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**UNION CARBIDE CORPORATION
NUCLEAR DIVISION**

**REPORT ON
EMERGENCY ELECTRICAL
POWER SUPPLY SYSTEMS
FOR NUCLEAR FUEL CYCLE
AND REACTOR FACILITIES
SECURITY SYSTEMS**

MASTER

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REPORT ON EMERGENCY ELECTRIC POWER SUPPLY SYSTEMS FOR FUEL CYCLE AND REACTOR FACILITIES SECURITY SYSTEMS

1. ABSTRACT

This report on emergency electric power for security systems at nuclear reactor and fuel cycle facilities was prepared for use in the safeguard program of the United States Nuclear Regulatory Commission. The report includes information that will be useful to those responsible for the planning, design and implementation of emergency electric power systems for physical security and special nuclear materials accountability systems. Basic considerations for establishing the system requirements for emergency electric power for security and accountability operations are presented. Methods of supplying emergency power that are available at present and methods predicted to be available in the future are discussed. The characteristics of capacity, cost, safety, reliability and environmental and physical facility considerations of emergency electric power techniques are presented. The report includes basic considerations for the development of a system concept and the preparation of a detailed system design.

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3. INTRODUCTION

The subject of this report is the supply of electrical power to physical security and materials accountability operations at nuclear reactor and fuel cycle facilities in the event of failure of the normal power source. The objective of the report is to present basic considerations for the provision of emergency electric power for security and accountability systems.

Security and accountability systems will include methods of detecting the misplacement of special nuclear materials and the threatened or actual breach of the physical security of the facility. The detection methods will include perimeter and area lighting to facilitate visual surveillance and a variety of detection devices that will require reliable sources of electric power.

Voice radio, video, data, telephone and other communications to transmit, receive and display or sound alarms in the notification or alarm process will require dependable electric power supplies.

The assessment and response activities may involve the employment of such measures as additional fixed lighting, portable or mobile lighting, voice radio, video, data, telephone or other communications, system monitoring devices and portable or mobile detection devices. The response activities may involve the remote control operation of the access and egress portals of the facility to confine, minimize or delay the effect of the incident. The assessment and response operations will require reliable electric power supplies.

The detection, alarm, assessment and response activities mentioned above occur only in the event of a threatened or actual breach of security, the misplacement of special nuclear materials or the occurrence of a false alarm. Emergency electric power is required in the day-to-day security and materials accountability operations. The monitoring and control of the various alarm systems and the communications systems employed in normal operations all require emergency power supplies.

Emergency power for fire alarm systems, criticality and radiation detection systems, process cooling control systems and for other similar systems is not included in the scope of the report. Such systems are referred to in the report as the plant emergency power system.

4. GENERAL REQUIREMENTS FOR EMERGENCY POWER SUPPLY SYSTEMS

4.1 General:

Certain elements of security and materials accountability systems must be operable, either in their entirety, or in part, irrespective of the interruption of the normal source of their electrical power. The elements of the security and materials accountability systems that require emergency power must be determined from those responsible for the operation of the systems. The electrical loads, electrical characteristics and allowable tolerances, allowable interruption periods and locations of the various components requiring emergency power must be determined.

4.1.1 The establishment of general requirements for emergency electric power involves analysis of the various types of electrical loads that must be supplied with emergency power. A typical analysis may involve grouping the loads by power requirements, voltage, direct current, alternating current, permissible interruptibility, location, physical security constraints, and other combinations of groups that are expeditious to proper analysis.

4.1.2 Conclusions derived from the analysis will establish the general system requirements. Consideration of the established basic requirements and familiarity with available methods of supplying emergency power will provide general indications of practical methods to serve the various electrical loads.

4.1.3 A typical basic determination that may be evolved from the establishment of general systems requirements is whether a particular electrical load may be satisfactorily served by the plant emergency power supply or requires a separate source of emergency power. Considerations involved in this basic determination are discussed below:

4.2 Separate Emergency Power Systems:

A separate emergency power system is required if any of the following conditions exist:

4.2.1 The plant's emergency power system does not have sufficient capacity to serve the required load.

4.2.2 The response time of the plant's emergency power system is insufficient to serve the required load.

4.2.3 Regulations prohibit use of the plant's emergency power system.

4.2.4 It is uneconomical to connect to the plant's emergency power system because of the cost of distribution lines, inverters, rectifiers, voltage stabilizers, transformers, or other costs that may be encountered.

4.2.5 The plant's emergency power system does not provide the required degree of reliability or security.

4.3 Use of Plant's Emergency Power System:

The plant's emergency power system may have reserve capacity that could supply the emergency electrical power to the entire protection system. In the event that the plant's

emergency power system is not suitable or sufficient to meet all of the protection system electrical requirements it may be capable of meeting portions of the requirements. Devices that are of secondary importance to the protection system, and devices that can be dropped from service for short periods of time with minimal detrimental effect upon the protection system's efficacy may be served adequately by the plant's emergency power system. Examples of such devices are heating, ventilating and air conditioning equipment, secondary lights and battery chargers.

4.4 Uninterruptible Power Systems:

Some protection devices are rendered ineffective, or are reduced in effectiveness if there is any interruption of their input power. Interruption of the electric power input to data handling systems of older vintage will cause the loss of the executive and operating programs and the data in volatile storage in the computer. Most computers of recent manufacture will detect a power slump and will go into a power-down mode automatically and preserve all executive and operational programs and transfer all data from core to disc storage. When power returns the system will return automatically to operating status. Some extremely sensitive intrusion detectors are activated by a loss of power. Each element of a protection system must be analyzed to determine if it can withstand momentary failures of the electric power input without significant detriment to the protection system. Components of the protection system that are unable to tolerate power interruptions require the employment of an uninterruptible power system. An uninterruptible power system (UPS) is one in which the device receiving power cannot detect when the source of power is transferred from the normal power system to the emergency power system. Several types of UPS are discussed below:

FIGURE 1

UPS WITH D.C. LOAD

4.4.1 UPS With D.C. Load:

The UPS configuration shown in Figure 1 employs a battery charger to maintain the charge on a battery which in turn drives a D.C. load. If the main power is interrupted the battery will continue to supply power to the load until its charge is depleted. Protection circuitry must be incorporated in the battery charger to prevent the battery charge from draining back into the battery charger when the main power source is interrupted. One difficulty with this device is that the voltage across the battery is higher when the charger is maintaining the battery than when the battery is supplying the load with no input from the charger. This problem may be circumvented by supplying the load from a regulated D.C. power supply powered by the main power source under normal conditions. Diode switching may be used to transfer the load to the battery when the main power source fails. The regulated D.C. power supply output can be adjusted to equal the output voltage of the loaded battery. Another difficulty is that only one D.C. voltage source is available. The UPS can be configured to provide A.C. as well as D.C. output by the configuration shown in Figure 2:

FIGURE 2

UPS WITH A.C. LOAD

4.4.2 UPS With A.C. Load:

The UPS shown in Figure 2 is similar to the one shown in Figure 1 except it provides an A.C. output. In fact, the configuration shown in Figure 2 is versatile and will provide a number of A.C. outputs as well as a D.C. output equal to the battery voltage. The principle disadvantages of this type of UPS are its high cost and the power losses and low reliability inherent in the inverter. A third type of UPS which eliminates the difficulty imposed by the short life of a battery is shown in Figure 3:

FIGURE 3

UPS WITH PRIME MOVER DRIVE

4.4.3 UPS With Prime Mover Drive:

The UPS configuration shown in Figure 3 has an alternator, or generator, instead of a battery delivering power to the load. The generator, or alternator, is normally driven by an A.C. motor which in turn is powered from the normal power source. If the normal power fails the clutch is engaged, the heavy flywheel maintains shaft rotation for a short period of time, starts the prime mover engine and assists the prime mover to attain operating speed rapidly. The main advantage of this type of UPS is that the length of time that the UPS will supply power is limited only by the life of the prime mover and the fuel supply. It should be noted that one major advantage of a UPS is the fact that power surges, spikes and other aberrations are smoothed by the UPS device and that one major disadvantage of all UPS systems is the added cost and reliability problems injected into the system by virtue of the added subsystems.

4.4.4 UPS Operating Modes:

It is convenient to discuss operation of a UPS system by dividing the operation into three modes — operate, emergency and recovery. During the operate mode the normal power source supplies power to the system and the UPS system floats on the line. The systems diagrammed in Figures 1 and 2 will actually be running off of the power supplied by the battery charger and the battery will be maintained at full charge by the battery charger. The system diagrammed in Figure 3 will be running off of the power supplied by the alternator (or generator) and the alternator (or generator) will be operated by the A.C. motor. The emergency mode commences upon cessation of the input power from the normal power source. At this time the battery, shown in Figures 1 and 2 will supply power for the load; and, in Figure 3, the flywheel will power the alternator (or generator) until the prime mover starts at which time the prime mover will drive the alternator (or generator). The emergency mode will continue until the battery is depleted (or the prime mover fails to run due to depletion of fuel, failure to start, or other reason), or until the normal power source resumes supplying power. The recovery mode commences, for the systems shown in Figures 1 and 2 whenever the normal power source resumes and continues until the battery is recharged. The system shown in Figure 3 has no recovery mode, but is ready to go back into the emergency mode immediately.

In addition to providing uninterrupted power, a UPS system acts as a filter and suppresses voltage transients, waveform distortions and frequency deviations, assuring a clean and stable source of power for critical loads. To avoid switching transients and phasing problems, modern UPS systems do not use transfer switches, but float the load across the emergency power source (battery, generator or alternator) and use the normal input power source to maintain the emergency power source in a state of readiness to immediately assume the load.

4.5 Interruptible Power Systems:

An interruptible emergency power system is applicable whenever a separate emergency power supply system is necessary and the special characteristics of the UPS are not mandatory. The capacity of the source, the period of interruption permissible, the type of available energy source and the capacity of the source determine the type of power system that should be employed. In some instances it may be economically advantageous to use more than one emergency power supply in time sequence. For example, a vital device can be kept operating for a short period of time with batteries until an emergency engine-driven generator can be employed or until connection can be made to the larger plant emergency power system, or until power from the normal source is restored.

5. EMERGENCY POWER SUPPLY TECHNIQUES

Most existing emergency electric power supply systems, whether interruptible or uninterruptible, employ engine driven generators and/or batteries. Some of the other types of systems such as solar powered photovoltaic, thermoelectric, fuel cell, inertial, wind or ocean wave powered or hydroelectric systems may be applicable at present to special requirements for emergency electric power or may become more feasible for such use in the future. The general characteristics of the various techniques are discussed below.

5.1 Engine Generators:

5.1.1 General:

5.1.1.1 Engine Types:

A wide variety of engine prime movers may be used to drive a generator/alternator to produce electric power. Internal combustion reciprocating, rotary and turbine engines, wind or water powered engines, steam powered engines and many others have been used or considered for use as prime movers in electric power generation. An external combustion Rankin Cycle engine that uses almost any combustible fuel to drive a turbine and produces 200 watts to 3000 watts of electrical power is commercially available. Power take-off devices on engine driven vehicles and conversion devices to produce 100 volt 60 Hertz electric power from vehicle alternators are available. Many types of generators and alternators convert the mechanical power of the prime movers to electrical power. The engine generator of this report is an Otto or Diesel Cycle internal combustion reciprocating engine driving a rotating machine that converts the mechanical power of the engine to electrical power.

