configured housing will be treated with acoustic suppressive foam selected to absorb the maximum energy in the problem frequency bands. Any potential escape routes for acoustic pressure, such as cooling air inlets etc., will be designed to block sound propagation yet maintain a minimum pressure loss.

2. Exhaust system. A larger, specifically designed, exhaust system will be installed. The increased volume issue must be resolved.

3. Component isolation. Those minor bolt-on components, which are themselves noise sources, will be identified, redesigned and/or isolated. New engine/alternator mounts will be installed providing maximum isolation between the major components and the skid/housing assembly.

INFRARED:

It is the opinion of KRC that the specifications, as written in the SSDED program, do not allow sufficient flexibility in design to develop a reliable, effective and cost efficient IR suppression system. It is proposed, therefore, that spectrally reflective IR coating be used in place of the standard CARC paint and that the generator IR signature be defined with the apparent surface temperature as a reference, not the absolute surface temperature.

The inside housing wall of the double wall structure will be coated with a highly (thermal) reflective paint thus reducing the thermal radiation exchange internally. The outside walls will be biased colder than any anticipated background scene using special IR low emissivity coatings being developed at KRC. By employing temperature and radiant energy sensors, the outside wall temperatures will be increased as necessary so that the thermal contrast between

the generator set and its immediate environment will be driven to zero. This manipulation will be accomplished using either an internally generated heat source or one specifically installed for this purpose. The result is an IR suppression system that actively senses its environment and alters the thermal characteristics of the housing to match the varying thermal characteristics of its environment.

Although a design approach is not provided at this time, it is the opinion of KRC that the load lead IR signature problem should also be addressed. These leads potentially extend far out from the generator set and creates a substantial "que feature" when viewing the generator imagery.

Any alterations in the present external dimensions of the generator sets are estimated to be minor. The increase in housing wall thickness is expected to be substantially offset by an internal reconfiguration to salvage unused internal volume.

RADAR:

During redesign of the generator set housing to achieve reduced IR and acoustic signature characteristics, it is appropriate that the radar characteristics also be evaluated. It is believed that some optimization of the radar signature can be obtained at this stage, with minimal impact on the physical configuration of the concept housing.

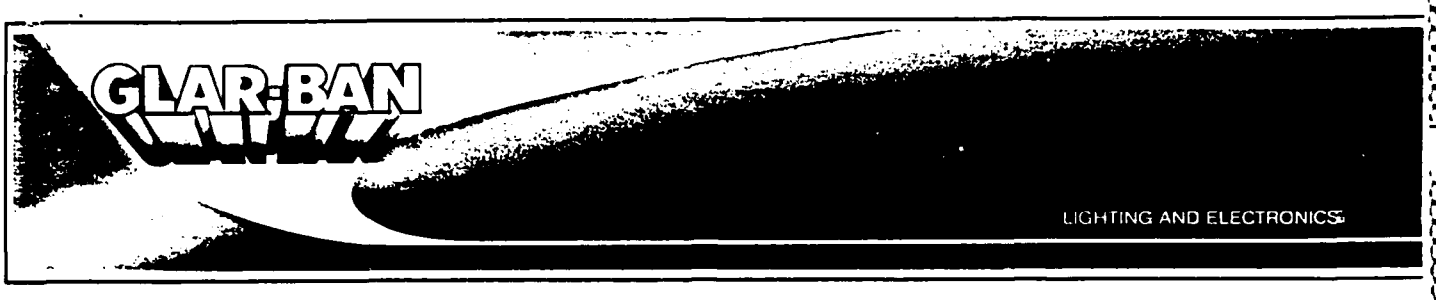
KRC suggests the following tasks:

a) determine the radar characteristics of the present housing

b) predict the radar characteristics of the concept housing.

c) investigate proposed housing alterations that tend to reduce the radar signature of the housing, without adversely affecting the primary goals of IR and acoustic suppression.

KRC possesses multi-spectral computer modelling capabilities which can be used as a concept evaluation tool before a hardware design is initiated. This has proven to be a cost effective and efficient method of design and will be used in this activity. Resident at KRC are the following models: PRISM (IR), ADRPM (acoustics), DBSM (radar) and USATACOM/NRL/Georgia Tech (radar).



199 Wales Avenue
Tonawanda, New York 14150
Phone 716-694-5076

March 4, 1987

U.S. Army Belvoir R&D Center
Power Equipment Support Team (Noel Bishop)
Fort Belvoir, VA 22060-5606

Dear Mr. Bishop:

Enclosed is our completed questionnaire. Glar-Ban is a manufacturer of lighting products that include Fault, Catuion, and Warning Indicators, as well as lighting for instruments and nomenclature panels.

All of our products can be provided with Filter Lens that limit the IR energy for Secure Lighting.

I have enclosed several typical drawings of Indicators you may be able to directly interchange on the existing generator units. If you need an IR Secure Lamp assembly other than the drawings I have provided, please give me a call as we have many new products under development at this time.

Very truly yours,
GLAR-BAN, Div. Mark IV Ind.

Gordy Treichler
Chief Engineer

GT/ph

Encl: Drg.

DEPARTMENT OF THE ARMY
US ARMY BELVOIR RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
FORT BELVOIR, VIRGINIA 22060-5606

REPLY TO
ATTENTION OF

February 26, 1987

Power Equipment
Support Team

Mr. Gordy Treichler
Glar-Ban
199 Wales Avenue
Tonawanda, New York 14150

Dear Mr. Treichler

The Army is planning a program to build improved prototypes of our current standard family of DoD Diesel Engine Driven Generator Sets in sizes 5kW, 10kW, 15kW, 30kW, 60kW and 100kW. Our primary areas of interest are reliability, noise and infrared suppression.

The purpose of this questionnaire is to solicit industry input for resolving operational problems of the DoD generator set fleet. Completion and return of the questionnaire and any additional information you may wish to furnish, is appreciated. The information thus furnished may be the basis for procurement of services and material for purposes of experimentation, and for eventual incorporation into the improved generator set fleet. In the interest of protecting your company's technology, it is requested that any information furnished at this time be of a non-proprietary nature; furthermore, it must be understood that any information furnished as a result of this questionnaire is without obligation to the Government. Your information is requested by March 16, 1987.

Please contact me if you have any questions at (703) 664-5596.

Sincerely,

Noel D. Bishop
Chief, Power Equipment Support Team
Power Generation Division
Logistics Support Directorate

Enclosure

QUESTIONNAIRE

1. Are you a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets? Please describe. INDICATOR LIGHTS, INSTRUMENT LIGHTS & CAUTION INDICATORS

If you manufacture other diesel engine driven equipment, what is the equipment?

NONE

2. What is an estimated average yearly usage for your equipment? _____

What is the estimated operating cycle of your equipment (8 hours per day, 5 days per week, etc.)? Please describe. FROM CONTINUOUS 24 HR/DAY TO INTERMITANT.

3. By what methods do you receive feedback from users on your equipment (application, engineering, sales, warranty replacements, etc.)? Please describe. SALES, AND SERVICE REPLACEMENTS

4. If you are not a manufacturer, what is your position in the market place? Please furnish description. MANFACTURE OF LIGHTED INDICATORS, FOR CAUTION, WARNING AND ILLUMINATED DEVICES TO LIGHT PANELS AND INSTRUMENTS *

5. The DoD generator sets, once in user hands, are operated outside, exposed to the elements in many parts of the world and are exposed to all climatic conditions. Their operating cycle may be around the clock, for extended periods, with short shut down intervals for servicing or they may sit idle, being operated only a few hours per month. The majority of our sets are trailer

* A.L LIGHTING PRODUCTS ARE AVALIBLE WITH IR SECURE LENS TO REDUCE IR SIGNATURE OVER CURRENT LIGHTS.

mounted on open trailers and during some field exercises they are frequently transported over roads ranging from highways to open cross country terrain. The sets are typically operated by soldiers primarily trained to operate other equipment such as radios, radar, trucks, etc. Typically they are maintained by trained repairmen with limited experience. If you are interested in the reliability portion of the program, please consider the above, look at the attached reliability tree and answer the following questions:

a. Based on your experience, what part(s) of the tree do you think you can improve? _____

_____.

b. How much improvement do you think you can provide? _____

_____.

c. Describe your approach for making the improvements. _____

_____

_____.

d. Furnish a cost estimate for your program. _____.

6. The generator set described in the attached figure is a typical military liquid cooled diesel engine driven generator set. It is designed so that the engine fan pulls air through the generator end for cooling the electrical apparatus, as well as combustion air and cooling air for the engine. The air is discharged through thermostatically controlled louvers on the radiator end. The 120hp at 1800 RPM/6 cylinder turbocharged engine uses a 15hp standard four blade metal fan for moving the air. The engine muffler is located within the set housing and the engine exhaust is out the radiator end near the top. The generator is single bearing, four pole, with a synchronous speed of 1800 RPM.

The engine generator set assembly uses a three point mounting, two generator feet and an engine trunnion mount, and is mounted directly to the skid base. The present noise level of the set is 87dBA at a 7 meter distance from the set. The set has a metal housing, with all bolted construction. The present housing + muffler offers very little sound attenuation. Considering the above, please answer the questions applicable to your area of interest.

a. Please describe your general approach for lowering the noise emitted from the set in any direction to 70 dBA at 7 meters. _____

_____

_____

_____

b. What would be your guesstimation of the set weight and dimensional increase required for your sound attenuation effort? _____

_____

c. Please describe your general approach for decreasing the infrared signature of the set. CHANG ALL LIGHTING + FAULT CAUTION INDICATORS TO IR SECURE ASSEMBLIES WITH LIMITED VIEWING ANGLES

d. What would be your guesstimation of the set weight and dimensional increase required for decreasing the infrared signature of the set? NO SIGNIFICANT INCREASE TO CONFIGURE ALL LIGHTED DEVICES WITH IR SECURE LENS ASSY,

e. If you are interested in both the sound and infrared reduction efforts, how do you foresee their interrelation? _____

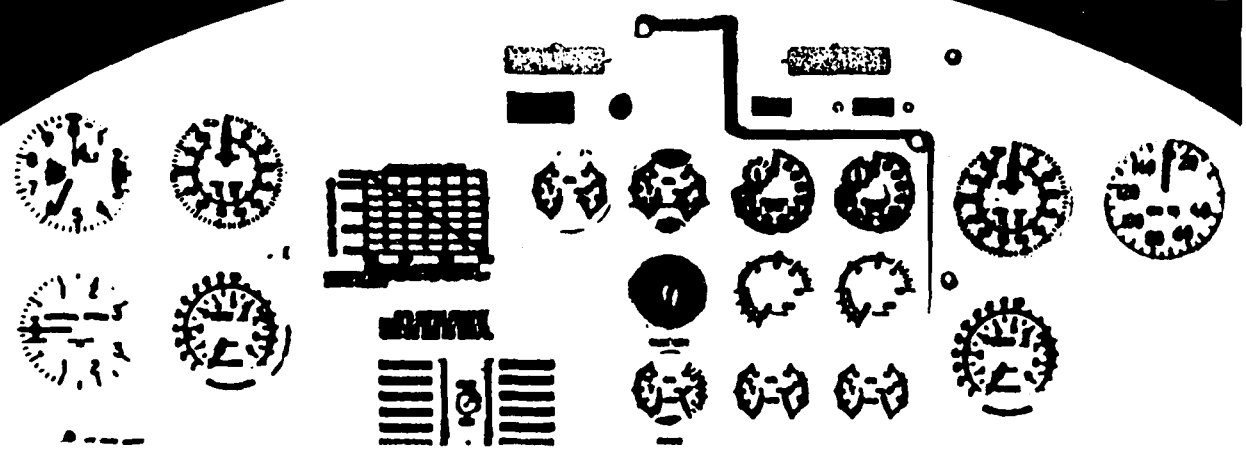
_____

_____.

f. What would be your guesstimate of the net set weight and dimensional increase for both efforts? _____

_____.

GLAR-BAN



produces Infrared Secure and Night Vision Goggle Compatible Lighting.

In the early 80's the U.S. military began a program to provide air and land vehicles with infrared secure lighting. One of the first tasks was to convert helicopters to night vision compatibility. It was at this point that GLAR-BAN was called in. We were the first non-military source to produce light assemblies for the military as part of the IR secure program. We shipped our first order in 1982. Since that time we have become the primary source in the U.S. for this type of lighting.

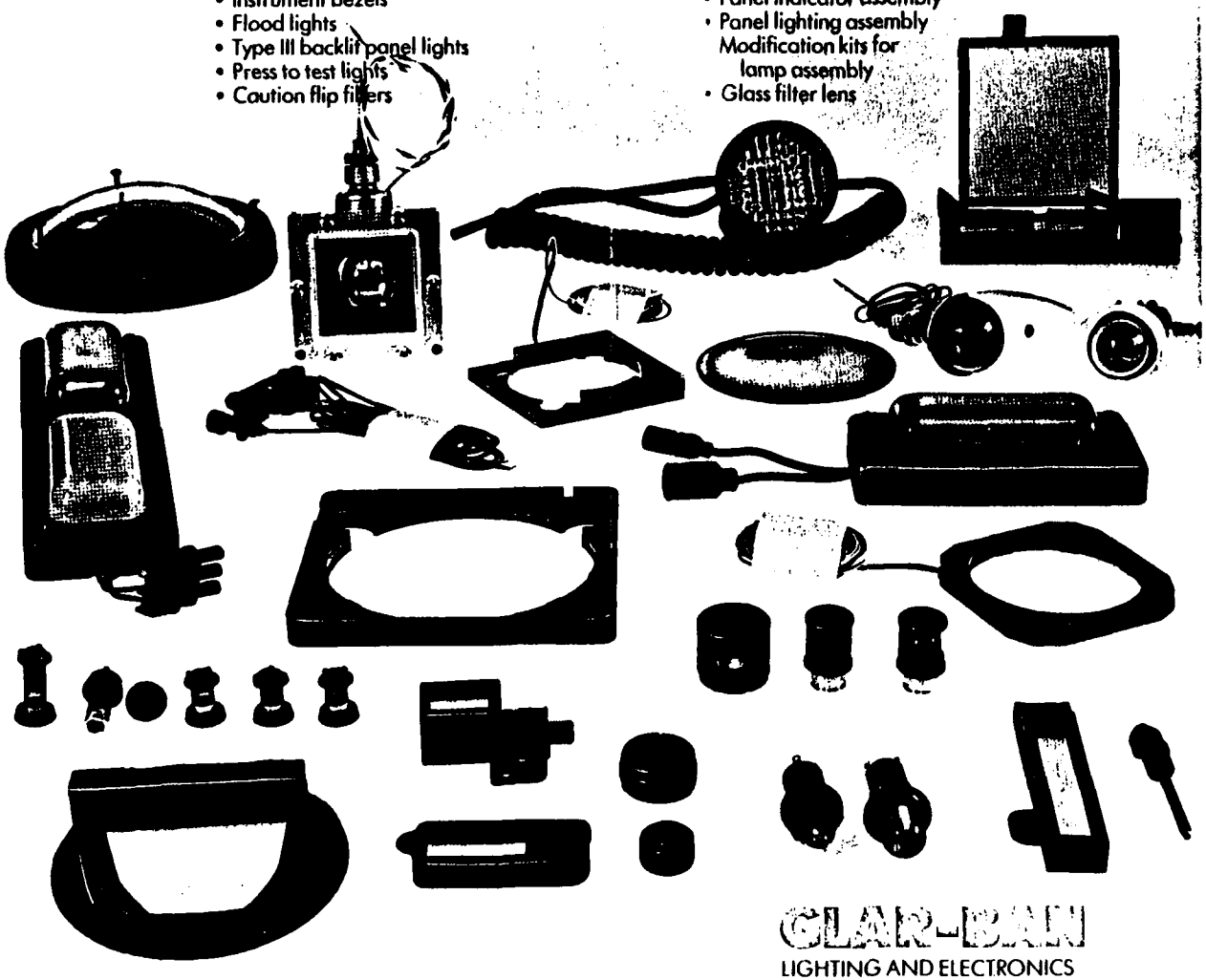
- Wing position
- Tail lights
- Fixed landing
- Extendable search and landing
- Inspection and logo

Aircraft Interior Instrument Lighting
- Bolt lights
- Tab lights
- Panel flood

Night Vision Goggle Compatible Instrument Lights
- Bolt lights
- Instrument bezels
- Flood lights
- Type III backlit panel lights
- Press to test lights
- Caution flip filters
- MOD kits for MS assembly
- Replacement lens
- Complete dome light assembly

Infrared Transmitting Covert Lighting
- IR search light filter STD PAR 46
- IR search light assembly PAR 64
- Covert IR position/navigation
- Area illuminators, hook or loading
- Dual IR white search light MOD kits
- Complete dual search lights

Ground Vehicles IR Secure Lighting
- Dome light assembly
- Panel indicator assembly
- Panel lighting assembly
- Modification kits for lamp assembly
- Glass filter lens



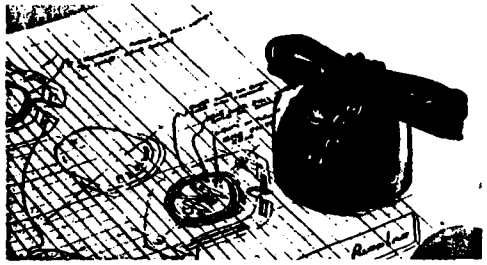
GLAR-BAN
LIGHTING AND ELECTRONICS
199 Wales Avenue Tonawanda, NY 14150
716/694-5076

customer to develop products.

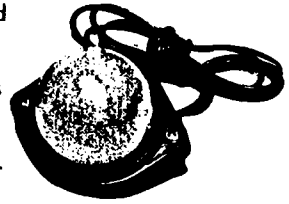
Having worked side by side with the military for many years, we are often sought by companies who need to meet military specifications for IR security. We advise a growing number of contractors to the military, helping them to develop new products or retrofit programs for air, land and sea vehicles. As the experts in the IR secure lighting field, we provide valuable service to our customers in the private sector as well as in government.

Our service: high reliability and fast turnaround.