5.1.1.2 Future Improvements Expected:

Engine generators have become ubiquitous. They provide the most prevalent emergency source of electric power in use at present. The existing improvement trends of increased efficiency, decreased weight and greater reliability of internal combustion reciprocating engines are expected to continue their gradual progress to keep these engines in their present dominant position in the emergency electric power field for a number of years. This dominance could be challenged in the future by the development of smaller less expensive internal combustion turbine engines than those available at present.

5.1.1.3 Generators/Alternators:

Most engine generator units are used to serve an alternating current load and have the internal combustion engine directly coupled to a four, six or eight pole, self-excited alternator. The excitation for the alternator may be obtained from a combination rectifier and regulator, or from a separate excitation generator built into the alternator. The speed of these units (therefore the output A.C. frequency) is controlled by a simple throttle control actuated by an inertial governor, or, on the smaller and less expensive units, a vane in the path of the cooling air flow. The units are available for the generation of a wide variety of single phase and three phase alternating current voltages, direct current voltages and combinations of both alternating and direct current voltages. The combinations available at present in capacities ranging from 1 KW to 100 KW are tabulated in paragraph 5.1.12 below.

5.1.2 Capacity:

The engine generator must have enough capacity to serve the largest total continuous load that it will be expected to carry and to start the largest motor it will drive without excessive voltage dip. The largest voltage dip tolerable will be equal to, or slightly less than, the smallest of all of the permissible dips of the loads which will be connected to the generator. The engine generator units commercially available will provide a voltage regulation and surge protection that exceeds the requirements of communication, alarm and control equipment that would be normally connected to them if their capacity is not exceeded. Normal practice is to specify an engine generator for an installation which has a capacity that is at least 25% higher than the maximum anticipated load (Ref. 11). No matter what the load, a unit smaller than 2.5 KVA should not be employed. Unit smaller than 2.5 KW sold to the recreational, hobby and other non-commercial users are frequently not as reliable as the larger units. An additional disadvantage of many of the smaller units is that they employ a two-pole alternator which, in turn, requires a 3600 RPM engine to produce 60 Hertz power. This high operating speed is not conducive to long engine life. The capacity range of engine generator units normally employed as emergency power sources for communications systems, alarm systems, security systems, etc., is usually between 2.5 KVA and 100 KVA. Manufacturers' listed capacity ratings are for sea level installations and must be derated for installations at higher elevations. Information regarding the available capacity increments from 1 KW to 100 KW are tabulated in paragraph 5.1.12 below.

5.1.3 Initial Cost:

5.1.3.1 The initial installed cost of an engine generator system to provide emergency power to protection systems may include several costs besides the supplier's price for the engine generator equipment. Accurate determination of the installed cost must include all of the optional accessories offered by the equipment manufacturer that are needed to meet the requirements of the particular installation. Optional accessories may include such items as remotely mounted radiators or control panels, additional monitoring and control devices, vibration isolating mounts, flexible exhaust pipe connections, exhaust pipe insulation, skid mounts, weatherproof housing dual-fuel carburation, etc. Other costs involved in the initial installation may include the cost of exhaust pipe extensions and weatherheads, fuel storage tank and piping, transfer switch, distribution lines, foundation, vibration isolation, cooling air intake and exhaust louvers, screens and dampers, flexible fuel line connectors, time clock exercisers and the labor for the installation. Small installations will require fewer optional accessories and other provisions; for instance, a 2.5 KVA engine generator may be adequately supported by the floor of a building, paving or even firm soil that is well drained, and will not require a massive or complex foundation. Dual-fuel capabilities are seldom justified on small systems because of the minimal fuel storage required. Sophisticated monitoring and control provisions on small systems are seldom feasible due to the simplicity of the units and their small replacement cost compared to the cost of sophisticated monitoring and control equipment.

5.1.3.2 At present the listed prices for standard engine generator units that are gasoline fueled and air cooled with capacities below 15 KW will vary from approximately 250 dollars to 375 dollars per KW of rated output with the lower end of the price range applying to the larger units. The present prices of standard liquid cooled gasoline units with capacities below 100 KW range approximately from 125 dollars to 400 dollars per KW of rated output with the lower end of the price range applying to the larger sizes. The present prices for standard liquid cooled diesel engine generators with capacities below 100 KW range from approximately 150 dollars to 450 dollars per KW of rated output. In this category the lower end of the price range is also applicable to the larger sizes.

5.1.4 Operation and Maintenance Cost:

The cost of maintaining an engine generator emergency power system will include the cost of parts, labor, materials and expendable supplies such as lubricating oil and cooling fluid to maintain the equipment in conformance with the manufacturer's recommendations or with established maintenance policies of the facility. The operation cost will include the cost of the fuel expended during the periods that the equipment is exercised or operated due to a failure of the normal power source. Warranties on engine generator systems issued by the manufacturer or installing contractor will usually include the replacement of defective parts and perhaps the labor for their installation for a specific period of time after the installation is completed. Substantial savings in maintenance costs may be realized by invoking the provisions of a good warranty where they are applicable during the period that the warranty is valid. Minimum warranties are generally for a period of one year but warranty periods of 2, 3, 4 and 5 years are not uncommon. Estimating fuel consumption is discussed under 5.1.11 Fuel Considerations.

5.1.5 Training:

Adequate training of the maintenance and operations personnel responsible for an engine generator emergency power system is mandatory for reliable performance. Rigid adherence to adequate maintenance procedures will usually insure that the system will perform as needed when the normal power source fails; however, it is conceivable that both the normal and emergency power sources could fail. In such an event the thorough training of the responsible personnel in testing, adjusting and repairing the system; and in the implementation of alternate emergency measures can be vital to the continuation of the effective operation of the protection systems.

5.1.6 Total Life System Cost:

The total cost of the engine generator emergency power system for the duration of the useful life of the system is the summation of all of the costs discussed above. The total life system cost may be estimated by estimating the initial and annual operating and maintenance costs and projecting these costs for the predicted useful life of the system and subtracting the salvage value. Care must be exercised in comparing the total life system costs of the various types of systems to equitably assign dollar amounts to training, salvage value and escalation and in applying objective judgement regarding the time before obsolescence of the system may occur.

5.1.7 Monitoring and Control:

5.1.7.1 Satisfactory operation of the transfer switch is vital to the reliability of an engine generator emergency power system (Ref. 12). The transfer switch has the principal functions of exercising the engine generator equipment periodically, sensing a failure of the normal power source, starting the prime mover and transferring the electrical load from the normal power source to the emergency power system. This element of the emergency power system must be selected carefully to provide the maximum practical reliability.

5.1.7.2 Transfer switches that are available fall into three general categories: (a) mechanical/manual, (b) electromechanical, and (c) static (Ref. 19).

5.1.7.3 The mechanical transfer switch is one that is thrown manually to permit no-break transfer to the secondary source when maintenance is necessary. Customarily, it is a make-before-break type. With the inverter phase-locked to the commercial power source, it can be thrown without interrupting power to the load (Ref. 19).

5.1.7.4 The electromechanical transfer switch is used in systems that can tolerate the transients normally encountered on power lines, since its transfer time is normally 50 milliseconds or less (about 3 cycles). It may operate automatically, being actuated when a power outage or fault is sensed (Ref. 19).

5.1.7.5 Static transfer switches are used for load switching when the load is adversely affected by short-term transients. They operate on the same principle as the electromechanical switches, but the moving armature is replaced by signal control rectifiers to reduce transfer time (Ref. 19).

5.1.7.6 The monitoring and control provisions supplied by the manufacturers of engine generator units will vary with the manufacturer and with the various models offered by any one manufacturer. Most manufacturers offer the monitoring and control provisions included in the list in paragraph 5.1.12.6 either as standard items or as optional accessories.

5.1.8 Safety Considerations:

The major manufacturers of engine generator equipment generally comply with the safety requirements of the National Electrical Manufacturer's Association, Institute of Electrical and Electronic Engineers, Occupational Safety and Health Administration, American National Standards Institute and other safety codes and regulations applicable to the manufacture of the equipment. Compliance may be, in some instances, provided by optional accessories. Several safety code provisions must be considered in the installation of the system. Typical of these considerations are the safety codes, regulations and policies governing the storage of volatile fuels, penetration of structures by hot exhaust pipes, disconnection of electrical power sources during repair or maintenance operations, the discharge of toxic gases to atmosphere, battery venting and provisions for combustion air. The installation of

engine generator emergency power systems must comply with existing applicable safety codes, regulations and policies and in cases where such codes, regulations and policies are not specifically applicable sound engineering judgement must be applied to provide a safe and reliable installation. A list of codes and standards references that may be applicable is included in The Appendix.

5.1.9 Environmental and Physical Facility Considerations:

Engine generator emergency power systems require space for their installation and access sufficient for maintenance. The allocation of space for an engine generator system must provide for the equipment to be removed and replaced and for adequate maintenance access. Where growth of the need for emergency power is predicted, the physical facilities housing the engine generator equipment must provide space for the installation of additional equipment and access for the additional equipment to be transported to the allocated space. Engine generator equipment must be protected from the weather if it is to be reliable. Most manufacturers include a raintight enclosure as an optional accessory to their equipment, and most of these will adequately protect the equipment from rain when it is installed in a location exposed to the elements. The climate of the locality of the facility may require measures to prevent freezing of the engine coolant at low ambient temperatures, and in extremely cold climates, lubricating oil pre-heaters may be necessary. Installations in locations with high ambient temperatures may require special cooling or ventilating measures to prevent overheating the equipment. Tropical installations may require special moisture and fungus resistant provisions. Where the equipment is installed inside a building, provisions must be made for the satisfactory discharge of the exhaust fumes, the supply of combustion air and the intake and discharge of air for cooling. The transmission of objectionable noise and vibration from the unit to the building structure must be prevented.

5.1.10 Lifetime and Reliability Considerations:

The length of the useful life of an engine generator emergency power system may be predicted with some degree of accuracy from the manufacturer's records of the operating life of similar installations. Such predictions must consider the predicted quality of the maintenance that the equipment is expected to receive, the environment in which it is installed and the ratio of idle and operating time periods anticipated, including exercise periods, and periods of full and partial load operation. The manufacturer's statement regarding the predicted lifetime of the equipment can be verified by communications with the users of the manufacturer's systems. The reliability of an engine generator system may be predicted by analysis of tests previously conducted by the manufacturer, independent testing laboratories or various government agencies. The Nuclear Regulatory Commission has established standards concerning testing procedures and reliability criteria for emergency electric power systems. The various branches of the U.S. Armed Forces have conducted extensive tests of numerous emergency electric power systems. System reliability considerations must include all elements of the system and must not be confined to the engine generator equipment.

5.1.11 Fuel Considerations:

The prevalent fuels used in engine generator systems at present are gasoline, diesel oil, natural gas and liquified petroleum gas. These fuels are discussed below:

5.1.11.1 Gasoline is used extensively since it is universally available, is a liquid at atmospheric pressure and is easy to handle. Engines for gasoline fuel have a lower initial cost than diesel engines. Gasoline engines are easier to start than diesel engines under difficult conditions and in extremely low temperatures. Care must be exercised in the storage of gasoline because it vaporizes readily when exposed to air and can create conditions conducive to the occurrence of an explosion. The storage life of gasoline is limited and it will deteriorate and damage an engine in which it is used after approximately six months in storage. Gasoline has a lower octane rating than the gaseous fuels and it has a greater fouling tendency.

5.1.11.2 Diesel fuel is less volatile than gasoline and is safer to store and to use. Diesel fuel has a longer storage life than gasoline, is readily available and easy to handle. Most engine generator manufacturers recommend No. 1-D or No. 2-D grades of diesel fuel for use in their engines since other grades of fuel in this general class have lower octane ratings and higher sulphur content, both detrimental to engine performance. The initial cost of diesel engines is generally greater than for engines of the same size built to use gasoline or gaseous fuels. Diesel fuel costs less per gallon than gasoline and has a greater heating value. Fuel consumption in a diesel engine is significantly less than that of a gasoline engine operating with the same load. The construction of diesel engines is inherently heavier and more rugged than that of engines built to use gasoline or gas fuels and the diesel engine has no points, spark plugs or condensers which require frequent maintenance on gasoline or gas fueled engines.

5.1.11.3 Natural gas is usually obtained from a municipal distribution system or from a public utility source. The use of natural gas to fuel an engine generator requires no provisions for storage of the gas. The use of natural gas will generally reduce the capacity of the engine to 85 to 90 percent of its capacity when using gasoline or liquified petroleum gas. This is due to the lower BTU content of natural gas.

5.1.11.4 Liquified petroleum gas consists of a mixture of propane and butane. The mixture ratio is usually varied with the seasons to account for the effect of ambient temperature on the vapor pressures of the gasses. The fuel is readily available in most areas of the U.S., is generally stored in re-fillable pressure tanks and is reasonably easy to handle.

5.1.11.5 Natural gas and liquified petroleum gas both have a higher octane rating than gasoline. They have a lower residue content than gasoline and contain no tetra-ethyl lead. They mix more thoroughly with the air in the engine cylinders than liquid fuels and are more completely consumed by the combustion process. The introduction of the gaseous fuels into the cylinders of the engine causes no washing of the lubricating oil from the cylinder walls as occurs with the liquid fuels. The use of the gaseous fuels will produce less engine wear, less carbon formation, less sludge in the lubricating oil and less fouling than the use of gasoline.

5.1.11.6 A gaseous fuel manufactured by some municipalities by burning coal in a mixture of air and steam is composed primarily of carbon monoxide and hydrogen with some nitrogen. Sewer gas, or natural gas, may be added to enrich the manufactured gas. Manufactured gas is being widely replaced by natural gas, but is still used in some areas. Manufactured gas is less desirable as a fuel than the more commonly used fuels discussed above due to its low BTU content.

5.1.11.7 Fuel consumption varies with the manufacturer and varies between different models and sizes of equipment offered by any one manufacturer. Approximate fuel consumption may be estimated at full engine load as follows:

5.1.11.7.1 Gasoline fuel consumption is approximately .16 gallons per KWH of rated generator output and varies approximately from .10 to .18 gallons per KWH.

5.1.11.7.2 Natural gas consumption is approximately 18 cubic feet per KWH of rated generator output and varies approximately from 13 to 25 cubic feet per KWH.

5.1.11.7.3 Liquified petroleum gas consumption is approximately 7.5 cubic feet per KWH of rated generator output capacity and varies approximately from 4 to 10 cubic feet per KWH.

5.1.11.7.4 Diesel fuel consumption is approximately .08 gallons per KWH of rated generator output and varies approximately from .04 to .10 gallons per KWH.

5.1.11.8 The selection of a fuel for use in engine generator emergency power systems must consider fuel availability, the engine efficiency required, the initial cost of the equipment, fuel cost, maintenance costs, reserve fuel storage and reliability requirements.

5.1.12 Summary of Engine Generator Unit Availability (1 - 100 KW Nominal Capacity):

Nominal Capacity (KW)	Nominal Electrical Characteristics	Cooling	Fuel
1, 1.25, 1.5	120 V. A.C., 60 Hz., 1 PH., 2 W. 12-15 V. D.C. 24-30 V. D.C. 32-40 V. D.C.	Air	G,N,LP
2.5	120 V. A.C., 60 Hz., 1 PH., 2 W. 120 V. A.C., 60 Hz., 1 PH., 2 W. & 12-15 V. D.C. 240 V. A.C., 60 Hz., 1 PH., 2 W. 120/240 V. A.C., 60 Hz., 1 PH., 3 W.	Air	G,N,LP
3	120 V. A.C., 60 Hz., 1 PH., 2 W. 120/240 V. A.C., 60 Hz., 1 PH. 3 W	Air	G,N,LP,D
4	120 V. A.C., 60 Hz., 1 PH., 2 W. 120/240 V. A.C., 60 Hz., 1 PH., 3 W. 120/208 V. A.C., 60 Hz., 3 PH., 4 W.	Air	G,N,LP
5, 6.5	120/240 V. A.C., 60 Hz., 1 PH., 3 W. 120/240 V. A.C., 60 Hz., 3 PH., 4 W. 120/208 V. A.C., 60 Hz., 3 PH., 4 W.	Air	G,N,LP
7.5	120 V. A.C., 60 Hz., 1 PH., 2 W. 120/240 V. A.C., 60 Hz., 1 PH., 3 W. 120/240 V. A.C., 60 Hz., 3 PH., 4 W. 120/208 V. A.C., 60 Hz., 3 PH., 4 W. 277/480 V. A.C., 60 Hz., 3 PH., 4 W. 240 V. A.C., 60 Hz., 3 PH., 3 W.	Air or Liquid	G,N,LP,D
10	120 V. A.C., 60 Hz., 1 PH., 2 W. 120/240 V. A.C., 60 Hz., 1 PH., 3 W. 120/240 V. A.C., 60 Hz., 3 PH., 4 W. 120/208 V. A.C., 60 Hz., 3 PH., 4 W. 277/480 V. A.C., 60 Hz., 3 PH., 4 W.	Air or Liquid	G,N,LP,D
12.5	120 V. A.C., 60 Hz., 1 PH., 2 W. 240 V. A.C., 60 Hz., 1 PH., 2 W. 120/240 V. A.C., 60 Hz., 1 PH., 3 W. 120/240 V. A.C., 60 Hz., 3 PH., 4 W. 120/208 V. A.C., 60 Hz., 3 PH., 4 W. 277/480 V. A.C., 60 Hz., 3 PH., 4 W. 240 V. A.C., 60 Hz., 3 PH., 4 W.	Air or Liquid	G,N,LP,D
15	120 V. A.C., 60 Hz., 1 PH., 2 W. 120/240 V. A.C., 60 Hz., 1 PH., 3 W. 120/240 V. A.C., 60 Hz., 3 PH., 4 W. 120/208 V. A.C., 60 Hz., 3 PH., 4 W. 277/480 V. A.C., 60 Hz., 3 PH., 4 W. 240 V. A.C., 60 Hz., 3 PH., 3 W.	Air or Liquid	G,N,LP,D
30, 45, 55, 60, 65, 70, 85, 90, 100, 115	120/240 V. A.C., 60 Hz., 1 PH., 3 W. 120/240 V. A.C., 60 Hz., 3 PH., 4 W. 120/208 V. A.C., 60 Hz., 3 PH., 4 W. 277/480 V. A.C., 60 Hz., 3 PH., 4 W. 240 V. A.C., 60 Hz., 3 PH., 4 W.	Liquid	G,N,LP,D

5.1.12.1 Engine generator sets with capacities of 5 KW and smaller are available in portable models with one-man or two-man carrying frames. An optional available accessory is a two-wheeled cart. Two-wheeled and four-wheeled trailers are available for mobile applications of any size engine generator set listed above.

5.1.12.2 Most of the portable units are drip-proof construction for use exposed to the weather. Weatherproof enclosures are available for all of the sizes listed above.

5.1.12.3 Available starting methods include rope-recoil manual starting on portable models, local push-button starting using a battery and starter, remotely controlled starting and automatic starting and load transfer.

5.1.12.4 Frequency regulation available will range from plus or minus 1.8 Hertz to plus or minus 7 percent of the rated frequency.

5.1.12.5 Response performance of engine generators will vary with the manufacturer and with different models produced by the same manufacturer. The instantaneous voltage dip that will occur upon the application of full load will vary from 12 to 20 percent of rated voltage on the units presently available. The period of recovery from the instantaneous voltage dip to stable operation varies from 1 to 2 seconds and stable operation ratings vary from one half to one percent of rated voltage.

5.1.12.6 Most of the engine generator combinations listed above are available for dual fuel operation using gasoline and one of the gaseous fuels; natural gas or liquified petroleum gas.

The list presented below is representative of the controls, instruments and accessories available with engine generator equipment:

- Current Transformers
- Voltmeter
- Circuit Breaker
- Frequency Meter
- Battery Charge Rate Ammeter
- Oil Pressure Gauge
- Water Temperature Gauge
- Running Time Meter
- Timed Engine Exerciser
- Automatic Over-Speed Shutdown
- High Water Temperature Cut-off
- Remote Start-Stop Control
- Automatic Transfer Switch
- Cranking Limiter
- Local Start-Stop Control
- Phase Selector Switch for Three Phase Models
- Radio Interference Suppression
- Exhaust Mufflers

Remote Radiators
Priming Tanks, Day Tanks and Fuel Storage Tanks
Safety Alarms and Indicating Panel
Vibration Control
Carrying Frames and Two-Wheel Carts for Portable Models
Two-Wheeled and Four-Wheeled Trailers
Engine Block Heater
Radiator Duct Connector
Skid Base
Convenience Electric Outlet
City Water Cooling Controls and Filter

5.1.12.7 Below is a partial list of the U.S. manufacturers of engine generator units:

General Electric Company
Kohler Company
Generac Corporation
Caterpillar Tractor Company
Onan Division of Onan Corporation
Winco Division of Dyna Technology, Inc.

5.1.12.8 Specific availability, delivery schedules and prices may be obtained from local manufacturers' representatives or distributors.

5.2 Solar Powered Generators:

5.2.1 General:

5.2.1.1 Construction:

A solar powered emergency electric power generator is composed of an array of solar cells and a storage battery. The solar cell converts sunlight energy into electric energy directly by the photovoltaic effect produced by the absorption of sunlight in a cell composed of two semiconductors arranged to provide a pn junction. One of the semiconductors (n type) is a material in which conduction is due to electrons and the other semiconductor (p type) is a material in which conduction is due to positive holes. Solar cells have been known for over 80 years (Ref. 1). Early cells were made of selenium and had conversion efficiencies of about 0.3 percent and approximately 440 square inches of cell area was required to produce 1 watt of electrical power. Silicon cells were developed during the space program and have been gradually improved in performance. Panels are available today which produce 1 watt of electrical power with approximately 20 square inches of cell area. The solar cells in an array are connected in series-parallel to provide the desired output voltage and current. Some solar powered generators may contain a converter/regulator for suppression of radio interference noise, voltage regulation and isolation. The major shortcoming of solar powered generators, in addition to their present high cost, is the fact that they produce power only when sunlight is shining upon them. Another type of solar powered generator uses mirrors to focus solar energy upon a boiler which, in turn, is used to drive a prime mover which drives an alternator. This type of arrangement is being considered for large, fixed power installations, but is not applicable as an emergency power source due to the large capital investment necessary, large size of the installation and slow start-up characteristics of the system.

5.2.1.2 Future Improvements Expected:

During the year prior to the writing of this report the initial cost of solar cell modules has decreased to one third of their cost one year ago. Further reductions in the initial cost and the minimal maintenance requirements of these units are predicted to contribute to their expanded use. The most recent development in the field of solar powered units are the announcements by RCA, Bell Laboratories and others of the development of amorphous, i.e., non-crystalline structure, solar cells. The amorphous cells will be less expensive to produce than those presently used.