Our knowledge and reliability are the core of our service in product development. We have been in the program since the beginning. Dozens of our products have been accepted by the military and are in use. We carry an inventory to serve our customers more quickly. On an initial contact, we put a customer in touch with our engineering department to discuss specifications. From that point we move quickly from paper to prototype. When we



find the prototype is acceptable to the customer, we can move right into production. Our turnaround time is typically measured in months, where other companies put their new product time lag in terms of years.



We have the flexibility to produce and deliver product very quickly.

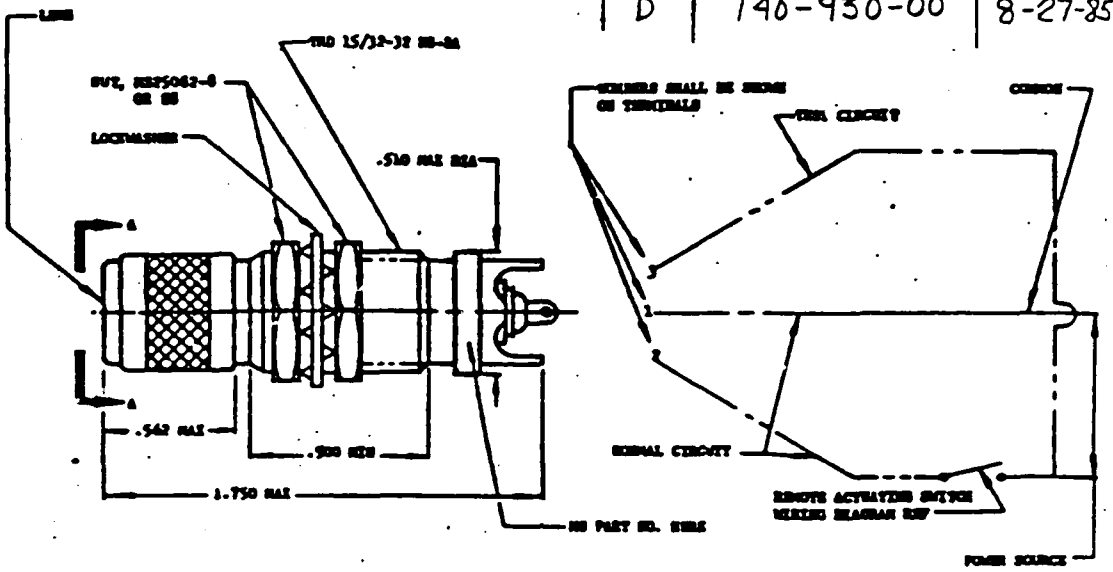
Because we are a relatively small company, we can respond quickly, to accomodate customers' needs. Our flexibility allows us to as easily produce a single unit as to go up to thousands of kits. Our quality control system meets the requirements of MIL-I-45208.

"...give GLAR-BAN a call."

Our name is well known in the military when it comes to IR secure lighting. They have experienced our reliability, our ability to meet demanding challenges and our quick turnaround time. In fact, for any company who needs to meet the military's IR secure/NVG requirements, we would repeat the advice of many of our customers in the Army: "...give GLAR-BAN a call."

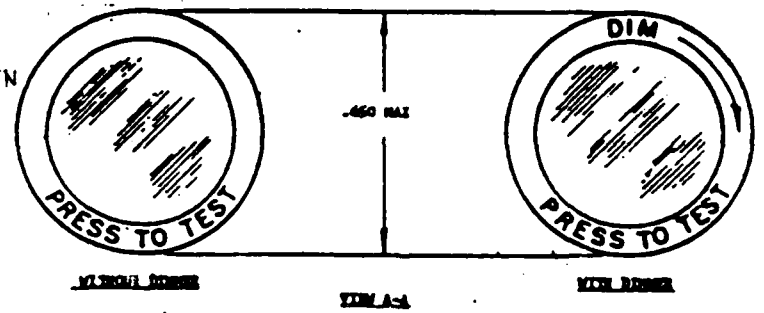
APPLICATION	
NEXT ASSY.	USED ON

REVISIONS			
REV.	E.C.R. NO.	DATE	APPROVED
A	140-784-00 REDRAWN	8-19-83	GLT
B	140-814-00	4-19-84	GLT
C	140-827-00 RELEASED PER ECR 140-879-00	7-6-84 4-4-85	JIM STANTLEY
D	140-930-00	8-27-85	



NOTE:

1. FILTER GLASS BLUE PER GB SP014-1
2. FILTER GLASS GREEN PER GB SP020



X	0	1	3	4	5
BASE		✓		✓	✓
CAP W/DIM.			✓	✓	
CAP W/O DIM.	✓	✓			

X NO. OBTAINED FROM COMBINATION CHART AT LEFT

923-10X-YZ-G

- G — DENOTES OPTIONAL GREEN LENS (SEE NOTE 2)
- YZ NO. DESIGNATES BULB
  - -00 - NO BULB
  - -06 - 6 VOLT BULB
  - -28 - 28 VOLT BULB

UNLESS OTHERWISE SPECIFIED
FRAC. ±1/64 ANGLE ±1/2°
.XX ±.01 .XXX ±.005
ALL SURFACES √ PER MIL STD 10
BREAK SHARP EDGES .010
DRILLS < 1/2 DIA. +.003 −.001
> 1/2 DIA. +.003 −.002

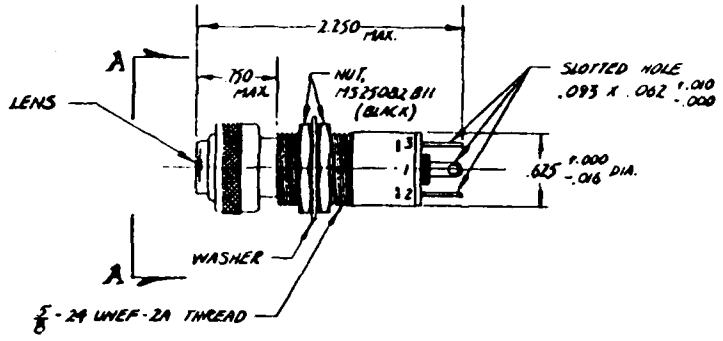
DRAWN BY Steve Sharp 8-19-83
CHECKED
ENGR. APPROVED
MFG. APPROVED 8-19-83

GLAR-BAN DIV.
MARK IV INDUSTRIES INC.
P. O. BOX 177 N. TONAWANDA, N. Y. 14120

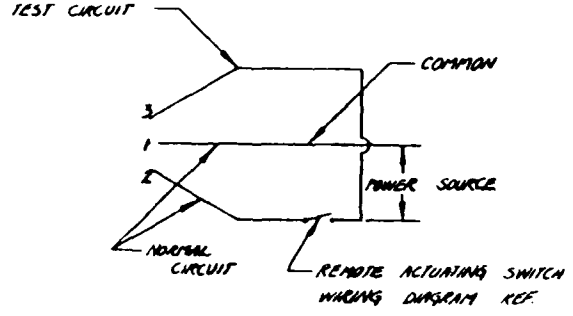
TITLE LIGHT ASSEMBLY PRESS TO TEST W/DIMMER BLUE LENS "N.V.G" COMPATIBLE TO MS 25041 TYPE

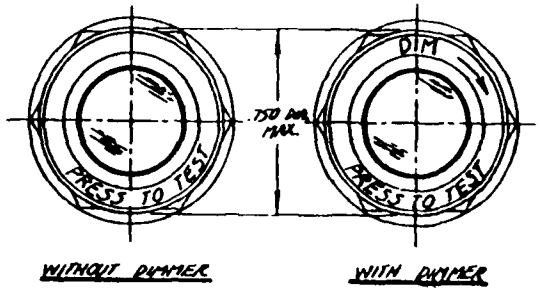
FOR MATERIAL OR PARTS SEE	APPROVAL DESIGN ACTIVITY	SIZE	FSCM	DRAWING NO.	REV.
		A	22973	923-10X-YZ	D
FINISH	APPROVAL OTHER	SCALE NONE		SHEET 1 OF 1	

REVISIONS			
REV.	E.C.R. NO.	DATE	APPROVED
A	140-196-00	12-13-95	GLF



NOTE:
FILTER GLASS BLUE PER GB-3901A





VIEW A-A (2X SCALE)

X	0	1	2	3	4
BASE		✓		✓	✓
CAP W/O DIM	✓	✓			
CAP W/DIM			✓	✓	

923-31X-YZ

X NO. OBTAINED FROM COMBINATION CHART ABOVE

YZ NO. DESIGNATES BULB
-00 - NO BULB
-06 - 6 VOLT BULB
-28 - 28 VOLT BULB

NEXT ASSEMBLY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED
FRAC. ± 1/64 ANGLE ± 1/2°
.XX ± .01 .XXX ± .005
ALL SURFACES ✓ PER MIL-STD-10
BREAK SHARP EDGES .010
DRILLS < 1/2 DIA. +.003 -.001
> 1/2 DIA +.003 -.002

FINISH

DRAWN BY Steve Sauer 11-30-95
CHECKED [illegible] 11-30-95
ENGR. APPROVED GLF 30 NOV 95
MFG. APPROVED
APPROVAL DESIGN ACTIVITY
APPROVAL OTHER

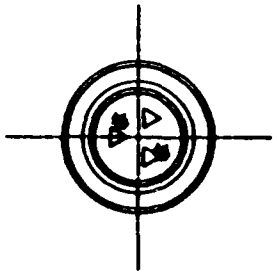
GLAR-BAN DIV.
MARK IV INDUSTRIES INC.
P.O. BOX 177 N. TONAWANDA, N.Y. 14120

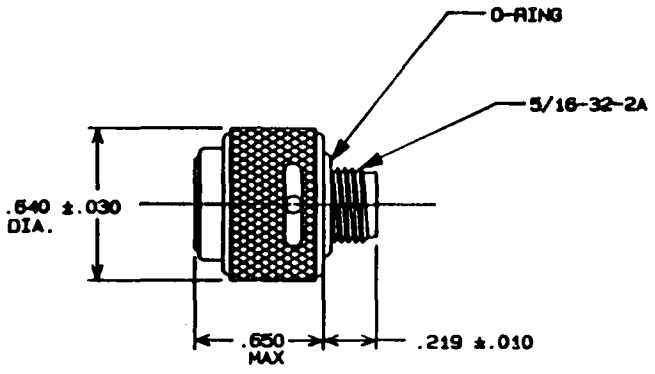
TITLE
LIGHT ASSEMBLY PRESS TO TEST INDICATOR
BLUE LENS "N.K.G." COMPATIBLE TO
REPLACE MS 25231 1WC

SIZE	FSCM	DRAWING NO.	REV.
B	22973	923-31X-YZ	A

SCALE 1/1 SHEET 1 of 1

REV.	E.C.A. NO.	DATE	APPROVED
A	141-118-00	12-10-00	





NOTES:
1) APPLICATION: USE THIS PART FOR MILITARY APPLICATIONS REQUIRING INDICATORS THAT ELIMINATE I.A. SIGNATURE.
2) LAMP: T 1-3/4 MINIATURE FLANGE TYPE.
3) PRESS TO TEST FEATURE.
4) DIMMABLE USING THREE TRIANGULAR OPENINGS.
5) ENVIRONMENTAL SHIELDED
6) LENS COLORS: BLUE, GREEN AND YELLOW.
7) WHEN ORDERING SPECIFY: LENS COLOR & LAMP VOLTAGE.

LENS COLOR — LAMP VOLTAGE

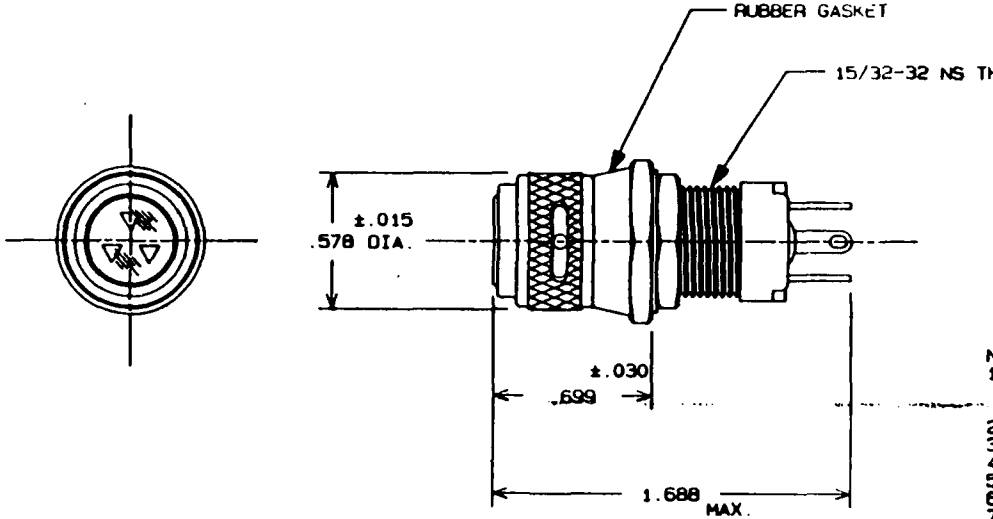
800-302-XX

6 VOLT - 3
12 VOLT - 6
28 VOLT - 9

BLUE - 2
YELLOW - 4
ANVIS GREEN A - 6
ANVIS GREEN B - 8

		DRAWN BY J.K.S. 7-20-00	GLAR-BAN DIV.
			TITLE: LIGHT ASSEMBLY, I.A. SECURE, DIMMABLE
			SIZE B | PART 22973 | DRAWING NO. 800-302-XX | REV. A
NEXT ASSEMBLY	USED ON	BREAK SHARP EDGES .005	SCALE 2X | LEVEL 4 | SHEET 1 OF 1

REVISIONS			
REV.	E.C.R. NO.	DATE	APPROVED
A	141-089-00	8-11-88	



NOTES:
1) APPLICATION: USE THIS PART FOR MILITARY APPLICATIONS REQUIRING INDICATORS THAT ELIMINATE I.R. SIGNATURE.
2) LAMP: T 1-3/4 MINIATURE FLANGE TYPE.
3) PRESS TO TEST FEATURE.
4) DIMMABLE USING THREE TRIANGULAR OPENINGS.
5) ENVIRONMENTAL SHIELDED
6) LENS COLORS: BLUE, GREEN AND YELLOW.
7) WHEN ORDERING SPECIFY: LENS COLOR & LAMP VOLTAGE.

LENS COLOR — LAMP VOLTAGE

810-110-XX

6 VOLT - 3
12 VOLT - 6
28 VOLT - 9

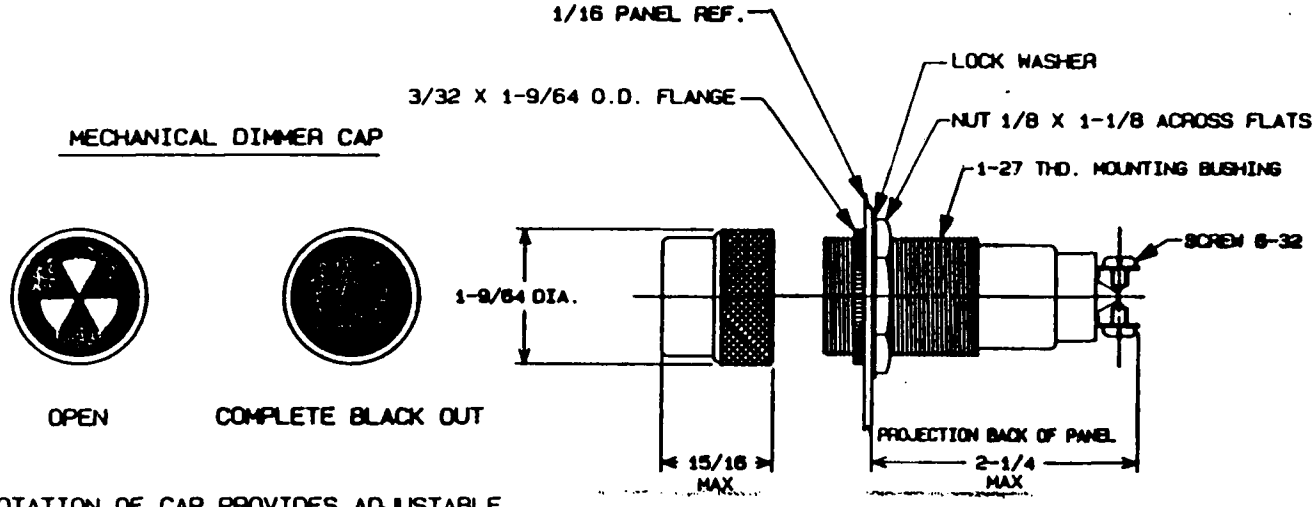
BLUE - 2
YELLOW - 4
ANVIS A GREEN - 6
ANVIS B GREEN - 8

NEXT ASSEMBLY	USED ON	DRAWN BY B.SHARP 4/24/88 CHECKED ENGR. APPROVED UNLESS OTHERWISE SPECIFIED FRACTIONS ±1/64 DECIMALS .XXX ±.005 .XX ±.010 ANGLES ±1° HOLES ≤ .500 DIA. +.005 -.000 > .500 DIA. ±.005 BREAK SHARP EDGES .005	GLAR-BAN DIV. MARK IV INDUSTRIES INC [illegible]

TITLE: LIGHT ASSY., I.R. SECURE DIMMABLE, PRESS TO TEST

SIZE	FSCM	DRAWING NO	REV.
B	22973	810-110-XX	A

SCALE	LEVEL	SHEET
2X	3	1 OF 1



MECHANICAL DIMMER CAP

OPEN

COMPLETE BLACK OUT

ROTATION OF CAP PROVIDES ADJUSTABLE INTENSITY OF LIGHT EMISSION

NOTES:

1) APPLICATION: USE THIS PART FOR MILITARY APPLICATIONS REQUIRING INDICATORS THAT ELIMINATE I.R. SIGNATURE.
2) LAMP: S6 DOUBLE CONTACT BAYONET BASE.
3) WHEN ORDERING SPECIFY PART NO. FOR DESIRED LENS COLOR AND LAMP VOLTAGE.