5.2.1.3 System Availability:

The present manufacturers of solar electric generators offer packaged units with mounting hardware, voltage regulator, batteries and battery housings. An optional accessory is a wire whisker bird chaser to prevent birds from landing on the solar cell array. Some models are hermetically sealed for marine applications.

5.2.2 Capacity:

5.2.2.1 The accepted value of solar radiation constant at normal incidence outside the earth's atmosphere is 136 milliwatts per square centimeter. Approximately one third of this energy is scattered when passing through the earth's atmosphere (Ref. 14). If the remaining 45 milliwatts per square centimeter were to fall at normal incidence upon a pn silicon junction with an area of one square centimeter it would produce approximately 4.9 or 5.0 milliwatts since the efficiency of pn silicon solar cells is now approximately 11%. Cells available at the present time vary from two-inch round modules to eight-inch square modules and can be stacked and connected to provide a variety of voltage and current outputs. Care must be exercised by the manufacturer in stacking the cells to insure that they are matched units. The voltage-current characteristics of a solar panel are seriously degraded unless all of the cells are members of a matched set.

5.2.2.2 The output ratings of solar cells used at present to power solar electric generators are based upon a standard test using a light intensity input value of 100 milliwatts per square centimeter and a cell temperature of 28 degrees C. Under these conditions a single cell will produce a short circuit current of 25 to 30 milliamperes per square centimeter and an open circuit voltage of 0.55 to 0.60 volts. Each degree C. rise in cell temperature will result in a voltage decrease of .0022 volts and will decrease the short circuit current by approximately 0.1 percent.

5.2.2.3 The listed capacity ratings of the units available at present are generally derated from the standard test capacities to approximate the capacities of the units when operating at 60 Degrees C. This derating compensates for the voltage drop experienced on very hot days. In extremely hot climates further derating may be necessary.

5.2.2.4 The sizes and numbers of cells used by the manufacturers of solar electric generators to fabricate their energy collection arrays vary with the manufacturer. Generally, the manufacturers arrange the cells into standard modules containing a number of cells held in a frame. The modules can be connected in series or parallel to produce the desired output voltage and

current. The standard module units available generally produce 6 to 16 volts and 0.5 to 1.0 amperes. The design enables the arrangement of the modules in the energy collection array to produce a wide variety of output capacities and voltages.

5.2.3 Initial Cost:

The cost of solar powered electric power supplies has been in a constant state of flux since their development by NASA. The cost trend has been constantly downward, and at a very fast rate. At the time of this writing panels can be purchased to power navigation aids, radio base stations, alarm systems, telephone amplifiers and other similar loads, at a cost of 20 dollars per watt of installed power. The cost of the battery, mounting hardware and other appurtenant accessories is negligible compared to the cost of the panel, so the 20 dollars per watt may be considered essentially the total cost of the power supply system.

5.2.4 Operation and Maintenance Cost:

Operation and maintenance of a solar powered electric power system is minimal. The panels must be cleaned whenever accumulated dirt, falling leaves, bird droppings and other foreign objects appreciably obstruct the amount of sunlight that falls upon the pn junction. Efficiency of the system can be improved if the panels are re-oriented seasonally to maximize the angle of incidence of the sunlight upon the cells, or the panels may be servo-controlled. If unsealed batteries are used in the system they must be checked periodically to maintain proper electrolyte level.

5.2.5 Training:

The only training involved in operating and maintaining a solar powered electric power system is to facilitate the minimal operating and maintenance chores mentioned in the above paragraph, and to insure that no attempt is made to attach loads to the solar system which will deplete the battery faster than the solar cells recharge it and reduce the battery output voltage to a level that is below the requirements of the emergency load.

5.2.6 Total Life System Cost:

The total life system cost for a solar powered emergency electric power system is essentially the initial cost of the system since the operating and maintenance costs are so small compared with the initial cost.

5.2.7 Monitoring and Control:

The size of the solar panel and the size of the storage battery used in a solar powered emergency electric power system must be selected on the basis of the size of the expected load and the worst-case sunshine expectancy. The amount of energy generated during summer months and fair weather will be far in excess of the worst-case conditions and a voltage regulator must be incorporated into the system to prevent battery overcharge and damage. This regulator will constitute the major control element of a solar powered emergency electric power system. An ammeter and voltmeter can be incorporated into the system to monitor the charging and discharging rates and battery voltage to insure that system capacity is not exceeded by load demands.

5.2.8 Safety Considerations:

There are no unusual features of a solar powered emergency electric power system that merit special safety considerations.

5.2.9 Environmental and Physical Facility Considerations:

The solar panel must be mounted where it will not be in the shadow of objects such as mountains, buildings, trees, etc., if possible. If shadows cannot be avoided the loss of power that results from the shadow must be taken into consideration when selecting the panel size. The panel should be mounted where drifting snow will not obscure it. In areas of high snow incidence the tilted position necessary for the array to operate will tend to keep falling snow from collecting on it. Clear ice collecting on the panel will have only a small effect, but severe icing can cause structural failure and must be avoided. A direct lightning strike can cause structural damage to panels and ruin associated wiring; therefore, a panel should be placed within the cone of protection of the lightning protection system at a site. In desert areas blowing sand will sandblast the face of the array to the point that it becomes milky white, but this will have a very small effect upon power output.

5.2.10 Lifetime and Reliability Estimates:

The lifetime and reliability of solar panels is far in excess of the lifetime and reliability of any associated electrical and electronic devices. Batteries incorporated into solar powered emergency electric power systems will need to be replaced periodically.

5.2.11 The major manufacturers of solar electric generator units are listed below:

Spectrolab, Incorporated; A Subsidiary of Hughes Aircraft Company
SES, Incorporated
Motorola
Solarex Corporation
Sensor Technology

5.3 Thermoelectric Powered Generators:

5.3.1 General:

Thermoelectric generators employ heat produced by the catalytic oxidation (flameless burning) of propane, butane or natural gas to produce electricity with a thermopile. A thermopile is a number of thermocouples connected in series to produce useful levels of voltage and current by Seebeck effect. Thermoelectric powered emergency power systems consist of a thermoelectric generator, a voltage regulator and a battery. Inverters may be included to convert the battery output to A.C. power. In some installations the generator supplies the load directly. In other instances the generator charges the battery which in turn supplies power to the load. In very cold environments the waste heat from the heat source may be utilized to control the temperature in the space enclosing the electrical or electronic equipment, and even the living and working quarters at the facility.

5.3.2 Applications:

The general applications for thermoelectric generators are remote unattended locations where a continuous source of power is required and environmental conditions which preclude the use of solar or wind power units. Butane/propane fuel is normally used to power thermoelectric generators. Care must be exercised in unusually cold climates to prevent freezing of moisture in the fuel lines or pressure regulator and care must be exercised to use a propane to butane mix that will develop sufficient vapor pressure to operate the thermoelectric generator.

5.3.3 Capacity:

Approximately 30 minutes is required for the thermoelectric generator to come up to 90 percent of output capacity from a cold start and approximately 45 minutes is required to reach 100 percent of output capacity from a cold start. The thermoelectric generators available at present must be operated at more than 70 percent of their rated maximum output capacity for stable operation. The capacity increments of the units which are available at present are tabulated under paragraph 5.3.12.2 below.

5.3.4 Initial Cost:

The initial cost of thermoelectric generator units available at present will range from approximately 100 to 150 dollars per watt of output capacity in the 10 to 30 watt capacity range. The present initial cost of units in the 30 to 100 watt capacity range is approximately 50 to 60 dollars per watt of rated output capacity. Capacity requirements above 100 watts are met by using more than one unit. The cost of the thermoelectric generator unit is the major initial cost of an installation. The units may be bracket mounted on walls or posts or on any reasonably firm foundation and the cost of the hardware and labor required for the installation is minimal unless lengthy fuel lines are required. The initial cost must include the cost of any batteries required. Available optional accessories include a volt-ampere meter and a pyrometer for use in adjusting the burner at approximately 60 dollars each. Some units have a reverse diode built into the unit to enable adding a battery to the installation. If a battery is to be used and this diode is not included it must be added at a cost of approximately 15 dollars.

5.3.5 Operation and Maintenance Cost:

The cost of maintaining and operating a thermoelectric emergency power system is mainly fuel cost since there are no moving parts to lubricate or wear out and replace. If the unit becomes overheated due to inaccurate pressure regulation the catalytic converter may become damaged and have to be replaced. Transportation costs for replenishing the fuel supply periodically can be significant if the system is located in a remote location with difficult access. Fuel consumption of a thermoelectric generator is approximately one pound per week per watt of power output, but this is dependent upon the BTU content of the fuel, the temperature of the cold junction and the percentage of maximum output power being developed by the generator.

5.3.6 Training:

The principal operator functions for a thermoelectric emergency power generator are to maintain the fuel supply, keep the air inlet and exhaust openings free from obstructions and adjust the fuel pressure. The fuel pressure determines burner temperature; therefore, electric energy output. If the burner becomes overheated it may be ruined. If there is a battery in the installation the electrolyte must be periodically replenished unless the battery is sealed. The operating training for these tasks is simple and training courses are offered by the manufacturers of the thermoelectric generators.

5.3.7 Total Life System Cost:

The total life system cost for a thermoelectric generator is a function of fuel cost, initial installation cost and the replacement cost of any burners that are damaged by overheating.

5.3.8 Monitoring and Control:

Once installed and adjusted, a thermoelectric generator should operate as long as the fuel supply lasts and air flow is not impeded. Care must be exercised that the energy output is not taxed beyond the capabilities of the system by adding electrical loads that are greater than the electrical supply capabilities of the thermoelectric generator. If the system contains a battery the reserve capacity of the battery can be used to supply power levels beyond the generating capacity of the thermoelectric generators for short periods of time. The depletions of the battery charge during such periods must be offset by additional time allotted to recharging the battery. Ammeters and voltmeters in the system will permit such an operation. A pyrometer is a useful monitoring device to enable accurate burner adjustment and to assure that burner over temperature limits are not exceeded.

5.3.9 Safety Considerations:

No special safety precautions are necessary other than normal precautions that should be observed in handling fuel, electrical circuits and batteries.

5.3.10 Environmental and Physical Facility Considerations:

The manufacturers of thermoelectric generators recommend them for installations exposed to the weather. Ambient temperature limits are sub-zero to 155 Degrees F. and the wind velocity limit set by one manufacturer is 70 MPH. The cooling fins of the units require an unobstructed convective current of air to dissipate the unit's heat to the atmosphere. The units require a sufficient supply of air to support the combustion of the fuel.

5.3.11 Lifetime and Reliability Estimates:

Thermoelectric generators have not been in use for a sufficient period of time in sufficient numbers to establish a reliable record of the lifetime that may be expected from the units. The small amount of life expectancy information available appears to indicate a useful lifetime of five to ten years. The reliability of the units may be estimated based upon the manufacturer's history of the operation of the units. Estimates of useful lifetime or reliability of these units must include consideration of the environment of the installation, the fuel type and the control devices required, especially the method of regulating the fuel pressure to prevent over heating the unit.

5.3.12 Availability and Characteristics:

5.3.12.1 Thermoelectric generators are available in the United States from Teledyne Isotopes in Timonium, Maryland; and from Global Thermoelectrics in Bassano, Alberta, Canada. Global Thermoelectrics recently purchased the manufacturing rights and product line of thermoelectric generators that were developed and sold by the 3M Electrical Products Division of Minnesota Mining & Manufacturing Co. The thermoelectric generators available from these sources can be connected in multiples to produce voltage and power levels higher than can be produced by individual units.