LENS COLOR — LAMP VOLTAGE

830-701-XX

BLUE - 1
YELLOW - 3
GREEN - 5
DRK. GRN. - 7

A - 24 VOLTS
B - 30 VOLTS
C - 48 VOLTS
D - 75 VOLTS
E - 125 VOLTS
F - 135 VOLTS
G - 145 VOLTS
H - 230 VOLTS
I - 250 VOLTS

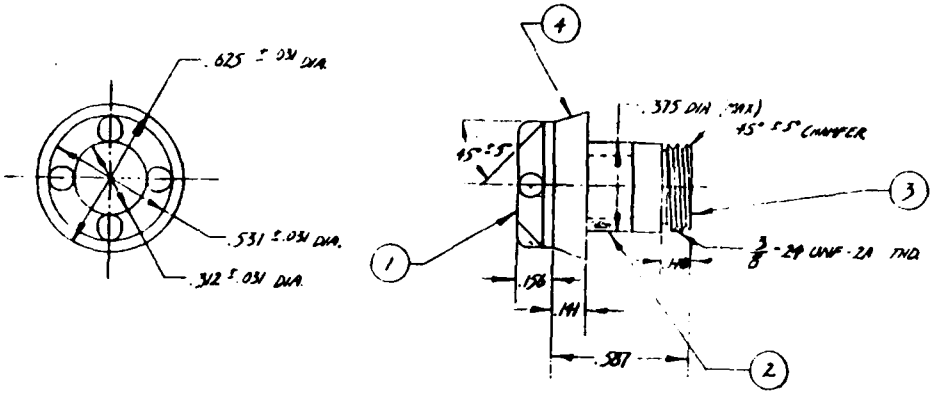
GLAR-BAN DIV.

INDICATOR LIGHT ASSY.
I.R. SECURE 1" MNT. DIA.

SIZE	FSCM	DRAWING NO.	REV.
B	22973	830-701-XX	0

SCALE	LEVEL	SHEET
1X	ONE	ONE OF ONE

REVISIONS			
REV.	E.C.R. NO.	DATE	APPROVED
A	140-784-00	8-19-83	GAST
B	140-812-00	4-10-84	GLT
C	140-814-00	4-19-84	GLT
	RELEASED VERSION 140-911-00	4-1-85	SAS
D	190-901-00	6-18-85	[illegible]



NOTE:

1. FILTER MATERIAL WILL DISCOLORABLE GLASS PER MIL-G-9444 TYPE 2
2. 923-250-01 PART NUMBER FOR PANEL LIGHT ASSY. MINUS ITEM 4 923-251-00 GASKET
3. THIS PART IS A DIRECT REPLACEMENT FOR MS 25010 TYPE LAMPS

ITEM	PART NUMBER	DESCRIPTION
4	923-251-00	GASKET
3	923-249-00	BASE ASSY. 3/8-24 UNF-2A
2	920-405-10	FILTER
1	923-253-00	CAP

TOLERANCE DECIMALS ± .016

NEXT ASSEMBLY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED
FRAC. ± 1/64 ANGLE ± 1/2°
ALL SURFACES √ PER MIL-STD-10
BREAK SHARP EDGES .010
DRILLS < 1/2 DIA. +.003 −.001
> 1/2 DIA. +.003 −.002

FOR MATERIAL OR FINISH SEE

FINISH

DRAWN BY Steve Sinon 8-12-83
CHECKED [illegible] 8-12-83
ENGR. APPROVED GLT 12 Aug 83
MFG. APPROVED [illegible] 8-19-83
APPROVAL DESIGN ACTIVITY
APPROVAL OTHER

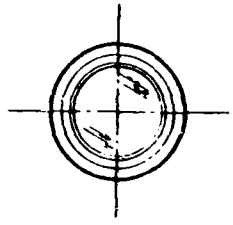
GLAR-BAN DIV.
MARK IV INDUSTRIES INC.
P.O. BOX 177 N. TONAWANDA, N.Y. 14120

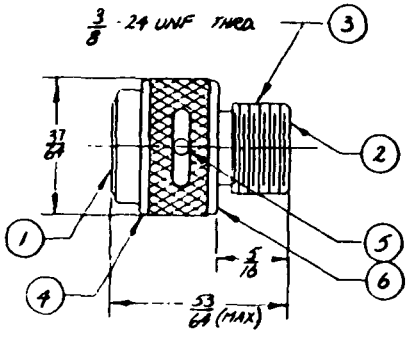
TITLE
MS 25010 TYPE
PANEL LIGHT CAP ASSY.
(N.V.G. COMPATIBLE)

SIZE	FSCM	DRAWING NO.	REV.
B	22973	923 250 00/01	D

SCALE 2/1 SHEET 1 OF 1

REVISIONS			
REV.	E.C.R. NO.	DATE	APPROVED
	RELEASED PER ECR 141-000-00	1-9-85	SAF
A	141-000-00	1-19-86	GLT
B	141-003-00	9-24-86	[illegible]





NOTES:

1) DESCRIPTION: DIMMING LENS CAP WITH BLUE N.V.G. GLASS FILTER FOR USE ON MIL-P-7788 PANEL INDICATOR LAMPS.
2) BLUE FILTER GLASS PER GB SP014-1
3) COMPATIBLE WITH LAMPS 6V (MS-25237-328), 12V (MS-25237-330), 28V (MS-25237-327) T-1 3/4 MIDGET FLANGE.
4) FINISH: BULL BLACK NICKEL
5) ADD -G TO PART NUMBER TO OBTAIN GREEN FILTER GLASS PER GB-SP020.

ITEM	PART NUMBER	DESCRIPTION
6	923-309-00/01	SPRING
5	923-308-00/01	RETAINER PIN
4	923-307-00/01	CAP
3	923-306-00/01	THREADED BASE
2	923-255-00/01	LAMP SPRING
1	920-914-00	BLUE N.V.G. GLASS LENS

BILL OF MATERIAL

NEXT ASSEMBLY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED
FRAC. ± 1/64 ANGLE ± 1/2°
.XX ± .01 .XXX ± .005
ALL SURFACES √ PER MIL-STD-10
BREAK SHARP EDGES .010
DRILLS < 1/2 DIA. +.003 -.001
> 1/2 DIA. +.003 -.002

FOR MATERIAL OR PARTS SEE

FINISH

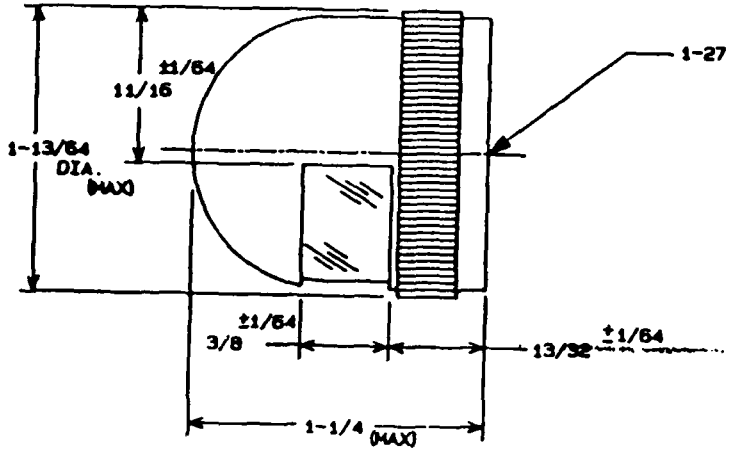
DRAWN BY Jane Sumner 5-5-84
CHECKED [illegible] 5-7-84
ENGR. APPROVED GLT 7 May 84
MFG. APPROVED
APPROVAL DESIGN ACTIVITY
APPROVAL OTHER

GLAR-BAN DIV.
MARK IV INDUSTRIES INC.
P.O. BOX 177 N. TONAWANDA, N.Y. 14120

TITLE
DIMMING LENS CAP N.V.G.
FOR MIL-P-7788 PANEL USE

SIZE	FSCM	DRAWING NO.	REV.
B	22973	141-305-00	B

SCALE 2x SHEET 1 OF 1



NOTES:
1) APPLICATION: USE THIS PART FOR MILATARY APPLICATION TO ELIMINATE I.R. SIGNATURE WITH SHIELD 3/8" X 1" WINDOW.
2) FOR USE WITH LARGE LAMPS
3) FINISH: FLAT BLACK
4) FILTER MATERIAL:
   (A) PHOSPHATE-FREE SILICATE GLASS.
   (B) SPECTRAL TRANSMITTANCE PROPERTIES:
      1. WAVELENGTH OF MAXIMUM TRANSMITTANCE 470-500 NM.
      2. TRANSMITTANCE AT THE MAXIMUM : GREATER THAN 40%
      3. TRANSMITTANCE BETWEEN 700-1200 NM LESS THAN 5% OF TOTAL EMISSION BETWEEN 400 AND 700 NM. (ACTUAL TRANSMITTANCE PER GB-SP020)
      4. PHOTOPIC TRANSMITTANCE WITH ILLUMINANT A (2854 DEG. K): 8-12%
   (C) CORROSION RESISTANCE: A POLISHED SAMPLE MUST PASS TRANSMITTANCE SPECIFICATIONS AFTER BEING SUBMITTEDTO HUMIDITY TEST DESCRIBED BY MIL-STD-810, METHOD 507, PROCEDURE I FOR AIRBORNE ELECTRONIC EQUIPMENT.
   (D) ULTRAVIOLET STABILITY: SHALL SHOW NO EFFECTS DUE TO EXPOSURE TO SUNLIGHT.

REV.	E.C.A. NO.	DATE	APPROVED

NEXT ASSEMBLY | USED ON

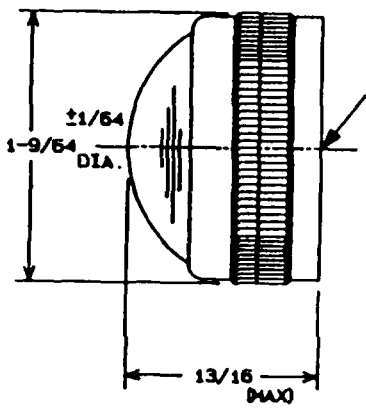
GLAR-BAN DIV.

TITLE: LARGE INDICATOR CAP LIGHT SHIELD I.R. SECURE

SIZE	FSCM	DRAWING NO.	REV.
B	22973	800-701-20	0

SCALE 2X | LEVEL 2 | SHEET 1 OF 1

REVISIONS			
REV.	E.C.R. NO.	DATE	APPROVED

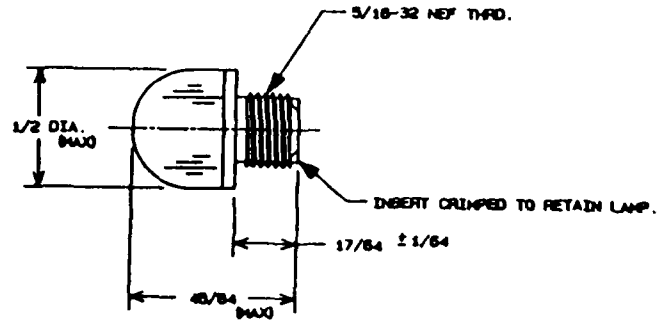


NOTES:

1) APPLICATION: USE THIS PART FOR MILITARY APPLICATION TO ELIMINATE I.R. SIGNATURE
2) FOR USE WITH LARGE LAMPS
3) FINISH: FLAT BLACK
4) FILTER MATERIAL:
   (A) PHOSPHATE-FREE SILICATE GLASS.
   (B) SPECTRAL TRANSMITTANCE PROPERTIES:
      1. WAVELENGTH OF MAXIMUM TRANSMITTANCE 470-500 NM.
      2. TRANSMITTANCE AT THE MAXIMUM : GREATER THAN 40%
      3. TRANSMITTANCE BETWEEN 700-1200 NM LESS THAN 5% OF TOTAL EMISSION BETWEEN 400 AND 700 NM. (ACTUAL TRANSMITTANCE PER GB-SP020)
      4. PHOTOPIC TRANSMITTANCE WITH ILLUMINANT A, (2854 DEG. K): 8-12%
   (C) CORROSION RESISTANCE: A POLISHED SAMPLE MUST PASS TRANSMITTANCE SPECIFICATIONS AFTER BEING SUBMITTEDTO HUMIDITY TEST DESCRIBED BY MIL-STD-810, METHOD 507, PROCEDURE I FOR AIRBORNE ELECTRONIC EQUIPMENT.
   (D) ULTRAVIOLET STABILITY: SHALL SHOW NO EFFECTS DUE TO EXPOSURE TO SUNLIGHT.

		DRAWN BY B.SHAFF 12/2/85	GLAR-BAN DIV.
		ENGINEER	
		QUAL. APPROVAL	TITLE: LARGE INDICATOR CAP I.R. SECURE
NEXT ASSEMBLY	USED ON		SIZE B | FSCM 22973 | DRAWING NO. 600-710-20 | REV. 0
			SCALE 2X | LEVEL 3 | SHEET 1 OF 1

REVISIONS			
REV.	E.C.A. NO.	DATE	APPROVED



NOTES:
1) APPLICATION: USE THIS PART FOR MILITARY APPLICATIONS TO ELIMINATE I.R. SIGNATURE.
2) USE LAMP TYPE (T-1 3/4) MIDGET FLANGE.
3) FILTER MATERIAL:
   (A) PHOSPHATE-FREE SILICATE GLASS.
   (B) SPECTRAL TRANSMITTANCE PROPERTIES:
      1. WAVELENGTH OF MAXIMUM TRANSMITTANCE 470-500 NM.
      2. TRANSMITTANCE AT THE MAXIMUM : GREATER THAN 40%
      3. TRANSMITTANCE BETWEEN 700-1200 NM LESS THAN 5% OF TOTAL EMISSION BETWEEN 400 AND 700 NM. (ACTUAL TRANSMITTANCE PER GB-SP020)
      4. PHOTOPIC TRANSMITTANCE WITH ILLUMINANT A, (2854 DEG. K): 8-12%
   (C) CORROSION RESISTANCE: A POLISHED SAMPLE MUST PASS TRANSMITTANCE SPECIFICATIONS AFTER BEING SUBMITTEDTO HUMIDITY TEST DESCRIBED BY MIL-STD-810, METHOD 507, PROCEDURE I FOR AIRBORNE ELECTRONIC EQUIPMENT.
   (D) ULTRAVIOLET STABILITY: SHALL SHOW NO EFFECTS DUE TO EXPOSURE TO SUNLIGHT.

NEXT ASSEMBLY	USED ON	DRAWN BY L.SWEP 12/2/85	GLAR-BAN DIV.
		CHECKED	
		ENGR. APPROVED	TITLE: INDICATOR CAP, I.R. SECURE DOME 5/16-32 THRD.
			SIZE B | FSCM 22973 | DRAWING NO. 800-101-20 | REV. 0
			SCALE 2X | WT. 1 | SHEET 1 OF 1

HOMELITE TEXTRON

Homelite Division of Textron Inc.

P O Box 7047
Charlotte, North Carolina 28217
704/588-3200

March 9, 1987

Mr. Noel D. Bishop
Department of the Army
US Army Belvoir Research
Development and Engineering Center
Fort Belvoir, VA 22060-5606

Dear Mr. Bishop:

We are in receipt of your Questionnaire for diesel engine driven generator sets, but are unable to complete it as we are a major manufacturer of gasoline only powered generators. The largest generators that Homelite manufactures is in the 5KW category.

If you should have future requirements for gasoline powered generators, please give me a call.

Sincerely,

Denise L. Collins

Denise L. Collins
Administrative Coordinator

DLC:dv

PAONE ASSOCIATES INC.
8032 Whitting Drive
Manassas, Virginia 22111

25 February 1 9[illegible]

Mr Noel D. Bishop
Chief, Power Equipment Support Team
Power Generation Division
US Army Belvoir Research, Development
and Engineering Center
Fort Belvoir, Virginia 22060-5606

Dear Mr. Bishop;

I would like to take this opportunity to thank you for the opportunity to respond to your questionnaire on power generating equipment.

After reviewing your questionnaire it is apparent that you are looking for responses from Hardware Manufacturers, which PAI is not.

We deal with IV&V, Testing, Operational Analysis, etc. and would welcome the opportunity to help you in those areas should you find a need.

Respectfully,

JOSEPH F. PAONE
President

VTEC LABORATORIES INC.

212 MANIDA ST. - BRONX, NEW YORK 10474 - (212) 542-8248

Mr. Noel Bishop
Chief, Power Equipment Support Team
Logistics Support Directorate
Dept. Of The Army
U.S Army Belvor Research, Development
and Engineering Center
Fort Belvoir, VA 22060-5606

Subject: IR and Acoustic Signature Reduction of DOD DED Generator Sets 5-100 kw Re: N.D Bishop Letter 17 Feb 87

Dear Mr. Bishop:

VTEC is in receipt of your questionanire on the above named topic. Unfortunately, all our information is proprietery and cannot openly be released. However, if a RFP or work becomes required in this area, VTEC would be very interested in quoting.

Very truly

Neil Schultz
Executive Director

16 March 1987
TL-EO-027

Commander
U.S. Army Belvoir Research Development & Engineering Center
Procurement Division
Fort Belvoir, Virginia 22060-5606

Attention: Mr. Noel Bishop, STRBE-FGP
Chief, Power Equipment Support Team
Logistics Support Directorate

Subject: Grumman Response to the Improved Generator Set Questionnaire

Enclosure: 1) "Response to the Improved Generator Set Questionnaire", TR-EO-008, 16 March 1987

References: a) "Improvement Program for Mobile Generator Sets", Grumman Sources Sought Letter AD-DIR-87-12, 13 February 1987

b) Your Questionnaire and letter to Jonas Bilenas, dated 17 February 1987

Dear Mr. Bishop:

As a follow-up to our Sources Sought letter (Reference a) and in response to your request (Reference b), we are pleased to submit, as Enclosure (1), Grumman's response to your Questionnaire regarding reliability improvements, noise reduction, and infrared suppression of U.S. Army's mobile generator sets.

Your RFP, as indicated in Reference (a), should be forwarded to corporate address listed above, to the attention J. Munger, Mail Station B41-05. Requests for technical information should be directed to the undersigned, Mail Station T02-05, telephone (516) 575-9538.