5.3.12.2 The characteristics of the thermoelectric electric power generators that are currently available are tabulated below:

Mfgr.	Watts Output	Voltage Output	Weight (Lbs.)	Size (L, W & H in Inches)
Global	15	12	31	12 X 18 X 12
Global	15	24	31	12 X 18 X 12
Global	24	12	50	12 X 18 X 30
Global	24	24	50	12 X 18 X 30
Global	50	12	130	16 X 21 X 38
Global	50	24	130	16 X 21 X 38
Global	108	12	300	32 X 25 X 36
Global	108	24	300	32 X 25 X 36
Teledyne	8	12	33	19 X 11 X 17
Teledyne	8	24	33	19 X 11 X 17
Teledyne	8	48	33	19 X 11 X 17
Teledyne	16	12	52	14 X 25 X 17
Teledyne	16	24	52	14 X 25 X 17
Teledyne	16	48	52	14 X 25 X 17
Teledyne	29	12	73	23 X 25 X 17

5.4 Wind Energy Powered Generators:

5.4.1 General:

Wind has been used as a source of power since antiquity (Ref. 2). Wind-driven generators manufactured by Windchargers, Jacobs and Delco were rather common in the United States from the late 1920's through World War Two, then their use dwindled due to the advent of inexpensive and versatile portable gasoline fueled engine-generator sets. Today, the fuel shortage has sparked renewed interest in wind powered generators and prompted numerous research and development programs in government, industrial and private sectors (Ref. 3). Some users of emergency power units in the United States have imported wind powered generators from Switzerland and Australia. All wind energy powered generator installations consist of a device to capture the energy of the wind and produce rotation of a shaft which in turn drives an alternator or a generator.

5.4.2 Equipment Sources:

Currently, there are two manufacturers in the United States supplying wind energy powered electric generators that are capable of serving as emergency electric power sources. Units available from each of these manufacturers will provide useful power output at a relatively low wind velocity — 7 or 8 MPH — and reach maximum output capacity at 20 to 22 MPH. Both have a means to prevent physical and electrical damage to the installation at high wind velocities. The user of a wind powered emergency electric power generator is at the mercy of the wind and a battery must be included in the installation to provide electric power output in the absence of adequate wind velocity. The two sources for wind powered emergency electric power supplies in the U.S., at present, are North Wind Power, Inc., and Dyna Technology, Inc.

5.4.3 Future Improvements Expected:

The numerous research and development projects in this area are bearing fruit and more extensive use of wind energy powered generators will be seen in the future, especially in locations where their added complexity, compared to solar units, is warranted due to lack of the sunshine needed by solar powered generators.

5.4.4 Capacity:

Wind powered electric power generators cannot be added in series, or series-parallel, as easily as solar and thermoelectric generators, and cannot be added in parallel as easily as engine generators; therefore, their use is normally confined to applications where a single wind powered generator will suffice for the load demand. One unit, commercially available at present, produces 200 watts of power at 12 volts D.C. in a 23 MPH wind and will commence producing useful power in a 7 MPH wind. A unit produced by another manufacturer produces electrical power in the 2 kilowatt to 3 kilowatt range, starts producing useful power in an 8 MPH wind and will produce maximum output in a 20 MPH wind.

5.4.5 Initial Cost:

The initial cost of a wind powered electric power system is the summation of the cost of a site survey (which is essential to determine the wind power potential of the site), the cost of the generator, propeller and governor, the cost of the structure to support the generator assembly above obstructions and high enough to prevent danger to humans from the revolving propeller, the cost of installing the generator-tower assembly, the cost of a voltage regulator and the cost of the battery.

5.4.6 Operation and Maintenance Cost:

The only operation and maintenance costs incurred with a wind powered electric power system are the cost of battery upkeep and periodic maintenance, which is similar to that of battery costs with solar and thermoelectric systems, and the cost of periodically replacing the brushes in the generator.

5.4.7 Training:

The simplicity of wind powered electric power systems, as with thermoelectric and solar systems obviates the necessity of special training.

5.4.8 Total Life System Cost:

The total life system cost for a wind powered emergency electric power system is essentially the initial cost of the system since the operating and maintenance costs are so small compared with the initial cost. If the generator and propeller assembly are mounted on a tall tower some expense will be incurred in having a professional tower climber change the brushes in the generator.

5.4.9 Monitoring and Control:

The capacity of the generator and propeller assembly and the size of the storage battery used in wind powered emergency electric power system must be selected on the basis of the size of the expected load and the worst-case wind expectancy. The amount of energy generated during windy seasons will be far in excess of the worst-case conditions and a voltage regulator must be incorporated into the system to prevent battery overcharge and damage. This regulator will constitute the major

control element of a wind powered emergency electric power system. An ammeter and voltmeter can be incorporated into the system to monitor the charging and discharging rates and battery voltage to insure that system capacity is not exceeded by load demands.

5.4.10 Safety Considerations:

Extreme care must be taken to insure that no individual and no objects come into the path of the rotating propeller, especially as it swings around the tower when the direction of the wind changes. Care must be exercised in climbing towers to replace generator brushes.

5.4.11 Environmental and Physical Facility Considerations:

Tower height and placement is the most critical factor in a wind power installation. A rule of thumb to determine the correct tower height is that the tower should be 20 feet above any obstruction within 500 feet (Ref. 15). Wind speeds at 40 feet above the ground can be as much as 50% stronger than the ground winds. Since the power from the wind is proportional to the cube of the wind velocity, correct tower height can significantly affect the amount of electric power a system will produce. Tower structural considerations must take into account the danger of icing and if severe icing conditions are possible precautions must be observed concerning falling ice. A site survey using a wind spectrum analyzer to determine the available wind power at a site is essential to sizing a wind power emergency electric system. The wind power spectrum as a function of time will determine the size of the generator and propeller assembly and the size of the storage battery necessary for a given emergency load.

5.4.12 Lifetime and Reliability Estimates:

Insufficient data is available to accurately estimate the lifetime and reliability of the wind powered systems presently available. The batteries incorporated into wind powered emergency electric power systems and the generator brushes will need to be replaced periodically.

5.5 Sea Energy Powered Generators:

5.5.1 General:

At present there is a broad spectrum of ideas for harnessing the energy potential of the sea. None of these have been developed to the point that they will provide a practical emergency electric power source today. They may be sufficiently developed in the future to be considered for emergency power for nuclear facilities installed on platforms or barges at sea. These techniques are:

5.5.1.1 Thermal Gradients — Many locations in the world's oceans have a temperature gradient of more than 15 or 20 Degrees C. between surface water and water at greater depths. This temperature gradient is sufficient to power a heat engine using a working fluid such as ammonia which would drive a generator (Ref. 3).

5.5.1.2 Wave Energy — Use of buoys or drogue chutes to develop useful mechanical energy from the motion of ocean waves is being currently investigated at several research locations in the United States (Ref. 4). The mechanical energy could be converted to electrical energy by appropriate connection to a generator or alternator.

5.5.1.3 Tidal Power — Passamaquoddy Bay in Maine and Cook Inlet in Alaska are being investigated for major power development, and these are the only two locations in the U.S. where tide level variations and flows are considered large enough for major power developments (Ref. 5); however, other locations near nuclear facilities may be suitable to produce lesser quantities of power that could be useful as special emergency electric power sources.

5.5.2 Capacity:

The capacity of wave energy generators, when they become available will be a direct function of user demand.

5.5.3 Initial Cost:

The initial cost of wave energy powered generators will probably be extremely high. If a wave energy powered emergency electric generator system is to be used as a reliable source of emergency power, a battery capacity equal to the total expected demand will be required since sufficient wave action to provide the necessary power cannot be relied upon to be available when needed.

5.5.4 Operation and Maintenance Cost:

The main difficulties that will be experienced with wave energy powered generators will be the effect of the environment, especially stormy seas, upon the devices. Normal operation and maintenance will probably consist of the prevention of corrosion and fouling of the structure by barnacles and other sea animals.

5.5.5 Training:

It is predicted that training in the care and maintenance of wave energy powered electric generators will be minimal, but special training will be required in cleaning and repair.

5.5.6 Total Life System Cost:

The total life system cost of a wave energy electric power generators will be determined by the initial cost of the generator, voltage regulator and battery and the cost of periodic cleaning and repair.

5.5.7 Monitoring and Control:

Little can be said about monitoring and control until commercially constructed devices become available.

5.5.8 Safety Considerations:

The same statement as 5.5.1 above also applies to safety considerations.

5.5.9 Environmental and Physical Facility Considerations:

The principle difficulty that will be experienced with wave powered generators will be the extremely wide spectrum of sea states that must be encountered by such devices. They will have to be constructed to generate useable power with gentle swells and with breaking seas, yet they must be able to withstand the onslaught of high sea states. The construction of wave powered generators must take into account the accumulation of marine life and the corrosive and sometimes violent environment in the sea to prevent incurring inordinately high maintenance and repair costs.

5.5.10 Lifetime and Reliability Estimates:

The lifetime and reliability of a wave energy powered generator will be dependent upon the construction of such devices and their ability to withstand rough seas. Little can be said on this subject until such devices become available.

5.6 Battery Power:

5.6.1 General:

Batteries are the most convenient source of a limited amount of D.C. power. The selection of a battery for a particular application involves compromises and tradeoffs. Theoretically, a battery can be constructed, using commercially available battery cells, to store any desired amount of power and to deliver that power at any desired voltage and current output; however, the size, weight and cost of such a battery could be prohibitive. The U.S. Department of Justice, under the Law Enforcement Standards Program, commissioned The National Bureau of Standards to compare the performance characteristics of batteries normally used with communication equipment which are the same batteries normally used with security systems. The result (Ref. 17) is a useful pamphlet which presents a thorough set of definitions of terms, comparisons of characteristics, and suggestions for selecting and using batteries. Batteries are usually grouped into three classifications — primary, secondary and reserve.

5.6.2 Primary Batteries:

Primary batteries are designed to deliver their stored power in a continuous or intermittent discharge. They cannot be recharged efficiently. The amount of energy a primary battery will deliver is determined by the materials used in their manufacture and the size of the cell. When the available energy drops below the point that the battery will deliver a useful voltage/current ratio to the load the battery is usually discarded. The use of primary batteries as a source of emergency power for security and materials accountability operations is probably limited to their use in hand held flashlights and other similar uses by the fact that they may not be efficiently recharged. Even this type of usage may be made obsolete by the availability of rechargeable batteries for such applications. Primary batteries may be classified by the type of electrolyte used (Ref. 7):

5.6.2.1 Aqueous-Electrolyte batteries use solutions of acids, bases, or salts in water as the electrolyte. These solutions have ionic conductivities around 1 MHO per cm and almost negligible electron conductivity. Examples of this type of battery are the Leclanche cell and the alkaline-manganese-zinc cell, both of which are used in the well-known flashlight battery.

5.6.2.2 Solid-Electrolyte batteries are electrolytes composed of solid crystalline salts that have predominantly ionic conductivity. Solid-electrolyte batteries may be classified in two categories: cells with solid crystalline salt as the electrolyte and cells with an ion-exchange membrane as the electrolyte. The conductivity of either of these types of solid-electrolyte batteries must be nearly 100% ionic as any electron conductivity will cause a continuous discharge of the cell and shorten shelf life. The lead-lead chloride-silver chloride cell is a typical example of a solid crystalline salt electrolyte battery. One cell of such a battery will produce a voltage potential of 0.49 volt and they have been stacked to deliver 90 to 100 volts at 10 microamps with a capacity of 1 amp-second. Such a battery is about 3/8

of an inch in diameter and 1 inch long. A representative of the ion exchange membrane battery is the zinc-silver battery which produces a voltage potential of about 1.5 volts. The capacity of such batteries is approximately 0.4 amp-hour per cubic inch of volume.

5.6.2.3 Wax-electrolyte batteries use waxy materials, in which a small amount of a salt is dissolved. The conductivity of these batteries is low and the current output is limited to approximately 1 microamp per square inch. A 25-cell stack zinc-polyethylene glycol-manganese dioxide battery 0.34 inches in length and 0.25 inches square weighs 1.5 grams and provides an output voltage potential of 37.5 volts.

5.6.2.4 Fused-electrolyte batteries use crystalline salts, or bases, which are solid at room temperature and are used while heated to a temperature above the melting point of the electrolyte.

5.6.3 Secondary Batteries:

Secondary batteries, commonly called storage batteries, are the predominant portable energy source in the United States today. Their usefulness in communication and alarm systems is enhanced by the fact that a secondary battery floated across the line between a solar or thermionic cell and an electronic device will suppress the radio interference noise inherent in these types of electric power sources. A storage battery is composed of one or more identical voltaic cells in which the electrochemical action is reversible so the battery can be recharged by passing a direct current through the cells in the opposite direction to that of discharge (Ref. 8). The availability and variety of secondary batteries have been developed to the point that they are replacing the use of primary batteries at an ever-increasing pace, including their use in the hand-held flashlight. There are two general classifications of secondary batteries — lead-acid and alkaline:

5.6.3.1 Lead-acid batteries are most commonly found as the starting battery of U.S. automobiles. They are composed of lead sponge and lead peroxide plates immersed in sulfuric acid. They develop 2.0 volts per cell when fully charged and produce 10 to 15 watt-hours of energy per pound of weight and 0.6 to 1.3 watt-hours of energy per cubic inch of volume. The lead in lead-acid batteries is hardened by the addition of 1.5 to 5% antimony or calcium. Batteries used in U.S. automobiles use the antimony hardener which provides the battery with an improved tolerance for high ambient temperatures and enables rapid recharging. When batteries with the antimony hardened plates are floated across the line the charges on the individual cells become unequal and periodic equalizing charges must be applied. Batteries with calcium hardened plates require slower charging rates than those with the antimony hardener. Batteries with calcium hardened plates may be floated across the line for long periods without equalizing as long as a charge of approximately 2.25 volts per cell is maintained. Lead-acid batteries are used to provide starting power for engine generators, to furnish power to the load for short periods until the engine generator reaches operating speed, and to supply power to electronic equipment when no other power source is available. Lead-acid batteries are generally available in 6 and 12 volt assemblies with output capacities of up to 200 ampere-hours.

Care must be exercised in specifying battery capacity and the capacity should be specified at a definite discharge rate. The slower the discharge rate specified the thicker the individual plates in the battery can be. The thicker plates provide a longer life expectancy of the battery.

5.6.3.2 Alkaline storage batteries employ nickel and iron, or nickel and cadmium or silver oxide and zinc plates immersed in an alkaline solution. The nickel-iron battery is known also as the Edison battery. It is lighter in weight than a lead-acid battery of equal capacity, and has a longer life because there is no chemical deterioration during charging. The Edison battery is commonly used as an emergency electric power source in industrial, alarm and communication applications. The nickel-cadmium batteries are commonly found in pocket calculators, hand-held portable radio transceivers and similar devices where a reliable, compact source of energy is required. Care must be exercised in cycling nickel-cadmium batteries from charge to discharge to charge or the capacity of the battery is greatly reduced. One nickel-cadmium cell will produce an output voltage of 1.28 to 1.15 volts during the useful discharge portion of its cycle. The silver-zinc battery has been used widely in military and space applications due to its high stored energy to weight ratio and its constant 1.45 volt output over the major part of the discharge portion of its cycle. The silver-zinc battery is the most expensive storage battery commercially available. Extreme care must be taken when charging the battery to develop a full charge and not destroy it due to the flat voltage vs. charge characteristics of this type battery.

Alkaline storage batteries employing nickel and iron were formerly used in large battery banks to provide standby power for telephone and alarm systems; however, few (if any) companies still manufacture this type of battery as the functions they used to fulfill are now being fulfilled by the lead-acid battery with the calcium hardener discussed above.

Nickel-cadmium batteries are becoming ubiquitous and are used in toys, games, flashlights, hand-held radios, calculators, etc. They are reliable, rechargeable and can be assembled to deliver any voltage-current capacity required, but they are much more expensive than the lead-acid battery; therefore, only used in applications where it is impractical to employ the lead-acid battery with its corrosive liquid electrolyte.

5.6.4 Reserve Batteries:

Reserve batteries transcend the primary and secondary classifications used above. A reserve battery is one which remains inert until it is activated. Initiation methods to activate reserve batteries include the puncture of a seal, the rupture of a membrane, the addition of an electrolyte, the application of heat to melt the electrolyte and other methods. Fused-electrolyte batteries can be considered to be reserve batteries. The main advantage of all reserve batteries is their extremely long shelf-storage life without deterioration.

5.6.5 Future Improvements Expected:

Technological improvements of batteries are continually being developed. Battery life and battery storage capacity are generally increasing and battery size and cost are generally decreasing. A wide variety of types and sizes of batteries is available at present and the availability of additional types and sizes is increasing rapidly. The

use of batteries for short-term energy sources will continue to increase in the future. The characteristics of existing commercially available batteries presented below are limited to secondary batteries of the types and sizes normally used as emergency power sources for components of security systems.

5.6.6 Initial Cost:

The initial cost of a battery power system includes the cost of the battery cells plus the cost of the charging and switchover circuitry and equipment. Normally, the cost of the battery cells is the predominant factor and is directly proportional to capacity. The cost of a nickel cadmium battery is 3 to 4 times that of a lead-acid battery of equivalent capacity.

5.6.7 Operation and Maintenance Cost:

A major advantage of battery powered emergency power systems is that they require very little, if any, maintenance. Some types of batteries must be checked periodically for electrolyte level and lead-acid batteries with antimony hardened plates require periodic equalizing charges.

5.6.8 Training:

Training in battery care usually consists of instruction in the method of checking electrolyte level and normal precautions in handling the electrolyte.

5.6.9 Total Life System Cost:

The major component of the total life system cost of a battery system will be the initial installed cost of the batteries since the maintenance and operating costs are very minimal.

5.6.10 Monitoring and Control:

Monitoring and control of a battery installation must include provisions to prevent battery overcharge, maintain proper trickle charge rate, prevent excessive rates of charge and discharge and prevent the discharge from exceeding the design limits of the battery. Some of these monitoring and control features are automatically incorporated into the device that employs the batteries and sometimes, in large battery installations, these monitoring and control features require alarms and manual control, or manual control over-ride features.

5.6.11 Safety Considerations:

Battery safety includes proper venting of lead-acid batteries to dispose of the hydrogen gas that is generated during the charging cycles, prevention of accidental shorts across the battery terminals and proper handling of acid electrolyte.

5.6.12 Sources:

The telephone directory of almost any U.S. city will list battery manufacturers and/or distributors. In many cases local manufacturers produce excellent products. A few of the larger U.S. battery manufacturers are listed below:

Acme Battery Corp.
Alexander Mfg. Co.
Bright Star Industries
Burgess Inc.
Chromalloy American Corp.
Electra Corp., Prestolite Battery Div.

Electrolite Battery Co.
 E.S.B. Incorporated, Ray-O-Vac Div.
 Exide Power Systems Div.
 Gates Energy Products, Inc.
 General Electric Co., Battery Business Dept.
 Globe International Corp.
 Globe-Union Inc., Globe Battery Div.
 Gould Inc., Industrial Battery Div.
 Gould Inc., Portable Battery Div.
 Gulton Battery Corp.
 Hughes Aircraft Co.
 Ideal Battery Co.
 Mallory Battery Co.
 McGraw-Edison Company, Edison Battery Div.
 Mule Battery Co.
 Ramsey Engineering Co.
 S.G.L. Batteries Mfg. Co., Dept. SM
 Singer Products Co.
 Solfan Systems Inc.
 Standard Electric Co.
 Surrence Storage Battery Co. Inc.
 Union Carbide Corp., Battery Product Div.
 Varta Batteries
 Yardney Electric Corp.

5.6.13 Environmental and Physical Facility Considerations:

Batteries should be installed in a facility that will insure that the minimum and maximum environmental operating temperatures of the batteries will not be exceeded. Physical protection should be designed into the installation to preclude the possibility of short circuiting the battery and, if the battery is not "maintenance free", to provide ease of checking electrolyte level and adding electrolyte when necessary. Devices which produce sparks, or could otherwise ignite the hydrogen gas produced by the batteries should not be installed in the same area as the battery bank. The standard ambient temperature for rating stationary lead-acid batteries is 25 Degrees C. The discharge capacity of the batteries is reduced as the ambient temperature falls below 25 Degrees C. and battery life is shortened as the temperature rises above that standard rating temperature. Achievement of the best life expectancy for lead-acid stationary battery systems requires an average ambient temperature in the range of 15 to 30 Degrees C. Solid freezing of the battery electrolyte is rare because as the water in the electrolyte freezes the specific gravity of the liquid is increased by the increased ratio of acid to the liquid water. Slush ice is formed in the electrolyte as the water freezes and the formation of ice crystals can permanently damage the positive plates. A discharged battery is more susceptible to freezing than one with an adequate charge. Slush ice may begin to form in a discharged battery at a temperature of approximately minus 9 Degrees C. while the freezing may not start in a battery with an adequate charge until the temperature drops below approximately minus 29 Degrees C. The major battery manufacturers publish data concerning physical and environmental requirements and offer special electrolytes and other provisions to compensate for environmental conditions.

5.6.14 Lifetime and Reliability Estimates:

A lead-acid battery bank that is designed for the service that is imposed upon it in terms of charge rates, discharge rates, temperature, depth of discharge, etc., will last from 10 to 25 years. If any of the design limits are exceeded the life expectancy of the battery will be seriously shortened. For example, the Bell Telephone Company warns that the lifetime of a lead-acid battery bank will be cut in half if the temperature in the room housing the bank goes over 90 Degrees F. more than 30 days a year.

5.7 Hydro-Electric Powered Generators:

5.7.1 General:

5.7.1.1 Hydro-electric power generation facilities normally require very large and complex installations and are not generally feasible for use as emergency electric power sources; however, the technique has been used by private individuals in isolated locations to build domestic electric power supply systems. It is conceivable that a nuclear installation near a satisfactory head of water could utilize the potential energy of the water for emergency electrical power generation.

5.7.1.2 There are no sources of hydro-electric powered generators that are suitable for use as emergency electric power generators known to be available at the present time. The North Wind Power Company in Warren, Vermont advertises that they offer a service to those who wish to seriously explore the potential for water power on their sites. This service includes a determination of the potential horsepower in the stream based upon head and flow, a recommendation on the optimum location for the impoundment and for the turbine, an explanation of system costs and a determination of applicable state regulations regarding proposed stream alterations.

5.7.1.3 It is not expected that hydro-electric powered generators can compete with the more prevalent techniques discussed above in emergency electric power generation any more in the future than they can today.