Very truly yours,
GRUMMAN AIRCRAFT SYSTEMS DIVISION

Jonas Bilenas

Dr. Jonas Bilenas
Countermeasures Projects Manager

DJB:lo
Enclosure

RESPONSE TO
THE IMPROVED GENERATOR SET QUESTIONNAIRE

Prepared by:

Grumman Aircraft Systems Division
Grumman Corporation
Bethpage, NY 11714

For:

Power Generation Division
U.S. Army Belvoir Research, Development, & Engineering Center
Fort Belvoir, VA 22060-5606

TR-EC-008
16 March 1987

GRUMMAN RESPONSE TO

THE IMPROVED GENERATOR SET QUESTIONNAIRE

QUESTION NO.1

Are you a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets? Please describe. _____

_____

If you manufacture other diesel engine driven equipment, what is the equipment? _____

_____

RESPONSE NO. 1

Although Grumman is not a manufacturer of Diesel Engine Driven (DED) generator sets or of major components(s) used on generator sets, we are interested, as outlined in Response No. 4, in the application of our reliability, noise and infrared (IR) suppression technologies to the improvement of Army's DED generator sets.

QUESTION NO. 2

What is an estimated average yearly usage for your equipment?

_____ What is the estimated operating cycle of your equipment (8 hours per day, 5 days per week, etc.)? Please describe.

_____

RESPONSE NO. 2

Not applicable (see Response No. 4).

QUESTION NO. 3

By what methods do you receive feedback from users on your equipment (application, engineering, sales, warranty replacements, etc.)? Please describe. _____

_____

RESPONSE NO. 3

Not applicable (see Response No. 4).

QUESTION NO. 4

If you are not a manufacturer, what is your position in the market place? Please furnish description. _____

_____

RESPONSE NO. 4

As a Department of Defense prime contractor and supplier of high performance aircraft and other weapon systems, the Grumman Corporation is committed to continued improvement in the survivability of aircraft and other military assets in a hostile environment. Therefore, we have participated in several efforts to evaluate and develop noise reduction, infrared suppression and reliability improvements for aircraft, land combat vehicles and mobile generator sets. In most instances, however, applications of these three technologies to the generator sets have not yet matured to the point where specific off the shelf components are available for purchase from catalogs with well defined cost, weight and performance characteristics. Nevertheless, Grumman's extensive experience in reliability, noise reduction, and IR suppression enables us to offer these technologies for application to the improvement of Army's mobile DED generator sets.

QUESTION NO. 5

The DoD generator sets, once in user hands, are operated outside, exposed to the elements in many parts of the world and are exposed to all climatic conditions. Their operating cycle may be around the clock, for extended periods, with short shut down intervals for servicing or they may sit idle, being operated only a few hours per month. The majority of our sets are trailer mounted on open trailers and during some field exercises they are frequently transported over roads ranging from highways to open cross country terrain. The sets are typically operated by soldiers primarily trained to operate other equipment such as radios, radar, trucks, etc. Typically they are maintained by trained repairmen with limited experience. If you are interested in the reliability portion of the program, please consider the above, look at the attached reliability tree and answer the following questions:

a. Based on your experience, what part(s) of the tree do you think you can improve? _____

_____

b. How much improvement do you think you can provide? _____

_____

c. Describe your approach for making the improvements. _____

_____

_____

d. Furnish a cost estimate for your program. _____

RESPONSE NO. 5a

Grumman, as leading system integrator and manufacturer, has a vast experience in the development and design of complex systems, performing reliability predictions; designing, tailoring and developing testing profiles; and the development of analytical techniques to identify failure modes and mechanisms. Grumman has an extensive failure analysis laboratory, staffed by reliability personnel. We routinely dissect components to uncover the cause of failures and to propose corrective actions. Our expertise in this area is applicable across-the-board to the whole design (reliability tree) of the Army's generator sets. Therefore, we can improve the current design by conducting indepth analysis of predominant field failures and develop appropriate corrective action in all parts of the reliability tree.

RESPONSE NO. 5b

The amount of improvement which can be provided is dependent upon a more detailed examination of the engine driven generator set which would be investigated during proposal preparation.

RESPONSE NO. 5c

- Perform circuit analysis in conjunction with cognizant electronic equipment engineering personnel to assure optimum selection and application of parts and circuits, including worst case study of component parameter variation and review of derating factors. An example where this applies is for the generator control system

- Review design to determine consequences of possible failures on the overall system operation, to uncover weak links in the design and develop appropriate corrective actions. This includes, utilization of existing handbook data for component reliability, and where appropriate supplementing this data from our extensive field data bank to improve current components utilized

- o In the structural area of our approach, we will highlight control of the operating environment through cooling/thermal control techniques, vibration isolation/attenuation, and humidity/water intrusion control

- o Consider imposing Environmental Stress Screening on selected items exhibiting infant mortality field failures and investigate the cost effectiveness by conducting a combined environment Test-Analyze And Fix (TAAF) assessment program

- o Conduct thermal analysis and/or thermal imaging tests using Grumman's Thermal Imaging System (TIS) to uncover hot spots and develop corrective action.

RESPONSE NO. 5d

Reliability cost estimate requires a detailed trade-off and costing of individual tasks, therefore it will be developed during our proposal effort.

QUESTION NO. 6

The generator set described in the attached figure is a typical military liquid cooled diesel engine driven generator set. It is designed so that the engine fan pulls air through the generator end for cooling the electrical apparatus as well as combustion air and cooling air for the engine. The air is discharged through thermostatically controlled louvers on the radiator end. the 120hp at 1800 RPM/6 cylinder turbocharged engine uses a 15hp standard four blade metal fan for moving the air. The engine muffler is located within the set housing and the engine exhaust is out the radiator end near the top. The generator is single bearing, four pole, with a synchronous speed of 1800 RPM. The engine generator set assembly uses a three point mounting, two generator feet and an engine trunnion mount, and is mounted directly to the skid base. The present noise level of the set is 87dBA at a 7 meter distance from the set. The set has a metal housing, with all bolted construction. The present housing and muffler offer very little sound attenuation. Considering the above, please answer the questions applicable to your area of interest.

a. Please describe your general approach for lowering the noise emitted from the set in any direction to 70 dBA at 7 meters. _____

_____

b. What would be your guesstimation of the set weight and dimensional increase required for your sound attenuation effort? _____

_____

c. Please describe your general approach for decreasing the infrared signature of the set. _____

_____

d. What would be your guesstimation of the set weight and dimensional increase required for decreasing the infrared signature of the set? _____

_____

e. If you are interested in both the sound and infrared reduction efforts, how do you foresee their interrelation? _____

_____

f. What would be your guesstimate of the net set weight and dimensional increase for both efforts? _____

_____

RESPONSE NO. 6a

Main sources of noise in a typical DED generator set include engine, exhaust gas discharge, air inlet and outlet, and air fans. Engine noise suppression requires vibration isolation by shock mounting the engine on the skid base. Engine body noise transmission requires acoustic treatment of housing walls. This will be implemented by designing wall acoustic insulation to reduce noise buildup and by use of damping tape on the housing skin panels. Exhaust gas discharge noise reduction requires a muffler or two mufflers in series with an expansion chamber. In a close-linked muffler case, a newer approach is to consider a noise cancellation or antinoise technology based on tuned speakers and microphones. Air inlet and outlet ducts must be acoustically lined with noise absorbing insulation and treated with a specially designed inner wall perforation patterns. Geometric configuration of inlet/outlet ducts also requires acoustically treated inner splitter plates and flow bends to prevent direct noise propagation through the air inlet/outlet openings. Radiator fan and generator fan noise levels depend on the blade shape, flow rate, static pressure and fan rpm. All of these variables require careful tradeoffs. During the design process, all noise suppression methods outlined above will be evaluated by Grumman analytical and experiment methods to ensure that the required 17 dBA noise reduction is achieved over the specified spectral bands in any direction at a 7 meter distance from the set.

RESPONSE NO. 6b

Generally, noise and IR suppression techniques are closely linked and characterized by some common components, as outlined in Response 6e. Therefore, combined impact on the set weight and dimensional envelope is addressed in Response 6f.

RESPONSE NO. 6c

Major IR signature components of a DED generator set are engine exhaust gas heating of external surfaces, engine exhaust hot parts, air discharge hot parts, and housing external IR contrast radiance. To

prevent engine exhaust gas impingement on the terrain or other adjacent surfaces, a horizontal or upper hemisphere discharge is generally preferred. Engine exhaust gas and air outlet discharge ports require either separate or combined IR suppressors. Grumman has extensive experience with many IR suppressor designs most of which require air cooling supplied by dedicated air fans and/or entrainment flow. In general, we prefer the so-called film cooling approach which provides relatively effective temperature control of hot surfaces and usually requires a fan characterized by a relatively low static pressure and a moderate flow capacity. External housing also requires thermal suppression to match housing radiance against the adjacent background radiance by minimizing the difference between housing and background apparent temperatures. Background thermal matching can be built into the housing or achieved by thermal camouflage which we are currently developing for the Belvoir Research, Development & Engineering Center. A number of IR suppression and background thermal matching techniques are unique Grumman inventions for which we hold patents and patent applications.

RESPONSE NO. 6d

There is a close interrelation between IR and noise suppression, as outlined in Response 6e. Therefore, combined impact on the set weight and dimensions is addressed in Response No. 6f.

RESPONSE NO. 6e

Hardware components of a combined noise and IR suppression design are interrelated and can be classified in accordance wih the following categories:

- Components common to both suppression modes and required for the common suppression purpose (e.g., common acoustic and thermal insulation of the generator set housing walls, overall engine exhaust system, overall air outlet duct, radiator fan, generator fan)

- o Thermal suppression components with impact on noise levels (e.g., engine exhaust IR suppressor and its air fan, air outlet IR suppressor and its fan, redesigned radiator/radiator fan, insulation over parts of engine and exhaust system, housing internal and/or external background thermal matching)

- o Noise suppression components with impact on thermal design (e.g., acoustically treated air inlet/outlet ducts, muffler discharge interface with engine exhaust IR suppressor)

- o Noise suppression components without impact on thermal design (e.g., engine vibration isolation).

RESPONSE NO. 6f

Although combined impact on the generator set weight and dimensional envelope is difficult to assess prior to the proposal effort, rough guesstimates are outlined below:

- o Several hundred pound net increase (about 10% of the baseline 4240 pound generator set weight) is expected due to new and redesigned components discussed in Response No. 6e

- o Optimistic dimensional guesstimate requires no expansion of the baseline envelope. Pessimistically, externally mounted air inlet elbow, air outlet silencer and a multispectral (visual, RF, IR) background thermal matching camouflage might be a result of tradeoffs between compactness, simplicity, and cost.

Grayarc

REPLY MESSAGE

REORDER ITEM # F269

TO

Dept. of the Army
U.S. Army Belvoir Research
Development & Engineering Center
Fort Belvoir, VA 22060-5606
Attn: Power Generation Division
Noel D. Bishop, Chief, Power Equipment Support Team

FROM

THE ELECTRIC TACHOMETER CORPORATION
68th And Upland Streets
PHILADELPHIA, PA 19142
Phone: (215) 726-7723 Telex 831-475 ELEC TACH PHA

SUBJECT: Your Letter Dated 2/17/87

DATE: 4/6/87

FOLD

Gentlemen:

In response to your letter of February 17 we apologize for not replying.

We have never manufactured generators of these larger types and really have no special suggestions for this application.

Very truly yours,
THE ELECTRIC TACHOMETER CORPORATION

T. J. Porter, President

TJP:pw

PLEASE REPLY TO → SIGNED

REPLY

DATE: SIGNED

Item # F269 © Wheeler Group Inc 1979

THIS COPY FOR PERSON ADDRESSED

Electric Company, Inc.

March 23, 1987

Noel D. Bishop
Chief, Power Equipment Support Team
Power Generation Division
Department of the Army
U.S. Army Belvoir Research & Development
Fort Belvoir, VA 22060-5606

Dear Mr. Bishop:

Lima as an independent manufacturer of electrical prime power alternators will primarily be interested in working with the military in terms of state-of-the-art technology offering improvements in reliability of design and performance over the existing DOD MEP generators used in the current MEP gen-set family.

Lima's activities with the DOD through past years have primarily been as subs teamed with prime contractors beginning with the design of the existing 100 and 200 KW alternators and currently providing commercial products for installations by the U.S. Coast Guard, Rock Island Contract Maintenance Vehicles, NASA, and commercial product military installations.

Enclosed is reliability data on the existing Lima line of generators as prepared for the past SSDED program along with typical service and maintenance manual to be used at your discretion.

Lima looks forward to being part of developing the new DED generator family.

Sincerely,

Michael Spees

Michael Spees
Marketing Manager

kb

LIMA ELECTRIC COMPANY, INC. P.O. BOX 918 LIMA OHIO 45802 419/227-7327 TELEX 242433

QUESTIONNAIRE

1. Are you a manufacturer of diesel engine driven generator sets or of major component(s) used on generator sets? Please describe. Manufacturer of major components - i.e. electrical generators 5-375kW A.C.

If you manufacture otner diesel engine driven equipment, what is the equipment? D.C. generators 5-300kW

2. What is an estimated average yearly usage for your equipment? 5000-7000 pcs. What is the estimated operating cycle of your equipment (8 hours per day, 5 days per week, etc.)? Please describe. continuous duty alternators are rated for 8 hours per day use, 365 days per year.

3. By what methods do you receive feedback from users on your equipment (application, engineering, sales, warranty replacements, etc.)? Please describe. Directly through O.E.M. equipment manufacturers and gen-set assemblers

4. If you are not a manufacturer, what is your position in the market place? Please furnish description.

5. The DoD generator sets, once in user hands, are operated outside, exposed to the elements in many parts of the world and are exposed to all climatic conditions. Their operating cycle may be around the clock, for extended periods, with short shut down intervals for servicing or they may sit idle, being operated only a few hours per month. The majority of our sets are trailer

mounted on open trailers and during some field exercises they are frequently transported over roads ranging from highways to open cross country terrain. The sets are typically operated by soldiers primarily trained to operate other equipment such as radios, radar, trucks, etc. Typically they are maintained by trained repairmen with limited experience. If you are interested in the reliability portion of the program, please consider the above, look at the attached reliability tree and answer the following questions:

a. Based on your experience, what part(s) of the tree do you think you can improve? Lima Electric's expertise would be in improving generator reliability. Standard Lima commercial product is exposed to operate in extreme adverse environments from irrigation and water spray to over the road refrigeration and in unattended extended operational periods such as U.S. Coast Guard unattended light-house buoys.

b. How much improvement do you think you can provide? see Lima reliability data as enclosed & relevant to current standard commercial designs.

c. Describe your approach for making the improvements. _____

d. Furnish a cost estimate for your program. _____.

6. The generator set described in the attached figure is a typical military liquid cooled diesel engine driven generator set. It is designed so that the engine fan pulls air through the generator end for cooling the electrical apparatus, as well as combustion air and cooling air for the engine. The air is discharged through thermostatically controlled louvers on the radiator end. The 120hp at 1800 RPM/6 cylinder turbocharged engine uses a 15hp standard four blade metal fan for moving the air. The engine muffler is located within the set housing and the engine exhaust is out the radiator end near the top. The generator is single bearing, four pole, with a synchronous speed of 1800 RPM.

The engine generator set assembly uses a three point mounting, two generator feet and an engine trunnion mount, and is mounted directly to the skid base. The present noise level of the set is 87dBA at a 7 meter distance from the set. The set has a metal housing, with all bolted construction. The present housing + muffler offers very little sound attenuation. Considering the above, please answer the questions applicable to your area of interest.

a. Please describe your general approach for lowering the noise emitted from the set in any direction to 70 dBA at 7 meters. Sound attenuation is primary concern for the engine and the enclosure. The electric generator is basically "silent" when compared to other major components. Sound attenuation should basically be addressed to set assemblers and enclosure manufacturers.

b. What would be your guesstimation of the set weight and dimensional increase required for your sound attenuation effort? _____

_____

c. Please describe your general approach for decreasing the infrared signature of the set. _____

_____

_____.

d. What would be your guesstimation of the set weight and dimensional increase required for decreasing the infrared signature of the set? _____

_____

_____.

e. If you are interested in both the sound and infrared reduction efforts, how do you foresee their interrelation? _____

_____

_____.

f. What would be your guesstimate of the net set weight and dimensional increase for both efforts? _____

_____.

The Lima Electric Co., Inc.
P.O. Box 918
Lima, OH 45802
(419) 227-7327
TLX 24-2438 LIMA ELEC LIM

RELIABILITY / SERVICE / MAINTENANCE

A.C. SYNCHRONOUS ALTERNATORS

Lima Electric Company proposed state of the art generators proposed for this solicitation consist of 100% existing in-service commercial components. In light of this feature, field proven reliability substanciates no maintenance checks are required under standard operating conditions until a minimum of 5000 hours of operation. Initial maintenance requirements are generally not required until a minimum of 10,000 hours operation.

ELECTRICAL WINDINGS

Under normal operating conditions all electrical windings will provide 30,000 hours insulation life. Preventative maintenance checks of insulation resistance by meggering the main stator, main rotor, exciter stator, and exciter rotor windings should be performed every 5,000 hours. The megohommeter used should measure the resistance between any one of the windings mentioned and ground. Readings below one (1) meg/ohm would require steam cleaning, re-dipping, baking, or replacing of the item in question. This measure is merely preventative and as mentioned windings under normal conditions provide 30,000 hours insulation life.

BEARING

If major maintenance is performed on the engine at 5,000 hours it is recommended that the alternator bearing be changed out. When engine maintenance is not required the bearing should only be changed every 10,000 hours of operation or 3 years service, whichever comes first.

RECTIFIER ASSEMBLY

The electrical rectifier assembly under normal operating conditions should never require replacement. The component diodes would only require replacement upon system failure.

Maintenance of electrical windings, bearings, and the rectifier assembly can be prevented by operating Lima's electrical alternators under the conditions which are compatible with those at which the equipment was designed to operate. Additional installation, operation, wiring diagrams, and maintenance instructions for Lima alternators may be found in the 3600S manual included with this quotation.

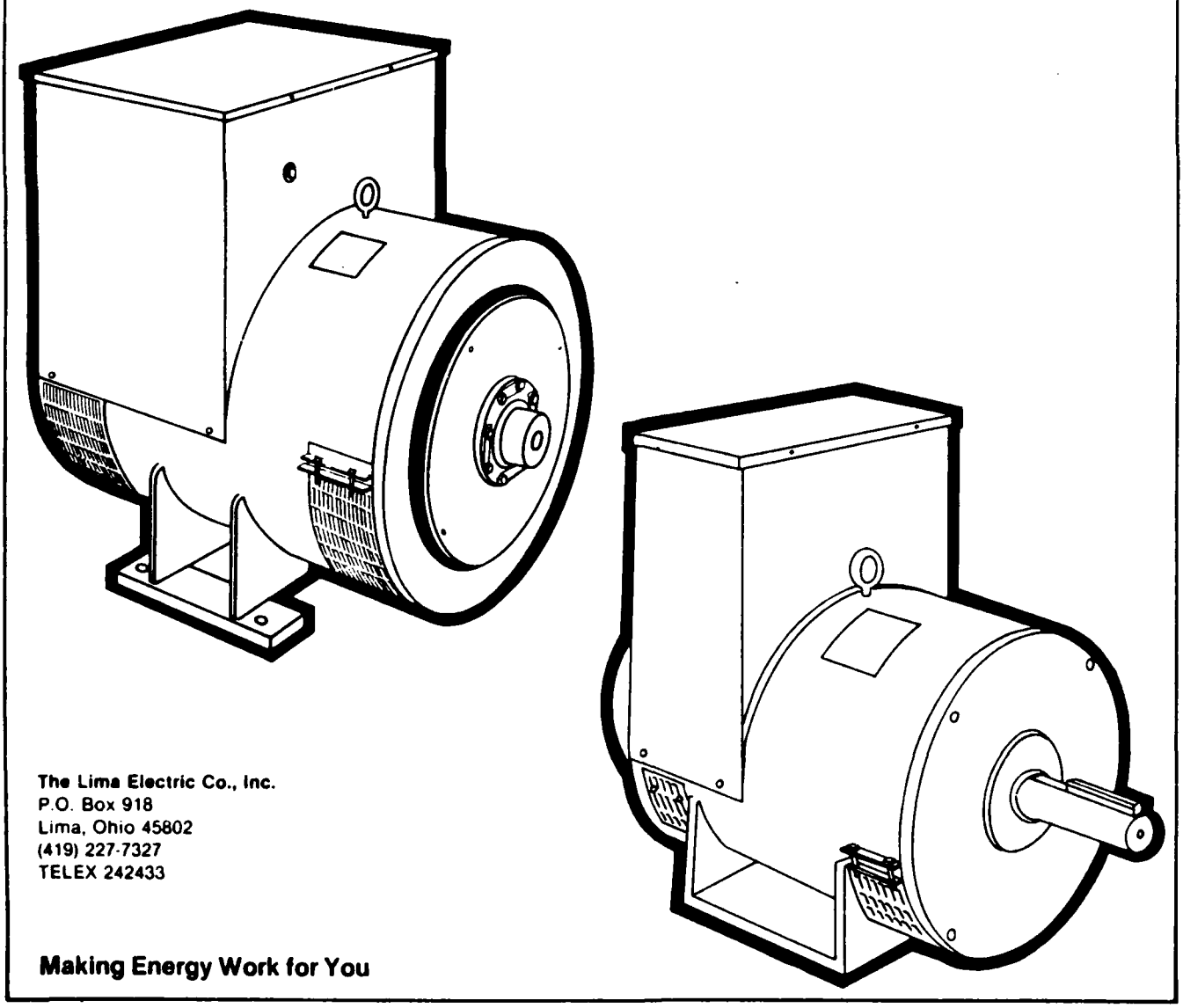
as prepared for the past SSDED Program

Lima® Electric Company, Inc.

3600S
485

INSTALLATION, OPERATION AND MAINTENENCE MANUAL

TYPE SER Brushless AC Synchronous, Externally Regulated Alternator
Frame 361, 441—1200/1000 RPM
Frame 360, 440, 580, 680, 680x—1800/1500 RPM



The Lima Electric Co., Inc.
P.O. Box 918
Lima, Ohio 45802
(419) 227-7327
TELEX 242433

Making Energy Work for You

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Maintenance 7
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THE LIMA ELECTRIC CO., INC.
TYPE SER INSTRUCTION MANUAL — FRAMES 360 THROUGH 680X

NOTICE
The following instructions are essential to assure the proper installation, operation, and maintenance of the alternator, and for the safety of operating and service personnel. Installation and maintenance should be performed only by qualified personnel in strict observance of procedures and safety measures set forth in this manual.

All electrical connections should be made in accordance with current government, industry, association codes and standards. Grounding (earthing) of this alternator should be in strict accordance with the National Electrical Code (NFPA 70), or the appropriate electrical code or standard having jurisdiction at the installation site.

Mechanical connections and assembly should be made with grade 5 or better hardware and fasteners.

SECTION I
GENERAL INFORMATION

INCOMING INSPECTION
Immediately upon receipt of your LIMA Alternator check for damage to housing, windings, and mechanical parts. Shipping damage claims must be instituted through the carrier, and must be made within the time limit specified by ICC regulations.

STORAGE
Alternators should be stored in a clean, dry place, not subject to rapid and severe changes in temperature and humidity. If humid storage conditions cannot be avoided, the unit should be warmed and dried prior to installation and test.

DRYING
It may be necessary to thoroughly dry the alternator windings prior to placing into service at full nameplate voltage in order to prevent damage to the unit. This is especially true if the unit has been: (1) Stored or left idle for extended periods of time in humid atmospheres; (2) subjected to wide temperature variations in storage or transit.

Drying can be accomplished by putting the alternator in a hot, dry room, or by circulating hot, dry air across the windings for a period of at least 4 hours.

Drying can also be accomplished more quickly by following the "Short Circuit" method after the unit has been installed on the engine as follows:

A. Short the alternator output leads L1, L2, L3. Apply a clamp-on ammeter to these leads. The ammeter must have a minimum range equal to the full load nameplate current of the alternator.
B. Disconnect the voltage regulator input power leads.
C. Remove the exciter field leads F+ and F− from the voltage regulator, and connect them to a variable DC power source of approximately 35VDC, 2 amperes or greater capacity. Observe polarity.
D. Start the engine and adjust the DC voltage source to an amperage not to exceed nameplate current rating at any time. Drying time will vary with moisture conditions. Properly dried windings will be indicated by megohmmeter readings across the exciter field leads F+ and F−, and each leg of the alternator L1, L2, L3 to neutral according to the following formula:
(Nameplate Voltage + 1000) + 1 = Min. Acceptable Megohm Reading.

CAUTION
Completely disconnect the automatic voltage regulator and output wiring prior to taking any megohm readings. Take all readings across the alternator and field leads themselves. Failure to do this may result in damage to the automatic voltage regulator or connected equipment.

DIRECTION OF ROTATION
The units covered by this manual may be operated with shaft rotation in either a clockwise, or counter-clockwise direction.

PHASE ROTATION
All LIMA three phase alternators have "A B C" phase rotation with the alternator shaft turning in a counter-clockwise direction when viewed from the end opposite the drive end. Should this phase rotation be improper for the application, reverse output load leads "L1" and "L2" at the circuit breaker.

PARALLEL OPERATION
All LIMA TYPE SER alternators are built with shorted damper (Amortisseur) windings for good paralleling and transient performance, and are designed with a two thirds pitch in the main stator winding. For proper parallel operation, the automatic voltage regulator must be equipped with paralleling circuitry such as a paralleling module, and a paralleling current transformer (C/T) installed in one phase lead — usually the "B" phase of three phase alternators. Paralleling of single phase units require special considerations. Consult with the factory prior to attempting to parallel units connected for single phase operation.

NOTE
When attempting to parallel this unit with one built by some other manufacturer, especially if the units are connected in a Wye (Star) connection with grounded neutrals, consult with the manufacturer of the other machine to assure compatability. Failure to do this could lead to high "third harminic' currents in the neutral, and possible over heating of both units.

SECTION II
ASSEMBLY OF THE ALTERNATOR TO THE PRIME MOVER

CAUTION: DISABLE OR RENDER INOPERATIVE ANY ENGINE CRANKING DEVICES BEFORE ATTEMPTING TO INSTALL OR SERVICE THIS ALTERNATOR. FOR ELECTRIC START SETS, DISCONNECT THE CRANKING BATTERY. FOR AIR START, DISCONNECT AIR SUPPLY. FAILURE TO COMPLY WITH THESE SAFETY PROCEDURES COULD RESULT IN SEVERE INJURY TO PERSONNEL OR DAMAGE TO EQUIPMENT.

CAUTION: LIFT THE UNIT ONLY BY THE PROPER LIFTING LUGS. FRAME 360 UNITS ARE PROVIDED WITH A SINGLE "EYE BOLT" LIFTING EYE. INSURE THAT THE EYE BOLT IS TIGHTLY THREADED IN THE FRAME PRIOR TO ATTEMPTING TO LIFT THE UNIT. 440 AND LARGER FRAMES ARE PROVIDED WITH TWO LIFTING LUGS WELDED TO THE FRAME. INSURE THAT LIFTING DEVICES HAVE ADEQUATE CAPACITY. SAFE PRACTICE CALLS FOR CAPACITY TO BE AT LEAST ONE AND ONE HALF TIMES THE LOAD TO BE LIFTED. IF IN DOUBT, CONSULT THE FACTORY FOR UNIT WEIGHT.

CAUTION: NEVER "BAR OVER" THE ENGINE-GENERATOR SET USING THE GENERATOR'S FAN AS A FULCRUM. FAN MATERIAL IS LIGHT WEIGHT ALUMINUM AND NOT DESIGNED FOR THIS PURPOSE. BARRING OVER THE SET WITH THE FAN COULD DAMAGE THE FAN AND RESULT IN SERIOUS INJURY TO PERSONNEL AND POSSIBLE SEVERE DAMAGE TO EQUIPMENT.

TORSIONAL VIBRATION
Torsional vibrations will be generated in all engine driven shaft systems to some degree. In some cases the magnitude of these vibrations at certain critical speeds may cause damage to either the alternator or its driver, or both. It is therefore necessary to examine the torsional vibration effect on the entire rotating system. It is the responsibility of the generator set manufacturer/assembler to assure the torsional compatability of the alternator and its driver. The Lima Electric Co., Inc. will make available drawings showing all pertinent shaft dimensions, coupling details, rotor weights, locations, and inertias for the customer to forward to the engine manufacturer for analysis.

SINGLE BEARING UNITS

A. The flexible disc couplings supplied with your alternator are sized and drilled to match standard SAE industrial engine flywheels. The frame engine ring is machined and drilled to match standard SAE industrial engine flywheel housings.
B. Loosely bolt the disc coupling to the engine flywheel using flat washers. **DO NOT USE LOCK WASHERS** for this purpose.
C. Loosely bolt the alternator frame engine ring to the engine flywheel housing. Insure that the alternator's engine ring register (lip) is properly seated inside the engine flywheel housing.
D. Insure that the flex discs are properly seated in the flywheel pilot bore. Tighten all bolts in rotation, making sure that the bolts are of the proper length so that they will not "Bottom Out" and prevent a secure coupling. Torque bolts to tension proper for the size, type and grade being used.
E. Shim under the alternator feet as necessary to assure proper alignment of the alternator frame with the engine so that tightening the alternator foot bolts will not result in placing a prestress on either the alternator engine ring, or the engine flywheel housing.

TWO BEARING UNITS

A. The shaft extension and keyway on two bearing units can be used with either a direct coupling adaptor, or belt driven with sheaves. For the latter, it is important that both the drive and driven sheave diameters are matched to assure proper running speed of the alternator.

ENDPLAY TEST PROCEDURE (ALL UNITS)

A. After the alternator is installed with the prime mover, check for proper endplay. Using a suitable lever, force the engine flywheel forward so that the crankshaft is pressed against its thrust bearing. When force is released, the engine crankshaft should remain in this position.
B. Apply force in the opposite direction and observe that the crankshaft again remains stationary.
C. If the crankshaft springs away from either thrust bearing when force is removed, it is an indication that the alternator shaft is not moving freely in the assembly, and normal life of the engine thrust bearings could be impaired.
D. Probable causes are:
   (1) Improper "G" dimension on either the alternator or the engine;
   (2) Improper seating of the drive discs in the engine flywheel;
   (3) Improper mating of the alternator and flywheel housings, or;
   (4) The alternator bearing is bottoming out in the bearing bracket.
E. Refer to the engine manual for recommended end play. Frequently, it will be in the range of 0.007" to 0.015".

SECTION III
ELECTRICAL WIRING PROCEDURES — WIRING DIAGRAMS

CAUTION

> Wiring of the alternator should be done in accordance with good electrical practices. Follow government, association and industry standards. In some wiring arrangements, groups of terminals are connected together with no further termination. These terminals must be properly insulated to avoid a hazard to personnel and potential equipment damage.

LIMA alternators are supplied in 4-lead, 10-lead, or 12-lead configurations. From the nameplate information and system voltage requirements, select the appropriate wiring diagram from the information that follows.

Note C-1: Some models intended for 4-wire WYE connection may be equipped with bus bar termination. Diagram "A" applies to these units.

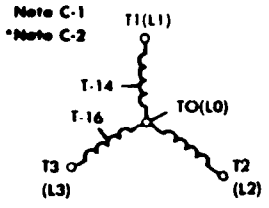
***Note C-2:** Certain 480 V, 4-lead units are supplied with two winding legs centertapped (T-14, T-16) to provide 240 V, 1-phase input power to the automatic voltage regulator. All other 4-lead, WYE connected units will require the addition of a power isolation transformer to obtain 240 V, 1-phase power for AVR operation.

WIRING REFERENCE CHART

	CONFIGURATION	SER TYPE ADJUSTABLE VOLTAGE RANGE (60 HZ)	REF. DIAG
3 PHASE	4-Lead Unit, Wye Connected	416-480 V	A
	4-Lead Unit, Wye Connected	575-600 V	A
	4-Lead Unit, 480 Volt Delta Connected	440-480 V	B
	12-Lead Unit, 4-Wire 240 Volt Delta Connected	220-240 V	C
	12-Lead Unit, High Voltage Wye Connected	416-480 V	D
	12-Lead Unit, Low Voltage Wye Connected	208-240 V	E
	10-Lead Unit, High Voltage Wye Connected	416-480 V	F
	10-Lead Unit, Low Voltage Wye Connected	208-240 V	G
1 PHASE	12-Lead Unit, Low Voltage Delta	110-120 V	H
	12-Lead Unit, 240 Volt, Zig Zag	220-240 V	I
	12-Lead Unit, 480 Volt, Zig Zag	416-480 V	J

DIAGRAM A

4-Lead Unit, 480 or 600 Volt, Wye Connected, 3 Phase

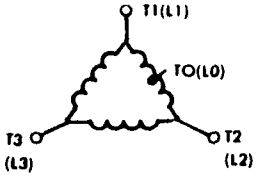


OUTPUTS:	480 V	600 V
L1 to L2	480 V. 3Ø	600 V. 3Ø
L2 to L3	480 V. 3Ø	600 V. 3Ø
L1 to L3	480 V. 3Ø	600 V. 3Ø
L1 to L0	277 V. 1Ø	346 V. 1Ø
L2 to L0	277 V. 1Ø	346 V. 1Ø
L3 to L0	277 V. 1Ø	346 V. 1Ø

CAUTION: Properly insulate all unused terminations

DIAGRAM B

4-Lead Unit, 480 Volt, Delta Connected, 3 Phase

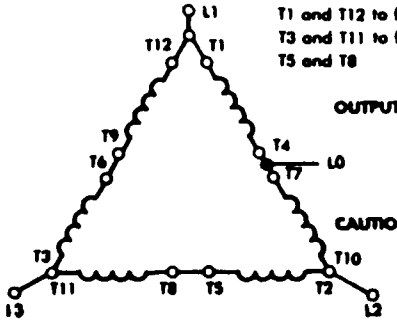


OUTPUTS:	240 V. 1Ø	480 V. 3Ø
	L1 to L0	L1 to L2
	L2 to L0	L2 to L3
		L1 to L3

CAUTION: Properly insulate all unused terminations

DIAGRAM C

12-Lead Unit, 240 Volt, Delta Connected, 3 Phase



Connect the following sets of terminations.

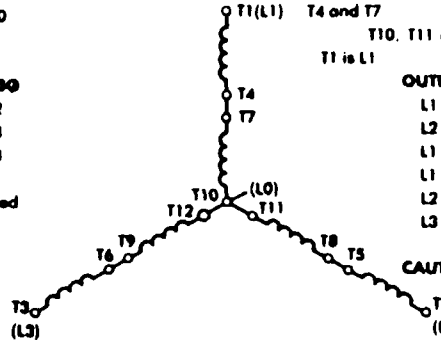
T1 and T12 to form L1 T2 and T10 to form L2
T3 and T11 to form L3 T4 and T7 to form L0
T5 and T8 T6 and T9

OUTPUTS:	120 V. 1Ø	240 V. 3Ø
	L1 to L0	L1 to L2
	L2 to L0	L2 to L3
		L1 to L3

CAUTION: Properly insulate all unused terminations

DIAGRAM D

12-Lead Unit, High Voltage, Wye Connected, 3 Phase



Connect the following sets of terminations.