5.7.2 Capacity:

The capacity of a hydro-electric powered generator is limited by the head of water that can be developed and the average flow that can be sustained.

5.7.3 Initial Cost:

The initial cost of a hydro-electric powered generator will be the summation of land acquisition cost for the impoundment area, the cost of the impoundment and the cost of the turbines, generators, regulators and batteries.

5.7.4 Operation and Maintenance Cost:

The operation and maintenance cost of a hydro-electric powered generator will be determined by the cost of maintaining the turbine(s) and generator(s), the cost of periodic battery replacement and the cost of maintaining the impoundment area.

5.7.5 Training:

The cost of training will be determined by the size and activities of the installation.

5.7.6 Total Life System Cost:

The total life system cost for a hydro-electric power generator system is a complex combination of initial cost, operation and maintenance cost, and system life.

5.7.7 Monitoring and Control:

Monitoring and control is a function of system design and little worthwhile discussion can occur until systems suitable for emergency power use are designed and become commercially available.

5.7.8 Safety Considerations:

The statement in the above paragraph also applies to safety considerations.

5.7.9 Environmental and Physical Facility Considerations:

The most difficult problem with a hydro-electric generator will be the construction and use of the impoundment area. There are few potential hydro-electric power sites left where permission can be obtained to construct a dam.

5.7.10 Lifetime and Reliability Estimates:

Hydro-electric power can be an extremely reliable power source. The length of time estimated for the impoundment area to silt to the point that it is unusable will be a major factor in the life expectancy of the system.

5.8 Inertially Powered Generators:

5.8.1 General:

5.8.1.1 The emergency electric power unit shown in Figure 3 depends upon a rotational mass for the short term supply of energy. Experimental transit buses use dynamic braking to store energy in a flywheel which is returned when the driver of the bus calls for acceleration. Some electric public utility companies are considering the use of flywheels to store energy during off-peak periods for delivery during peak periods (Ref. 6). No complete emergency electric power generating units are available today which rely solely upon inertial energy storage, but the technique has been employed on a limited basis as a system component in the past and may be more utilized in the future.

5.8.1.2 Inertially powered electric generators are usually encountered as a component of an emergency electric power system. Their normal use is to store power for instant availability and for use over a comparatively short period of time. Current interest in inertially powered electric generators is indicated by the special conference on this subject sponsored by ERDA and USPS (Ref. 16).

5.8.1.3 Inertially powered generators will continue to be useful to produce energy for very short intervals as part of UPS units. There is little, if any, ongoing developmental work for the application of inertially powered units to electric power supplies.

5.8.2 Capacity:

The capacity of an inertially powered electric generator component is determined by the mass and maximum rotational speed of the flywheel. The limit to the capacity will be determined by the capacity of the system into which it is incorporated.

5.8.3 Costs:

The cost of the inertially powered electric generator component will be included in the cost of the electric power supply system in which it is incorporated. Sufficient reliable cost data that is generally applicable to inertial generators is not presently available.

5.8.4 Monitoring and Control:

The monitoring and control of an inertially powered electric generator will normally be part of the monitoring and control of the overall electric power supply system.

5.8.5 Safety Considerations:

An inertially powered electric power system relies upon a rotating flywheel which must be fully enclosed and, if the system uses extremely high rotation speeds, must be arranged to insure that no damage to personnel will result in the event of a structural failure of the flywheel.

5.8.6 Environmental and Physical Facility Considerations:

This subject is not pertinent to inertially powered emergency electric power generators since it is a function of the overall system into which the inertial system is incorporated.

5.8.7 Lifetime and Reliability Estimates:

The lifetime and reliability of an inertial system will be much greater than the lifetime and reliability of the system into which it is incorporated.

5.9 Nuclear Powered Generators:

5.9.1 General:

5.9.1.1 Two types of small nuclear electric generators have been developed. One is a high voltage type using a Beta-emitting isotope separated from a collector by a vacuum or high dielectric solid which produces thousands of volts, but current only in the micromicroamperes range at an EMF of about 1 volt. The second type employs one of three techniques: thermoelectric, ionic transportation of charge between dissimilar metals or a two-step conversion of Beta energy into light via phosphorescence then conversion of the light energy into electricity by a photocell (Ref. 13).

5.9.1.2 The long life and reliability of these types of electric power generators are very attractive, but their cost and low energy output level limits their use to very special applications and it is not believed that their use is generally applicable to providing an emergency power source for fuel cycle and reactor facilities security systems.

5.9.1.3 There are no nuclear powered electric generators commercially available that supply the power levels necessary for alarm or communication systems.

5.9.2 Capacity:

The capacity of nuclear powered electric generators is in the microampere range.

5.9.3 Cost Considerations:

The cost of nuclear powered electric generators is extremely high.

5.9.4 Monitoring and Control:

Normally no control of a nuclear powered electric generator is required as the output is constant and can be operated open-circuit, but no damage results if the output is short circuited.

5.9.5 Safety Considerations:

The principal safety consideration of a nuclear powered electric generator is the necessary shielding which is incorporated into the design and fabrication of the unit.

5.9.6 Environmental and Physical Facility Considerations:

A nuclear powered electric generator is a sealed unit and can be used in practically any environment.

5.9.7 Lifetime and Reliability Estimates:

The lifetime of a nuclear powered electric generator is entirely dependent upon the half-life of the isotope used as the radiating source.

5.10 Fuel Cells:

5.10.1 General:

Fuel cells produce electric energy directly from a catalyzed electrochemical reaction harnessed in a galvanic cell. Fuel cells are in the prototype phase of their development at present and are not commercially available for use in emergency electric power systems. The basic characteristics of the existing prototype systems are discussed below.

5.10.2 Capacity:

Most existing prototype fuel cells have capacities in the range of 200 to 500 watts. A few prototypes have capacities up to 15 KW and one system being studied is expected to have a 100 KW capacity. Current densities available in the prototypes range approximately from 50 to 100 milliamps per square centimeter.

5.10.3 Initial Cost:

The initial cost of reproducing the existing prototype fuel cells is estimated to be at least 1000 dollars per KW of rated output. The high cost is largely attributable to the cost of the rare metals required for the catalyst and the need for materials in the equipment that can withstand rather high temperatures and resist corrosion. The catalysts used at present are mainly platinum, silver, nickel, cobalt and palladium.

5.10.4 Operation and Maintenance Cost:

Very little information on operation and maintenance costs of fuel cells is available at present. Most of the available information consists of estimated costs for specific designs and is not applicable except for the particular design. It is obvious that operating costs will include the cost of the fuels. Some of the fuels being used in prototype systems at present are hydrogen and oxygen, hydrazine and air and ammonia and air. Other fuel combinations are being considered. Most are composed in whole or in part of the combustibles hydrogen, carbon monoxide, methane, ethane, propane, butane and oil vapors and sometimes, of mixtures containing the inerts

nitrogen, carbon dioxide and water vapor. It is predicted that maintenance costs will include the cost of corrosion preventative measures and the cost of replacing equipment components damaged by corrosion.

5.10.5 Training:

As fuel cells are developed further and become available commercially it is predicted that operation of the systems will not require highly specialized training but that personnel involved in the maintenance and repair of the equipment will need to be thoroughly trained.

5.10.6 Total Life System Cost:

The total life system cost of fuel cells will include the initial equipment installation cost, fuel costs, maintenance cost, component replacement cost and the cost of disposing of the excess heat and unused products of the chemical reaction of the system process.

5.10.7 Monitoring and Control:

The controls required for the present systems include devices to control the flow and pressure of the fuels, the disposal of the excess heat of the reaction and the draw-off of the unused product of the reaction which is generally water. One of the most important control requirements is to maintain a working temperature at which the electrolyte is not decomposed and the material does not become too susceptible to corrosion. A critical control requirement in the hydrogen-oxygen units is to maintain a working pressure such that the gas is not forced to bubble through the electrolyte to create the danger of an explosion.

5.10.8 Safety Considerations:

As the fuel cell units are developed and made available commercially it is anticipated that safety provisions will be concurrently developed and published.

5.10.9 Environmental and Physical Facility Considerations:

The statement above is also applicable to environmental and physical facility requirements.

5.10.10 Lifetime and Reliability Considerations:

The lifetime and reliability of fuel cells will depend largely upon the materials used in the construction of the units and their resistance to the corrosive environment and relatively high temperatures inherent in the process if the present state of the technology is applicable to the units that become available. Considerable research is being conducted regarding operating temperatures ranging from 25 Degrees C. to 1000 Degrees C. with a variety of fuels and processes. Sufficient data has not been developed to predict the lifetime and reliability of fuel cell units that may become available commercially.

5.10.11 Some of the firms and organizations known to be involved in fuel cell development at present are listed below:

General Electric
Allis-Chalmers
Bacon
Monsanto Research Corporation
M.W. Kellogg Company

Armour Research Foundation
Westinghouse Electric
Engelhard Minerals and Chemicals Corporation
Union Carbide
United Aircraft
Electro-Optical Division of Xerox

6. SYSTEM CONCEPT CONSIDERATIONS - GENERAL

The design of an emergency electric power system must be generated by the application of system engineering principles, not by an attempt to select generators, batteries and prime movers to supply a given amount of electric power when "the lights go out." This entails determining objectives and requirements, then synthesizing the required system. The synthesized system must be analyzed in light of the requirements and the design modified, improved and optimized as indicated by the analysis. After the iterative application of the above process has been completed the system can be specified and procured (Ref. 18). Care must be exercised during this process to include all necessary provisions for support and growth to ensure a viable system.

6.1 Objectives:

The system engineering process commences with the recognition of a problem, problem definition, listing of constraints and the establishment of objectives. The problem will be a variation of the theme that some amount of emergency power must be assured for particular operations when the normally used power source fails. The individual that has a problem is the one who is responsible for having the emergency electric power source available when it is needed. Problem definition entails determining the conditions which will require use of the emergency electric power system, who will be responsible for designing it, how it will be procured, how soon it must be installed and other outside influences on the system engineering project. The constraints will be time, money, people, energy and physical facilities. Time constraints determine the length of time until the emergency electric system must be installed and working. Money constraints determine how much money is available to design and procure the system. People constraints determine who will actually design, procure and monitor system installation. Energy constraints determine the types of energy sources that can be utilized to provide the emergency electric power. Physical facility constraints will determine where and how the system is to be installed. After these factors have been determined the objectives of the project can be established. The objectives will include design responsibilities, procurement responsibilities, project budget, project schedule, and the overall direction of the project.

6.2 Requirements:

The requirements for the emergency electric power system will consist of the answers to questions typified by the following:

- Required system output in D.C. volts and amperes
- Required system output in A.C. volts, amperes and power factor
- Maximum length of time that emergency power will be required
- Maximum tolerable outage time before emergency power system must be started
- Allowable tolerances in voltage and current
- Availability of energy sources that may be used
- Physical sites and accommodations that may be employed
- Location of points where emergency power must be supplied
- Methods of detecting when emergency power is required
- Reliability required of the emergency power system
- Effects of the environment upon the emergency power system
- Skill level of operators of the emergency power system
- Effects of failure of the emergency power system
- Growth requirements of the emergency power system
- Length of time before the system must be operational
- Policies that affect the design and implementation of the system
- Lightning protection required for towers, control lines and power lines

6.3 System Synthesis:

The synthesis of the design of the needed emergency electric power system can commence after the objectives and requirements have been established. The synthesis operation may be no more than determining if a lead-acid or a nickel-cadmium battery is to be used to power an emergency telephone system, the capacity rating and other parameters of the battery, and how it is to be charged and switched into service when needed. On the other hand, the requirements may lead to the synthesis of a complicated UPS system with inverters, several different types of power sources, battery banks and a rotating flywheel to smooth power surges. The synthesis must respond to the requirements and produce a system design that will satisfy all requirements.