T4 and T7 T5 and T8 T6 and T9
T10, T11 and T12 to form L0
T1 is L1 T2 is L2 T3 is L3

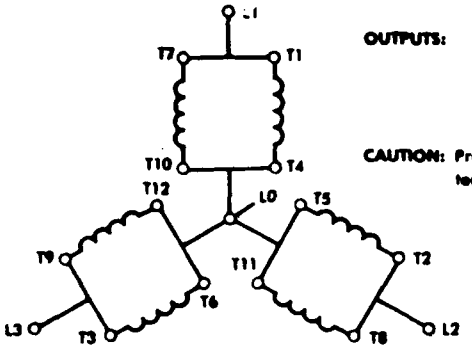
OUTPUTS:	416 V	480 V
L1 to L2	416 V. 3Ø	480 V. 3Ø
L2 to L3	416 V. 3Ø	480 V. 3Ø
L1 to L3	416 V. 3Ø	480 V. 3Ø
L1 to L0	240 V. 1Ø	277 V. 1Ø
L2 to L0	240 V. 1Ø	277 V. 1Ø
L3 to L0	240 V. 1Ø	277 V. 1Ø

CAUTION: Properly insulate all unused terminations

DIAGRAM E
12-Lead Unit, Low Voltage, Wye Connected, 3 Phase

Connect the following sets of terminations:

T1 and T7 to form L1 T2 and T8 to form L2
T3 and T9 to form L3
T4, T5, T6, T10, T11 and T12 to form L0



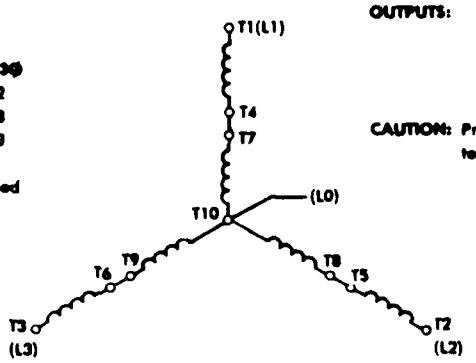
OUTPUTS:	120 V. 1Ø	208 V. 3Ø
	L1 to L0	L1 to L2
	L2 to L0	L2 to L3
	L3 to L0	L1 to L3

CAUTION: Properly insulate all unused terminations

DIAGRAM F
10-Lead Unit, High Voltage, Wye Connected, 3 Phase

Connect the following sets of terminations:

T4 and T7 T5 and T8 T6 and T9
T1 is L1 T2 is L2 T3 is L3



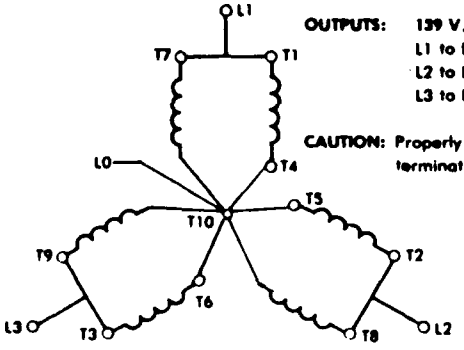
OUTPUTS:	277 V.1Ø	480 V. 3Ø
	L1 to L0	L1 to L2
	L2 to L0	L2 to L3
	L3 to L0	L1 to L3

CAUTION: Properly insulate all unused terminations

DIAGRAM G
10-Lead Unit, Low Voltage, Wye Connected, 3 Phase

Connect the following sets of terminations:

T1 and T7 to form L1 T2 and T8 to form L2
T3 and T9 to form L3
T4, T5, T6 and T10 to form L0



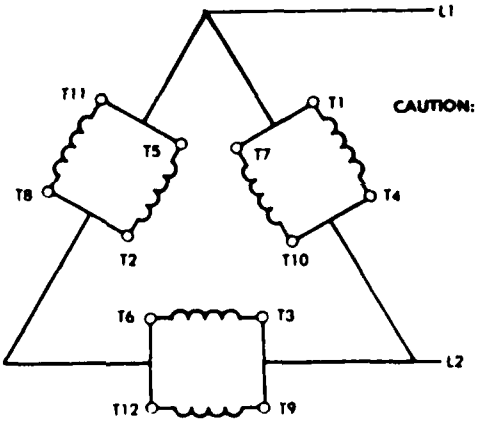
OUTPUTS:	139 V. 1Ø	240 V. 3Ø
	L1 to L0	L1 to L2
	L2 to L0	L2 to L3
	L3 to L0	L1 to L3

CAUTION: Properly insulate all unused terminations

DIAGRAM H
12-Lead Unit, Low Voltage, Delta Connected, 1 Phase

Connect the following sets of terminations:

T2, T8, T6, T12 and Insulate
T1, T5, T7, T11 to form L1
T3, T4, T9, T10 to form L2



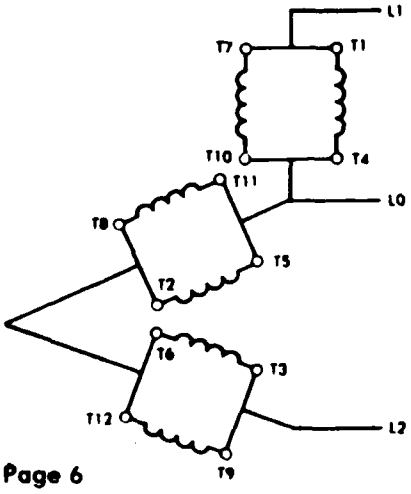
OUTPUTS:	120 V. 1Ø
	L1 to L2

CAUTION: Properly insulate all unused terminations

DIAGRAM I
12-Lead Unit, 240 Volt, Zig Zag, 1 Phase

Connect the following sets of terminations:

T2, T8, T6, T12 and Insulate
T1, T7, to form L1
T3, T9, to form L2
T4, T10, T5, T11 to form L0



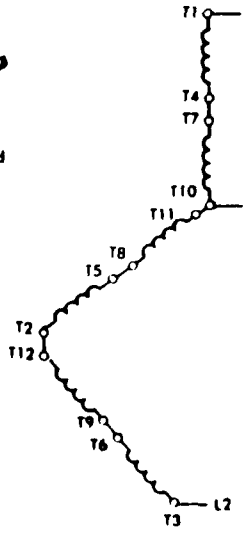
OUTPUTS:	120 V. 1Ø	240 V. 1Ø
	L1 to L0	L1 to L2
	L2 to L0	

CAUTION: Properly insulate all unused terminations

DIAGRAM J
12-Lead Unit, 480 Volt, Zig Zag, 1 Phase

Connect the following sets of terminations

T4 and T7 T2 and T12 T6 and T9 T5 and T8
T10, T11 to form L0
T1 is L1 T3 is L2



OUTPUTS:	240 V. 1Ø	480 V. 1Ø
	L1 to L0	L1 to L2
	L2 to L0	

CAUTION: Properly insulate all unused terminations

SECTION IV
START-UP AND SHUT-DOWN PROCEDURES

START-UP — IMPORTANT

Review alternator wiring diagrams for proper connection. Review voltage regulator and accessory manuals to insure that these devices are properly installed and connected. Make sure exciter field leads (F+ and F−) are connected in proper polarity at the voltage regulator.

A. Insure that the main line circuit protector is **OPEN** and that no external load is on the machine. If the voltage regulator is equipped with an ON/OFF switch or a FIELD CIRCUIT BREAKER, set the device to its OFF or OPEN position.

B. Reconnect and energize starting power to the prime mover. Adjust running speed and governor so the alternator is running at nameplate RPM.

C. With the regulator "off" output voltage will be approximately ¼ normal. This "residual voltage" is provided by the residual magnetism of the exciter stator. Read all voltages — line to line and line to neutral to check for equal and balanced values. If the unit has been improperly connected, unbalanced voltages will result. In this case, shut the unit down and correct any improper connections. **Energizing the regulator with the unit improperly connected could result in damage to the unit.**

D. Once checks listed in sub-paragraph C above are satisfactorily completed indicating proper connections, turn the regulator switch to the "ON" position and adjust the alternator's output voltage to the desired level according to the regulator manufacturer's operating manual.

NOTE

It is quite possible to observe a "no voltage" condition upon start-up due to a loss of residual magnetism in the exciter field during transit, storage or under certain electro-mechanical conditions. If no output is observed, shut-down the system and refer to the PROCEDURE FOR FLASHING FIELD (Sec. VI 1.) of the Disassembling and Servicing section of this manual.

SHUT-DOWN

There are no specific instructions for alternator shut-down, but several practices should be observed to prolong equipment life.

A. It is advisable to disconnect all loads prior to shut-down. This is especially important if loads can be damaged by low voltage and frequency conditions during alternator "wind down."

B. If at all possible, shut off the voltage regulator before shut-down.

C. Isolate any conditions that would cause the alternator to see an input voltage at its terminals. Failure to do this could result in rectifier damage.

SECTION V
MAINTENANCE

GENERAL

A. LIMA alternators use "lubricated for life" bearings and do not require maintenance beyond the good housekeeping practices that follow.

CAUTION: PRIOR TO CONDUCTING ANY MAINTENANCE OR SERVICE, OPEN MAIN DISCONNECT SWITCH. LOCK IT IN THE "OFF" POSITION IF POSSIBLE. PREVENT INADVERTENT START-UP OF THE PRIME MOVER, LOCALLY OR BY REMOTE CONTROL. SAFE PRACTICE CALLS FOR DISCONNECTING THE BATTERY, OR DISABLING ALTERNATE STARTING CIRCUITS OR DEVICES.

B. Periodically inspect ventilating screens for dust and dirt accumulation. Keep vents clear.

C. Periodically inspect windings for accumulation of dust, dirt, oil or moisture. Oil deposits should be removed with an approved solvent.

D. Periodically inspect terminal connections for tightness. Check terminals, voltage regulator and accessories for dirt and other conditions that could contribute to leakage or arcing.

E. Periodically check the prime mover and governor for proper RPM and the alternator for rated output.

F. Check ground straps for tight connection and good conductivity.

TROUBLE SHOOTING

Most field trouble shooting can be performed with a volt-ohmmeter, battery/light continuity tester, soldering iron, and conventional hand tools. Note that certain tests of shorted windings can only be performed with a Wheatstone, Kelvin or other bridge resistance tester. Disassembly and service instructions are contained in Section VI of this manual.

TROUBLESHOOTING

Most troubleshooting in the field can be performed with a multimeter, soldering iron and conventional hand tools. Note that certain tests for open or shorted windings can only be verified with a megohmmeter or bridge resistance tester. Disassembly and service instructions follow the troubleshooting chart.

TROUBLESHOOTING CHART

CAUSE	CHECK AND REMEDY
NO VOLTAGE OUTPUT	
Loss of residual magnetism in the exciter.	Flash the exciter field. See next section.
Open circuit in exciter field.	Check continuity. If open, return to factory for repair.
Open stator windings.	Check continuity. If open, return to factory for repair.
Faulty rectifiers.	Check per instructions that follow. Replace if faulty.
Malfunction of automatic voltage regulator.	See AVR manual. Replace if faulty.
Short circuit.	Check all leads and clear fault.
Open in main field coil.	Check continuity. If open, return to factory for repair.
Shorted exciter rotor.	Check for short with bridge-type resistance meter.
Grounded exciter rotor.	Check insulation to ground with megohmmeter after disconnecting AVR and rectifier assembly.
Shorted leads between exciter rotor and main field.	Test and repair.
LOW VOLTAGE OUTPUT	
Low rheostat setting.	Adjust to rated output.
Excessive load.	Reduce load. Balance all loads to as near equal as possible. Do not exceed rated current on any leg.
Low RPM.	Check engine and governor. Check system for overload.
Automatic Voltage Regulator.	See AVR manual. Replace if faulty.
Insufficient excitation.	Check regulator. Replace if faulty.
Line losses.	Use larger line wiring.
High resitance connections.	Check for warm or hot connections. Restore good connections.
Shorted main or exciter field.	Check main field with a bridge-type meter. Check exciter field with ohmmeter for approximately 17 ohms for parallel field and 35 ohms for series field. Return to factory for repair.
Low power factor.	Redue inductive (motor) load. (Some AC motors draw nearly the same current regardless of load. Do not use motors rated larger than necessary to carry the mechanical load.)

TROUBLESHOOTING CHART (Continued)

CAUSE	CHECK AND REMEDY
HIGH VOLTAGE OUTPUT	
High rheostat setting.	Adjust to rated output.
High RPM.	Check engine and governor.
Automatic Voltage Regulator.	See AVR manual. Replace if faulty.
FLUCTUATING VOLTAGE	
Irregular engine speed.	Check engine and governor.
Fluctuating load.	Stabilize load.
Loose connections.	Check alternator and load connections. Restore good connections.
Unstable voltage regulator.	See AVR manual. Replace if faulty.
Intermittent short in exciter field.	Check with ohmmeter for approximately 17 ohms for parallel field and 35 ohms for series fields. Return to factory for repair.
Uneven air gap.	Measure stator/rotor clearance at several points. Suspect bearing(s) drive discs, flywheel, flywheel housing or alternator frame if clearances are uneven.
OVERHEATING	
Excessive load.	Check with ammeter and compare with nameplate. Reduce load.
Clogged vent openings.	Clear air passages.
Environmental conditions.	Improve ventilation and air circulation.
Low power factor.	Reduce inductive loads or install capacitors to improve power factor.
Unbalanced load.	Strive for balanced load on each leg. Do not exceed rated current on any leg.
Dry bearing.	Replace bearing.
MECHANICAL NOISE	
Defective bearing(s).	Replace.
Rotor rubbing on stator.	Bad bearing(s); replace. Bent shaft; return to factory. Loose endbell; tighten. Loose drive discs: tighten.
Loose or misaligned coupling.	Align and tighten.
ALTERNATOR PRODUCES SHOCK WHEN TOUCHED	
Static charge.	Ground alternator frame.
Grounded stator or field coil.	Check with megohmmeter AFTER DISCONNECTING AVR. Return to factory for repair.

SECTION VI
DISASSEMBLY AND SERVICING

CAUTION: BEFORE SERVICING, MAKE CERTAIN THAT THE ALTERNATOR IS ISOLATED FROM ANY OTHER VOLTAGE SOURCE, AND THAT THE ENGINE OR OTHER PRIME MOVER CANNOT BE STARTED, EITHER LOCALLY OR REMOTELY. IT IS URGED THAT THE BATTERY OR STARTING SOURCE BE REMOVED FROM THE PRIME MOVER, OR AT LEAST RENDERED INOPERABLE.

RESTORING RESIDUAL MAGNETISM (FLASH NG THE EXCITER FIELD).
To restore the small amount of residual magnetism necessary to begin the voltage build-up, connect a 6 to 32 volt battery to the exciter field circuit. Normally a 6 to 12 volt DC source will be adequate to restore the excited field's residual magnetism.

A. Remove exciter leads F+ and F− from F+ and F− terminals of the voltage regulator. CAUTION: Failure to remove these leads may destroy the voltage regulator if the battery connections are reversed.
B. Connect the positive battery pole to lead F+.
C. Connect the negative battery pole to the negative (F−) terminal on the voltage regulator FOR APPROXIMATELY THREE TO FIVE SECONDS.
D. Reconnect the (F+) and (F−) leads to the automatic voltage regulator.
E. Start the unit and observe voltage build-up. Repeat the flashing procedure if build-up fails to develop.

NOTE: Inadvertent polarity reversal may be corrected by interchanging the battery leads.

FIELD TESTING STUD TYPE DIODES
Refer to Figure 1 below for reference to diode polarity and part identification.

A. Stud type diodes may be tested in the field without unsoldering and removing the load lead from the diode terminal. Remove the diode load lead terminal lug from its terminal post and insure that it is not making contact with any adjacent metalic part. An ohmmeter or a battery-light continuity tester may be used to find a short or open condition in the diode. Connect the positive test lead to the anode and the negative lead to the cathode, take a reading, and then reverse the leads and take a reading. These checks should indicate one of three conditions:
   (1) Good diode: Will have a much greater reverse resistance (positive lead on cathode) than forward resistance (negative lead on anode). Typical reverse resistance will be 30,000 - 300,000 ohms or greater, while typical forward resistance will be less than 10 ohms. The continuity tester will have the light "on" in one direction, and "off" in the other.
   (2) Shorted condition: Ohmmeter reading will be zero, or very low in both directions. Continuity tester light will be "on" in both directions.
   (3) Open condition: Ohmmeter will have a maximum (infinity) reading in both directions. Continuity tester light will be dark (off) in both directions.

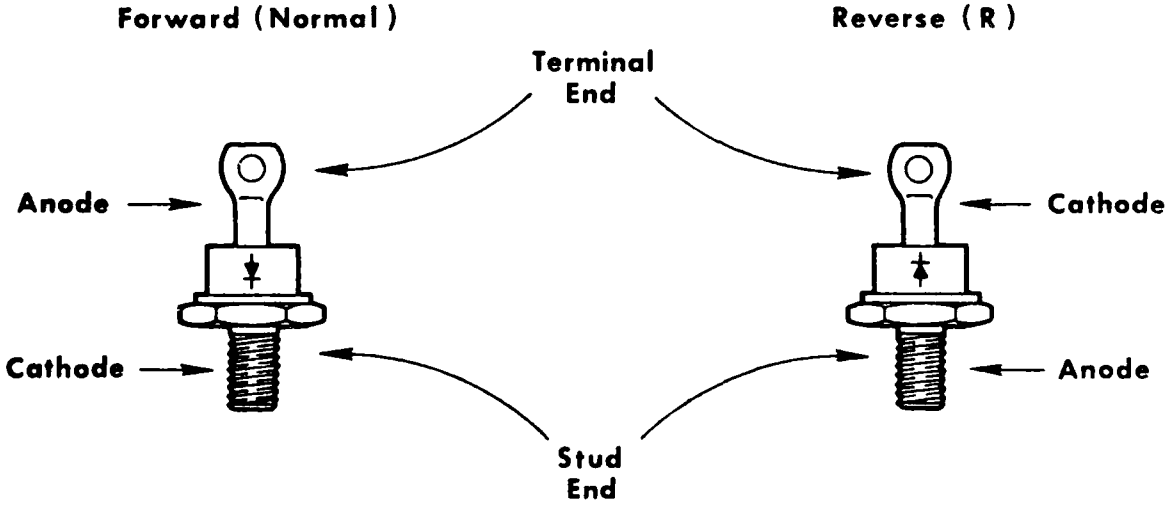


FIGURE 1

ROTATING RECTIFIER ASSEMBLY MAINTENANCE AND TEST PROCEDURE.

A. Individual rectifiers, or complete heat sink assemblies with both diodes still installed can be removed and replaced through the access port located on the top of the endbell opposite the drive end of the

unit (See Fig. 2). Remove the 4 inspection port cover plate retaining cap screws and the cover plate. The assembly is now available for inspection, test, and/or service. See Figure 3 for the rotating rectifier assembly parts identification and location. The individual diodes are "stud type", retained by 1/4 - 28 hex head nuts and star washers. To test the individual diodes, disconnect the diode's lead wire terminal lug from the main rotor terminal post. Since each diode stud is secured to a heat sink; use the heat sink and the diode terminal or output lead terminal lug as the two testing points, and proceed with testing as in paragraph 2 above. If the diode tests good, reinstall the load lead terminal lug on the main rotor post. If the diode tests bad, replace the device following the procedures given in sub paragraph B below.

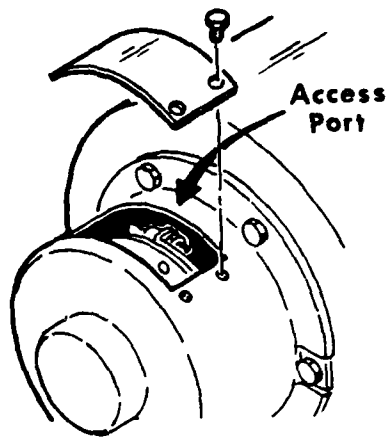
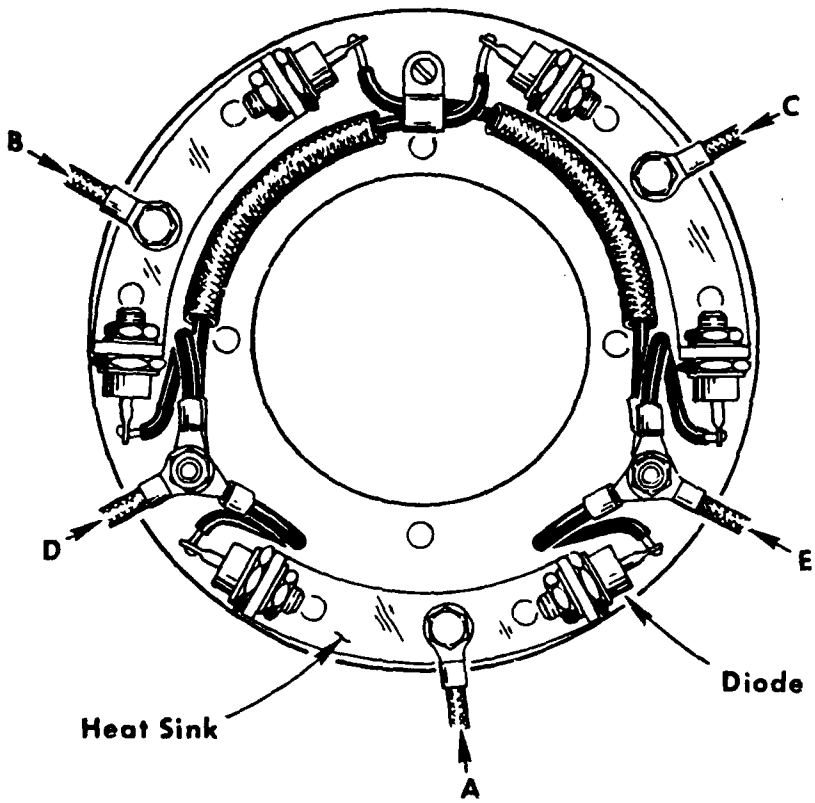


FIGURE 2

B. Prior to installing a replacement diode on the heat sink, run a bead of thermal-electrical contact compound such as the Brundy Company's Penetrox "A" around the base of the diode (do not coat the threads). When installing a diode on the heat sink, care should be taken not to over-torque the retaining nut which could cause damage to the device. Torque to 28 to 30 pounds-inches. If not damaged, the existing diode load lead may be unsoldered from the failed diode and resoldered on the replacement.



A - Exciter Rotor Lead
B - Exciter Rotor Lead
C - Exciter Rotor Lead
D - Main Rotor Lead
E - Main Rotor Lead

FIGURE 3

C. Should it be necessary to remove one or more heat sink assemblies, it will first be necessary to remove the two diode lead terminals from their respective main rotor posts. Next remove the exciter rotor lead, and the plastic lead wire clamp if it is retaining either of the two diode leads involved. Now remove the two 1/4 - 20 hex head cap screws which secure the heat sink to the insulating plate, and carefully pull the assembly out the inspection port. Reverse this procedure when reinstalling the heat sink assembly.

D. If the alternator is close coupled to an engine, it may well be necessary to "bar-over" the engine in order to position any specific area of the rectifier assembly directly under the access port. NEVER use

the alternator fan as a fulcrum to accomplish this. Use the engine manufacturer's recommended practice to manually turn over the engine. To prevent possible injury to personnel and damage to the equipment - insure that the engine cannot start during this procedure, especially if the engine's starter is used to "bump-over" the engine.

EXCITER FIELD (STATOR) REMOVAL AND REPLACEMENT.

The exciter field (exciter stator) is retained in position by the rear bearing bracket, and two "L" brackets welded to either side of the stator core. The "L" brackets are secured to the outside of the rear end plate of the main frame by two 1/2 - 13 hex head cap screws.

A. Remove the rear bearing bracket per instructions for BEARING AND EXCITER ROTOR REMOVAL. Remove exciter field leads F(+) (F−) from the voltage regulator. Attach a fish wire or cable to these two leads through the terminal lugs to assist in pulling these leads back into position during replacement. Remove the two "L" bracket retaining screws. Gently pull the core straight back and clear of the exciter rotor - taking care not to let it drop or cock and knick the end turns of the exciter rotor or the rotating rectifier assembly. When the assembly is clear set it down and remove the lead wire fishing wire.

B. To replace the assembly, position it close to the rear of the machine, and attach the fishing wire to the two exciter field lead terminals. Lift the assembly into position and gently slide it on over the exciter rotor. An assistant should be pulling gently on the exciter lead fish wire during this operation to assure the leads are clear and do not get hung up. When the assembly is in position, install the two "L" bracket retaining cap screws but do not torque them at this time. The inside ears of the rear bearing bracket provide alignment of the exciter core assembly. Re-install the rear bearing bracket and torque the retaining cap screws per instructions for BEARING REMOVAL AND REPLACEMENT. Torque the "L" bracket cap screws to the same (59 to 61 lb./in.) torque as the bearing bracket retaining screws. Remove the exciter lead fishing wire from the exciter leads. At this point it may be well to flash the exciter field per instructions for RESTORING RESIDUAL MAGNETISM, especially if the field has been rewound, or if the field is a replacement for the original assembly. After flashing the field, re-install the exciter field leads to the voltage regulator - taking care that F(+) is installed on the positive (+) terminal, and F(−) is installed on the negative (−) terminal of the regulator.

BEARING AND EXCITER ROTOR REMOVAL AND REPLACEMENT PROCEDURE.

Prior to commencing this operation, rotate the alternator shaft until two of the main rotor poles are in a "vertical" position. Once the bearing bracket is backed out the rotor will drop down on the main stator core. Having the main rotor in this position will limit the amount of rotor drop to that of the air gap.

A. Rear Bearing Bracket Removal Procedure. Loosen but do not remove the two 1/2 - 13 exciter stator "L" bracket retaining cap screws (Fig. 4). Remove the four 12 - 13 rear bearing bracket hex head cap screws (Item A, Fig. 4) to release the bracket. Rethread two of these cap screws in the threaded "back-out" holes in the flange of the bracket. Tighten these two screws together to back the bracket off of the bearing. If the exciter stator is to be removed during this operation, remove the rear bearing bracket first, and then follow procedures for EXCITER STATOR REMOVAL AND REPLACEMENT. Once the bracket is free of the bearing, pull it straight back until it is clear of the exciter stator and rotating rectifier assembly. As soon as the internal aligning register of the bracket is free of the rear plate of the frame, the rotor will drop until one pole is resting in the main stator core.

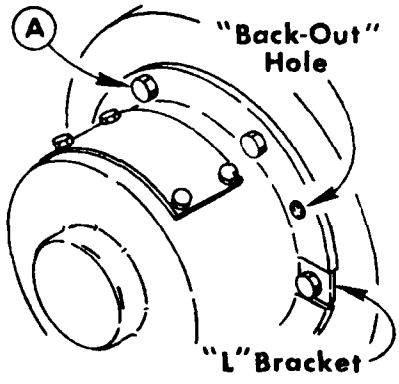


FIGURE 4

NOTE:
On 360, 361, 440, and 441 frames there is an "O" ring installed in the bearing bore of the rear bearing bracket. Inspect this "O" ring for wear or damage, and replace if necessary.

B. Front Bearing Bracket Removal (2-bearing units only). Remove the drive arrangement from the alternator shaft extension.

NOTE:
The shaft extension must be supported before proceeding further. A hoist and sling, jack, or some other means of support with a capacity of TWO TONS should be used.

Remove the six hexhead cap screws holding the bearing bracket to the frame. Rethread two of these screws in the threaded "back-out" holes provided and proceed as described above for the rear bearing bracket.

C. Bearing Removal Procedure. Using a bearing puller remove the bearing. Be sure that the puller is against the Inner Race of the bearing to prevent damage to the bearing. Prior to removal visually inspect the bearing for obvious wear and damage.

D. Rotating rectifier assembly removal procedure. Remove the three exciter rotor leads, and the two main rotor leads (Fig. 3 Items a, b, c, and d) from the rectifier assembly. Remove the four cap screws holding the rectifier asssembly to the rectifier hub.

E. Exciter rotor removal procedure. Using a bearing puller, remove the rectifier mounting hub. This hub is heat shrunk onto the shaft and may require the use of heat during the removal operation. When reassembling, this hub must be heated prior to being installed on the shaft. Pull the two main rotor load leads out of the holes in the exciter rotor. These two holes may be used to remove the exciter rotor with a hub puller.

F. Bearing replacement. **ALWAYS** install the same type bearing that was supplied as original equipment. Order by part number from the parts list, and include the alternator model and serial numbers from the unit's nameplate. Install the bearing with a conventional bearing tool. When replacing **avoid damage to the bearing outer race** and bearing shields. **Apply pressing force to the inner race only.**

G. Reasssembly. For reassembly, reverse the above procedures being careful that all electrical connections are clean and tight. When reinstalling either bearing bracket, it may well be necessary to provide a lifting device such as a sling and hoist or a jack to raise the bracket so that the aligning register will fit into the alternator frame. Insure that the bearing bracket register is properly seated in the frame prior to torqueing the retaining cap screws. Failure to do this may result in damage to the bearing bracket. Torque the four retaining cap screws to 59 to 61 lb./in. of torque. After the bracket is secure, torque the two exciter stator "L" bracket cap screws to the same values as for the bearing bracket screws.

RECOMMENDED SPARE PARTS

The table below lists spare parts which could be kept by the alternator owner to meet maintenance and service requirements. This list of parts and quantities should be adequate to support several like units located at the same operating site, especially if stocks of spare parts are replaced as they are consumed. For "critical" units, or those in service in extremely remote sites, it is strongly recommended that a complete set of the below listed parts be maintained for each unit at the site. For major repairs consult the factory for availability of replacement parts such as complete wound components and major sub-assemblies.

PART DESCRIPTION	QUANTITY
BEARING, DRIVE END (2 BEARING UNITS ONLY)	1
BEARING, OPPOSITE DRIVE END	1
DIODE, FORWARD	3
DIODE,REVERSE	3
AUTOMATIC VOLTAGE REGULATOR	1

See Pages 14 & 15 for Illustration and Part Numbers

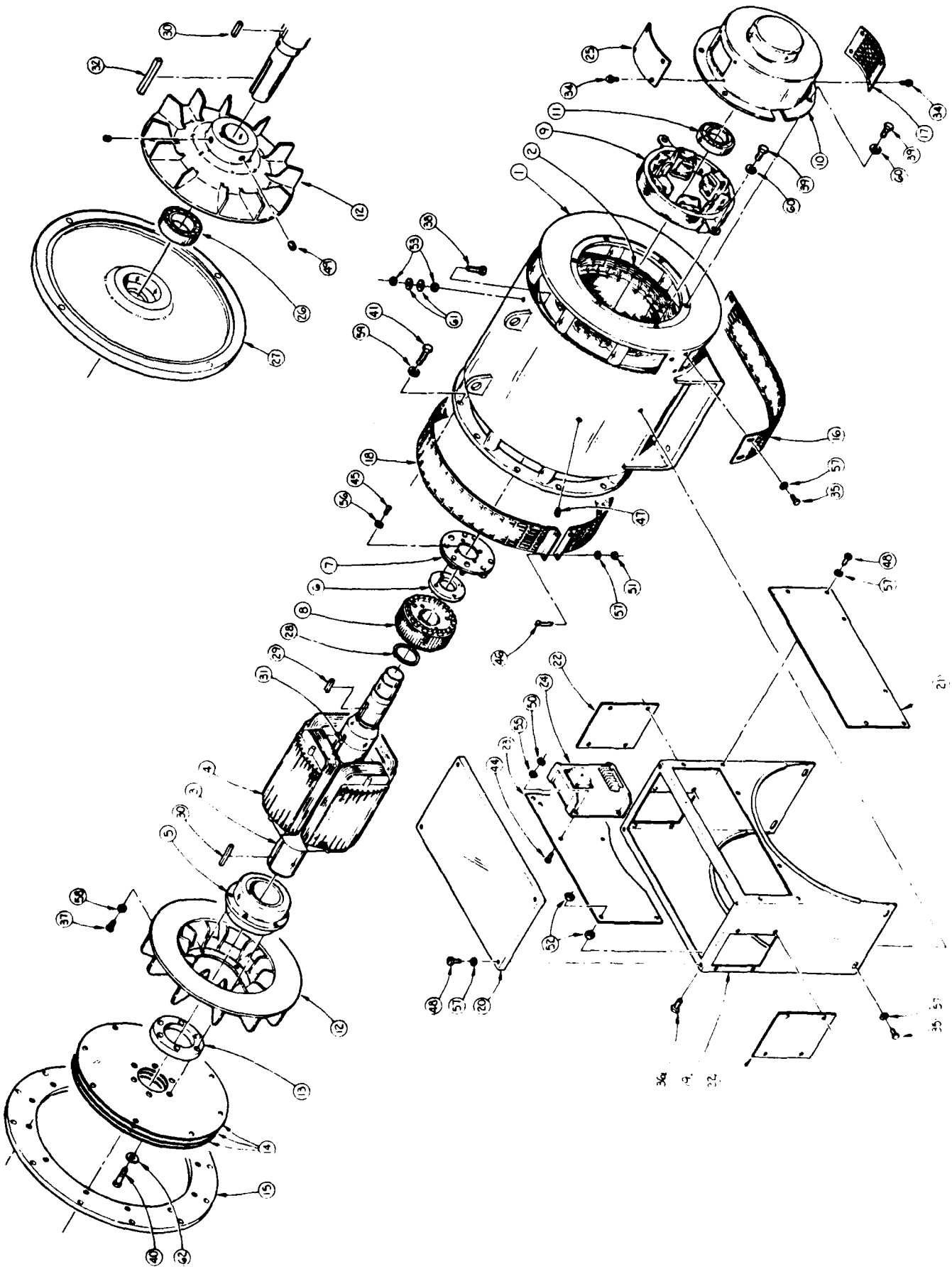
NOTE:
When ordering spare parts, include the unit serial number, model/part number, and adaption kit p n -if single bearing along with the part description from the parts list. Since Lima provides a number of different regulators, when ordering either a replacement AVR, or AVR accessories, indicate the manufacturer and model number of the device being replaced.

SECTION VII
RETURNED GOODS

Contact **THE LIMA ELECTRIC COMPANY** by letter, telex or telephone for a "RETURNED MATERIAL AUTHORIZATION" before returning either parts or a complete unit. We will take steps to return your unit to service quickly, and at the least expense possible. At the same time, we will analyze the cause of failure and recommend steps to prevent a recurrence of the failure.

CAUTION: SINGLE BEARING ALTERNATORS MUST HAVE THE ROTOR ASSEMBLY PROPERLY SECURED TO PREVENT DAMAGE DURING TRANSIT TO THE FACTORY OR AUTHORIZED SERVICE STATION.

THE LIMA ELECTRIC COMPANY, INC.
P.O. BOX 918
LIMA, OHIO 45802
419/227-7327
TLX 24-2433



DRIPPROOF GENERATOR
PARTS LIST
FRAME 360, 440, 580, 680
SINGLE BEARING

Part No.	Part Name
1	Frame
2	Main Stator
3	Shaft
4	Main Rotor
5	Drive Hub
6	Rectifier Hub
7	Rectifier Ass'y.
8	Exciter Rotor
9	Exciter Stator
10	Endbell
11	Bearing
12	Fan
13	Hub Spacer
14	Disc Coupling
15	Adaptor Ring
16	Intake Screen
17	Endbell Screen
18	Screen & Cover Band
19	Connection Box
20	Cover

Part No.	Part Name
21	Front Panel
22	Side Panel
23	Mounting Panel
24	Regulator
25	Cover Plate
26	Bearing
27	Endbell
28	Retaining Ring
29	Key
30	Key
31	Key
32	Key
34	Capscrew
35	Capscrew
36	Capscrew
37	Capscrew
38	Capscrew
39	Capscrew
40	Capscrew
41	Capscrew

Part No.	Part Name
44	Screw - Rd. Hd.
45	Screw - Rd. Hd.
46	Screw - Rd. Hd.
47	Screw - Socket Set
48	Screw - Pan Hd.
49	Screw - Socket Set
50	Nut
51	Nut
52	Nut
53	Nut
55	Washer - Split Lock
56	Washer - Shakeproof
57	Washer - Split Lock
58	Washer - Split Lock
59	Washer - Split Lock
60	Washer - Split Lock
61	Washer - Flat
62	Washer - Flat

WARRANTY

WARRANTY POLICY

I. THE LIMA ELECTRIC COMPANY, INC warrants only that the articles covered hereby and manufactured by it shall be free from defects in material and workmanship under proper and normal use as follows:

* CONTINUOUS DUTY SERVICE: Within two years in service, within two years six months from date of shipment from Lima factory, or 5000 operating hours, whichever occurs first;

OR

** STANDBY DUTY SERVICE: Within five years in service, within five years six months from date of shipment from Lima factory, or 2000 operating hours, whichever occurs first;

to have existed on such date, provided purchaser promptly notifies it in writing and, if requested, returns any defective part or parts freight collect. After two years service, operating hours must be verified with an hour meter or copy of the maintenance log demonstrating routine maintenance was performed as defined by the gen-set manufacturer. The Company's liability shall be limited to the cost of repairing such defective part or parts F.O.B. its factory. The Company will not assume any expense or liability for repairs made to its products outside its works, without its written consent. Equipment and accessories supplied by other manufacturers are not warranted; but the Company will use its best efforts to secure for the purchaser the benefits of warranties, if any, extended by the manufacturers of such equipment and accessories. This warranty is expressly in lieu of all other warranties of any kind, express or implied, which are hereby excluded IN PARTICULAR THERE SHALL BE EXCLUDED THE IMPLIED WARRANTY OF MERCHANTABILITY AS WELL AS THE IMPLIED WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE.

* CONTINUOUS DUTY SERVICE: Defined as applications in which the alternator temperature rise does not exceed 105° centigrade while operating in an ambient temperature not exceeding 40° centigrade per NEMA MG1-22.40.

** STANDBY DUTY SERVICE: Defines as applications in which the alternator temperature rise does not exceed 130° centigrade while operating in an ambient temperature not exceeding 40° centigrade per NEMA MG1-22.40.

The final determination as to whether the *Continuous Duty Service or **Standby Duty Service warranty applies shall be made by the Company whose decision shall not be subject to dispute.

II. THE LIMA ELECTRIC COMPANY, INC. warranty does not include troubleshooting expense, labor or expense associated with service calls, disassembly or reassembly of the alternator from the prime mover, or transporation of the alternator to or from a service facility.

III. OTHER WARRANTIES — The generator set manufacture (OEM) who assembled the generator to the engine may provide their own specific warranty. Their warranty may add to or detract from THE LIMA ELECTRIC COMPANY, INC. WARRANTY.

WARRANTY PROCEDURES

I. Contact your generator set manufacturer (OEM) for their specific warranty.
Follow their generator set warranty procedures, if provided.

II When the generator set manufacturer only provides a continuation of THE LIMA ELECTRIC COMPANY, INC. standard warranty, you must contact the LIMA Service Department for warranty.

A. Write, telex or phone (address above) the LIMA Service Department for location of the most convenient service center. You must provide LIMA with the alternator serial number, alternator part number, date in service, date of failure, hours of operation, and brief description of the problem.

B. In cases where initial troubleshooting cannot solve the problem, you will be instructed to remove the alternator from the prime mover and deliver the alternator to a service center at your expense, or you may contact a service center for a service call to your site at your expense.

C. Instruct the service center to evaluate the failure for warranty consideration before repairs commence.

D. If the failure is warrantable, the service center must contact THE LIMA ELECTRIC COMPANY, INC. Service Department for repair authorization. LIMA has the option of providing repair by:

1. LIMA contracts the service center for remanufacture and replacement of defective parts.
2. LIMA replaces the defective parts from the factory and contracts the service center for replacement of the parts.
3. LIMA or the generator set manufacturer (OEM) replaces the complete alternator with a new or RE-LIMA-BUILT Alternator.

FAILURE TO FOLLOW THESE WARRANTY PROCEDURES WILL VOID THE WARRANTY.

030185

Appendix F
10 kw SKID Mounted Suppression Testing

KAMPERMAN ASSOCIATES INC.

NOISE CONTROL FOR 10KW SKID MOUNTED GENERATOR SET

Presented to:

Mr. Lou Lawrence
Human Factors Engineer
VSE Corporation
2550 Huntington Avenue
Alexandria, VA 22303

Submitted by:

George W. Kamperman
Kamperman Associates Inc.
26100 Woodland Trail
Kansasville, WI 53139

3 November 1986

This is a report on the noise control experiments and measurements you and I performed on the 10KW generator set at VSE, October 23-24, 1986, and the subsequent analysis of the data. Ralph Adolph of VSE had already worked out an enclosure and the associated cooling problems prior to the noise control study. A temporary 1/2 inch plywood enclosure was use for both the cooling studies and the noise control study. The engine cooling fan was exposed at one end of the enclosure. The cooling air discharge was out the same end of the enclosure, near the top. The engine combustion exhaust was also fed into the cooling discharge duct. The engine cooling air did not ventilate the enclosure. The final configuration will incorporate a separate centrifugal fan to continuously purge the generator compartment of hot air. The generator enclosure cooling air will be drawn in through the side openings in the skid and discharged into the common exhaust duct at the top of the enclosure.

We lined the interior surfaces of the enclosure with one inch thick glass fiber blanket (Owens Corning Type 703). Because of space restrictions, only about 50 percent of the enclosure interior surface area could be covered. The hot air discharge duct at the top of the enclosure was also lined with one inch thick glass fiber. A lined bend was constructed over the engine cooling blower inlet opening. This baffle provided an air intake slot at the bottom frame, at skid level, with an open area equal to the engine fan opening after installing one inch thick glass

fiber blanket on both large surfaces inside the air intake enclosure.

The generator set was tested next to the parking area, on short grass. The acoustically treated enclosure reduced the noise level at one meter from about 98 dBA to about 81 dBA and approximately 71-72 dBA at a distance of 7 meters. Background noise from traffic ranged between 65 and 70 dBA and made the 7 meter data difficult to obtain. Figure 1 shows an average of the octave band noise levels around the unit before and after treatment. The enclosure reduced the speech interference level (average of the 500, 1000 and 2000 Hz octave band levels) 20 dB at one meter. The untreated data were obtained from measurements on a 10KW generator set mounted on a trailer. This unit was operated without an electrical load. The data on the quieted unit is reported with full electrical load (10KW) unless noted otherwise. Our tests showed that the difference in the noise level between no load and full load was a 2 dB increase in the level of the 63 Hz octave band while all other bands remained unchanged. Figure 1 shows that the 63 Hz octave band level is higher with the enclosure in place. This is because the plywood enclosure is being driven, or shaken, by the unbalanced dynamic forces in the engine.

Figure 2 gives a more detailed look at the noise reduction of the enclosure. The negative noise reduction in the 63 Hz octave band

is from the structure-borne vibration of the enclosure panels as mentioned in the paragraph above. This problem should be reduced if the enclosure is supported at the skid base and does not contact other parts of the existing generator set framing. One should also be careful that the enclosure panels do not resonate at the first few harmonics of the engine firing rate. If resonance is suspected, then panel stiffeners should be added to increase the panel resonant frequency. The dip in the noise reduction in the 250 Hz octave band is probably also due to panel resonance. The noise reduction at 7 meters is less than at one meter because, there are openings at the skid level and because the enclosed source is effectively larger and is now a more directive source at mid and high frequencies. The estimated noise reduction of 1/2 inch plywood and 4 mm Alucobond are shown in Figure 2. The preferred Alucobond enclosure material should perform better than plywood due to the coincidence dip at about 2000 Hz for plywood and the resulting reduced attenuation. The sound absorptive material on the interior walls of the enclosure can made a significant difference in the overall noise reduction. The one inch glass fiber blanket improved the enclosure performance about 10 dB above 500 Hz. If the treated surface area is doubled, (due to limited space only half the surface was treated for these tests) one would expect the noise reduction to improve an additional 2-3 dB above 500 Hz. If the blanket thickness is increased from 1 to 2 inches the low frequency

performance will improve as indicated on Figure 2. The A-weight noise spectrum in Figure 1 is almost flat from 63 Hz to 1000 Hz. Therefore, any improvement in the noise reduction in this frequency range will have a direct impact on reducing the dBA noise level outside the enclosure.

Figure 3 shows the measured noise level at different locations on and inside the enclosure. The noise level inside the enclosure (behind the generator) and at the very bottom (skid level) are essentially the same. The noise level at the exterior sidewall and at the three major openings is also similar. Ideally, the noise level at the enclosure sidewall should be about 10 dBA lower compared to the other sources because of the much large sidewall area. The present configuration is a fairly balanced design.

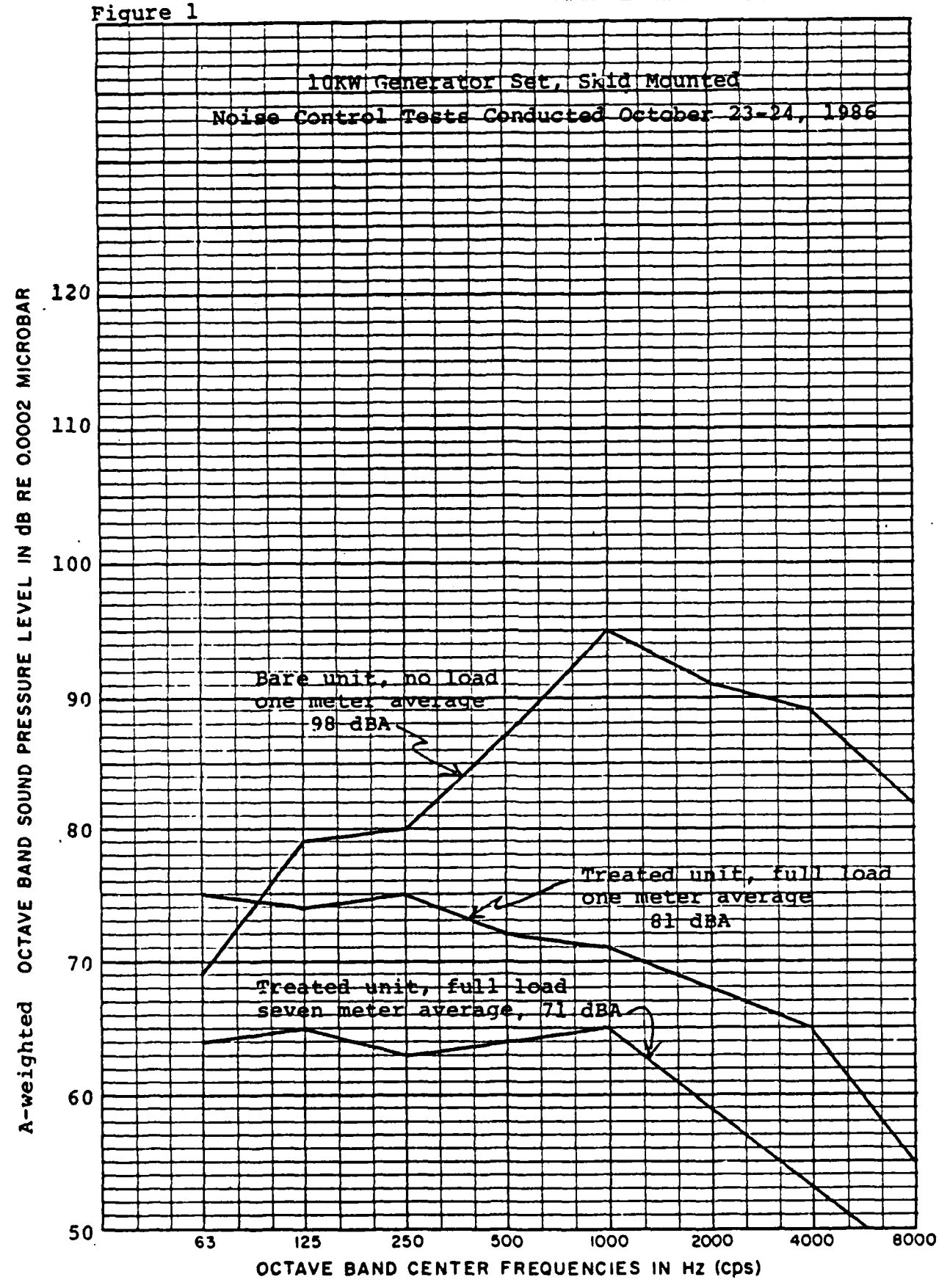
The 85 dBA criterion has been met. In fact no door or cover is needed over the control panel provided the perimeter of the control panel makes a soft gasket seal to the enclosure. The 70 dBA criterion at 7 meters has not been met. An additional 2 to 3 dBA noise reduction is required. Constructing the enclosure of 4 mm Alucobond and total interior surface treatment with one inch glass fiber blanket may just make the 70 dBA criterion. If not, it will be necessary to use two inch thick sound absorptive treatment over the enclosure interior surfaces. The glass fiber blanket should be wrapped and sealed in 0.001 inch thick plastic

covering to avoid oil contamination. The plastic wrap will degrade the sound absorption efficiency increasingly above 1 KHz. This should not present a problem. The one inch thick treatment in the hot air exhaust appears adequate provided the vertical opening in the duct silencer is not increased. The cooling air intake silencer is marginally acceptable. When this silencer configuration is installed inside the enclosure, (vs the outside configuration used for testing) every effort must be made to keep the inlet air gap as small as practical for best attenuation while the length of the opening should be large to minimize pressure drop. Also keep the sound path between the fan opening and the exterior silencer opening as long as possible. This silencer is attenuating the 1000 Hz fan tone 1/2 dB per inch between the fan opening and the external air inlet opening. If the hot air exhaust silencer will be subjected to temperatures above 450°F it will be necessary to use a glass fiber or mineral wool material without a binder. If the temperature is excessive for the plastic wrap under consideration, the plastic should be replaced with woven Fiberglas cloth to protect the sound absorptive material. It is assumed that expanded metal or perforated sheet metal will be used throughout the enclosure to cover and protect the sound absorptive material. The enclosure should be constructed to remain nearly airtight under normal use. The necessary access doors and all other flexible joints should be sealed with soft neoprene or silicone rubber gaskets.

The noise control recommendations for the trailer mounted 10KW generator set are the same as for th. skid mounted unit. The only recommended change is the addition of a noise barrier skirt to extend down over the skid area and seal to the trailer floor. Noise measurements made of the structure-borne noise radiated by the trailer floor indicate that the 70 dBA criterion at 7 meters will be difficult to achieve without inserting some form of rubber-in-shear vibration isolation pad or mounts between the floor and the generator set. Attenuation of the structur-borne path is required at all frequencies above 200 Hz. To accomplish this, the resonant frequency of the isolated generator set should be 100 Hz or less (avoid harmonics of engine rpm). Noise control on the 5KW generator set, both skid and trailer mounted, should be less difficult because the engine cooling system is the same as on the 10KW units but, with only half the thermal load.

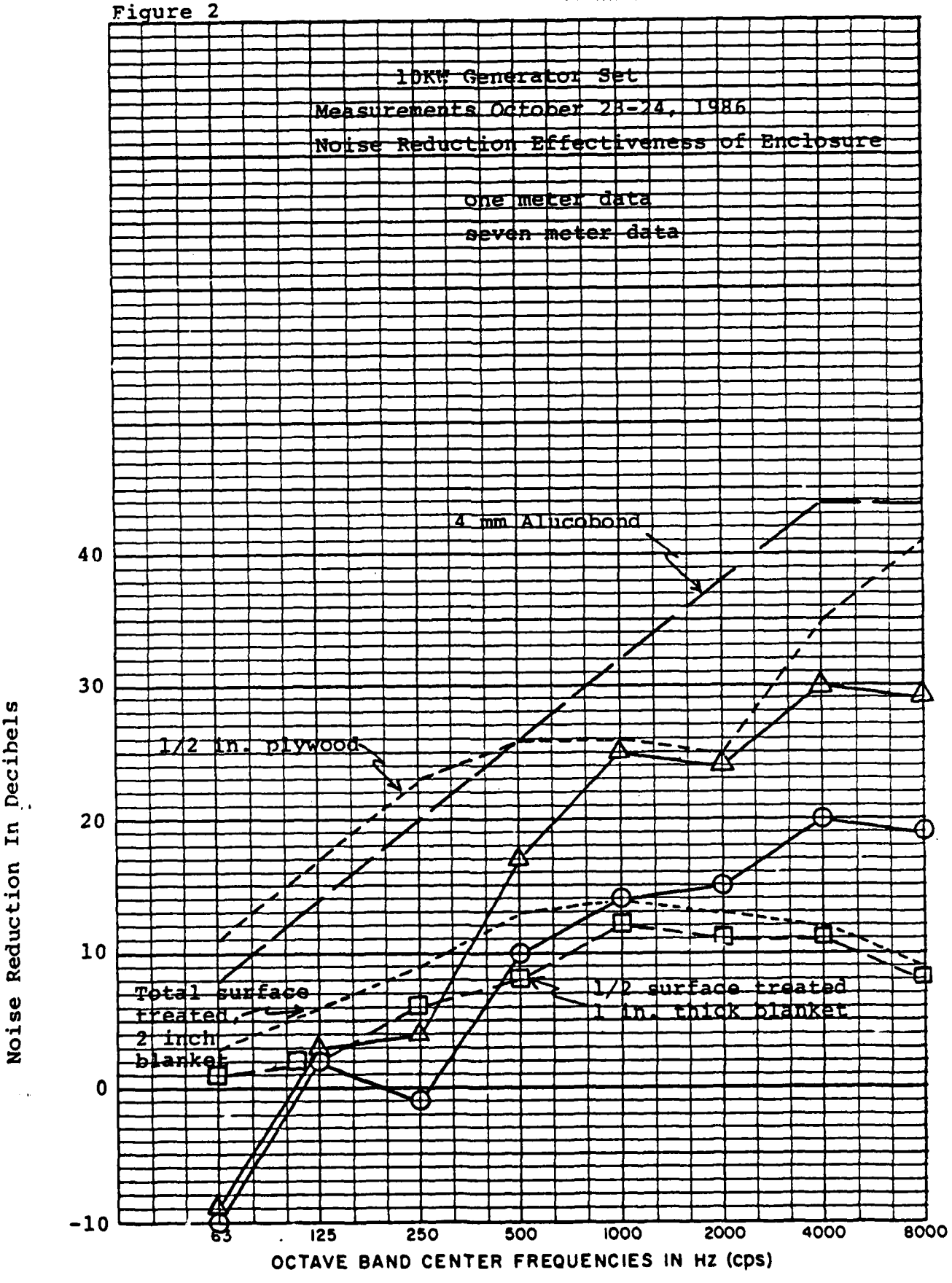
KAMPERMAN ASSOCIATES INC.

Figure 1



KAMPERMAN ASSOCIATES INC.

Figure 2



KAMPERMAN ASSOCIATES INC.

Figure 3