6.4 System Analysis:

The resultant design must be analyzed to determine if it is the best method of satisfying the requirements, and if a slight change in the requirements will produce a large simplification in system design. As a result of the analysis the design may be modified and improved, the requirements may be examined and modified to enable simplifying the system design.

6.5 System Specification:

When the system requirements have been firmly established and the resultant system design optimized the system may be specified. The primary purpose of specifications is to describe a system to meet the established requirements in sufficient detail that misunderstanding between the buyer and seller of the system is avoided. All of the features necessary to meet the system requirements must be described in the specifications since most manufacturers of emergency electric power supply equipment offer a variety of optional features and there is little standardization among them on the number of features offered on their basic units. The specifications must define the type, size, location, capacity, output characteristics, fuel to be used and overall performance of the system and must establish the responsibility for delivery, installation, testing and placing the system in operation. The specifications must take into account the procurement method to be used and must include provisions that are compatible with the procurement method.

6.6 Procurement:

There are numerous procurement methods in use at present. A few are simple but most are complex in practice. Procurement practice is likely to be well established at any facility requiring an emergency electric power system. Whatever method is used to procure the system the basic requirements are essentially the same. The procurement order must define the terms and conditions under which the procurement is to be made in sufficient detail that misunderstanding between the buyer and the seller is avoided. The specifications define the system to be procured and must be included in the procurement order. The specifications and procurement documents must not conflict and each must complement the other. Together they must define the system and the terms and conditions under which it is to be purchased. The responsibility of the buyer and the seller and all interfaces between them must be clearly defined.

6.7 Support Requirements:

The system design must contain provisions to ensure that system maintenance, resupply of expendable materials and training of personnel are performed.

6.8 Growth Requirements:

The system design and implementation must contain provisions to expand the system as necessary to keep pace with expansions that may occur in the operations which the emergency electric power system serves.

APPENDICES

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APPLICABLE CODES AND STANDARDS

AMERICAN NATIONAL STANDARD INSTITUTE (ANSI)	STD. NO.
Std. For Quick Disconnect Devices For Use With Gas Fuel (1971)	Z21.41
Std. For Installation for Gas Piping and Equipment on Industrial and Certain Other Premises (1972)	Z83.1
Safety Rules for the Installation and Maintenance of Electric Supply and Communication Lines (1960)	C2.2
National Electrical Safety Code, Part I: Rules for the Installation and Maintenance of Electrical Supply Stations and Equipment (1971)	C2.1
Safety Rules for the Installation and Maintenance of Underground Electric Supply and Communication Lines (National Electrical Safety Code) (1973)	C2.3
Std. Definitions for Power Switchgear (1972)	C37.100
AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)	
Emergency Std. Spec. for Automotive Gasoline (1974)	ES1
Std. Spec. for Reinforced Epoxy Resin Gas Pressure Pipe and Fittings (1973)	D2517
DIESEL ENGINE MANUFACTURERS ASSOCIATION (DEMA)	
Std. Pract. for Low and Medium Speed Stationary Diesel and Gas Engine Gauge Boards, Protective Devices and Instrumentation (1972)	*1-17
Std. Pract. for Low and Medium Speed Stationary Diesel and Gas Engine Air Intake and Exhaust Systems (1972)	*1-8
Std. Pract. for Low and Medium Speed Stationary Diesel and Gas Engine Cooling Water Systems (1972)	*1-10
Std. Pract. for Low and Medium Speed Stationary Diesel and Gas Engine Erection and Installation (1972)	*1-21
Std. Pract. for Low and Medium Speed Stationary Diesel and Gas Engine Factory and Field Testing (1972)	*1-22
Std. Pract. for Low and Medium Speed Stationary Diesel and Gas Engine Fuel Oil Characteristics (1972)	*1-14

Std. Pract. for Low and Medium Speed Stationary Diesel and Gas Engine Gaseous Fuel Characteristics and General Spec. (1972)	*1-15
Std. Pract. for Low and Medium Speed Stationary Diesel and Gas Engine Generators and Electrical Equipment (1972)	*1-18
Std. Pract. for Low and Medium Speed Stationary Diesel and Gas Engine Lubricating Oil Characteristics and General Spec. (1972)	*1-12
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- Omukai, Y., and others. "Thermal Batteries." National Technical Report, April 1970, vol 16, n 2, p 277-280.

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The experiences gained in design and operation of multiple gas engine driven generator sets are reviewed pointing out the advantages and disadvantages of such prime movers. Particular attention is paid to clutches, control and intermittent operation. (In German with English abstract)

Bjork, Gosta, and others. "... Gas Turbine Power Plants for Emergency Power in Nuclear Power Plants ." Energie, April 1974, vol 26, n 4, p 134-140.

An outline of the gas turbine standby and peaking power plants is given. General data on design, rating and control are briefly described. (In German)

Carter, James B.. "A Study to Reduce the Noise Level of a 60 KW U.S. Army Department of Defense (DOD) Diesel Engine Driven (DED) Generator Set and Produce a Prototype Modification Kit." Army Mobility Equipment Research and Development Center, Fort Belvoir, Va., June 1975, 56 p, NTIS AD-A015 509/35T.

The report describes a program undertaken to investigate the noise characteristics of a 60 KW U.S. (DOD) (DED) generator set, and reduce the noise to the lowest level attainable with a modification kit which would have minimum impact on set operation, performance, maintenance, size, weight and added cost.

Caunter, J.M.. "Low-Cost Emergency Power Generator." Wireless World, Feb. 1975, p 75-77. "Discussion." June 1975, p 165-166.

Cooper, David T., and others. "Engineering Design Test Report of the 100 KW, 400-Cycle, Gas-Turbine-Engine-Driven Generator Set, Solar Model T-350M-5." Rept. No. 1852, Army Engineer Research and Development Labs, Fort Belvoir, Va., April 1966, 2 p.

The report covers the engineering design testing and the evaluation of a 100 KW, 400-cycle, gas-turbine-engine-driven generator set for use in the AN/MPA-32 Radar System.

"Diesel-Electric Shunter with a Simplified Power Circuit." Ry Gaz, Sept. 19, 1969, vol 125, no 18, p 700-701, 704.

Discusses an automatic variable field-weakening and contractorless main power circuit with separate excitation of the traction motor.

"Electric Generator Set, Gas Turbine Engine Driver, Skid-Mounted, Alternating Current, Multi-Frequency." Teledyne Cae, Toledo, Ohio, Nov. 10, 1972, 254 p, NTIS AD-761 125.

The report concludes a study performed on 30 KW and 60 KW ground power units for the U.S. Army. Sections 2.0 through 6.0 provide the details of the introduction: generator set description: the engines, electrical systems and packaging investigations and discussions.

"Electrical System With Integrated Drive Generator." Aircraft Engineer, March 1974, vol 46, no 3, p 7-8.

The electrical power system consists of 2 engine-driven integrated drive generator channels. Each channel includes a 60/75 KVA generator, a miniature generator control unit, and a current transformer package. The 2 channels have isolated operation and each generator supplies power to its associated load bus. However, the 2 channels are interconnected in an automatic bus transfer configuration. If one channel is lost, its load bus is automatically transferred to the operating channel. Details are given on the generator, generator control unit and current transformer assembly.

Farinacci, Nick A., and others. USAF Bioenvironmental Noise Data Handbook, vol 24, EMU-10/U Generator Set, Gasoline Engine Driven. Rept. No. AMRL-TR-75-50-vol-24, Aerospace Medical Research Lab., Wright-Patterson AFB, Ohio, Aug. 1975, 56 p, NTIS AD-A029 598/OST.

The EMU-10/U Generator Set is a source of precise 60-cycle AC power and is designed to support communications electronics and radar. This report provides measured and extrapolated data defining the bioacoustic environments produced by this unit operating outdoors on a concrete apron at normal rated/loaded conditions.

"Gas Turbine Generator Sets For Mammoth Tankers." Tanker and Bulk Carrier, May 1969, vol 16, no 1, p 30-31.

Turbosafe marine gas turbine standby/emergency generating set systems provide a combined source of standby and emergency power with the Kongsberg 1200 KW gas turbine generating set located outside the engine room in a fireproof enclosure on the poop-deck.

Gasper, Kenneth A., and Keith E. Eester. "Cardiac Pacemaker Power Sources." Proceedings of the Intersociety Energy Conversion Engineering Conference, IEEE, Newark, N. J., Aug. 18-22, 1975, p 1205-1213.

Giorgi, Evo. 5 KW, "Engine-Driven Electrical-Power Generator Set for Amphibious Applications." Rept. No. NCEL-TR-484, Naval Civil Engineering Lab, Port Hueneme, Calif., Oct. 1966, 29 p, NTIS AD-800 626/4ST.

A 5 KW engine-driven electrical-power generator set incorporating a Lister air-cooled engine and a Lima totally amphibious enclosed generator was procured, tested, and evaluated for amphibious application.

The primary feature of a power source for a pacemaker is longevity: long life is desired with correspondingly high reliability. Discussed are longevity and power requirements for a pacing system including both pulse generator and electrode/lead.

"Humbolt Bay Power Plant, Unit 3. Malfunction of the Propane Engine Driven Generator." Pacific Gas and Electric Co., San Francisco, Calif., Dec. 5, 1973, 3 p, NTIS Docket-50133-142.

Iwabuchi, Hiroo. "Automatic Diesel Engine Driven Standby Electric Generator Plant." National Technical Report, Oct. 1972, vol 18, no 5, p 631-639.

A diesel plant controller utilizing digital integrated circuits that yields a smaller size controller with higher reliability for non-contacting is developed.

Jordan, James E., and James E. Griffin. "Development and Test Report of the 3 KW. 60-cycle, Military Standard Engine-Driven Generator Set, Model SF 3.0 MD." Rept. no AERDL-TR-1777, Army Engineer Research and Development Labs, Fort Belvoir, Va. June 2, 1964, 155 p.

The development and engineer design testing of a 3 KW, 60-cycle, gasoline engine-driven generator set for general use with the field army.

Kietzman, Robert L.. "Natco-Viking Emergency Power for American Express." Sawyers Gas Turbine Int., Sept.-Oct. 1976, vol 17, no 5, p 36-37.

Characteristic data for a backup power supply system module are given. American Express selected turbine powered generator sets for their emergency power installation over diesel engines due to significant space savings and starting reliability, both prime requisites in the design of major computer complexes.

Marshall, Otis W., and others. "Independent Energy Systems for Better Efficiency." Intersociety Energy Conversion Engineering Conference Proceedings, San Francisco, Calif., Aug. 26-30, 1974, p 531-537.

An On-site power plant practical for residential application is described. It used the Roesel generator and a diesel engine.

McCrank, J.M., and G.R. Short. "Power Generation From Shale Oil Process Off-Gas." Turbodyne Corp., Cloud, Minn., 1976.

This paper describes the application of the Turbodyne gas turbine generating system to electric power production with shale oil process off-gas.

Morgan, James A.. "Noise Control Modification of 30 KW, 400 HZ (DOD) Diesel Generator Set." Rept. No. 50-257, Industrial Acoustics Co. Inc., Bronx, N.Y., May 1975, 38 p, NTIS AD-A019 949/7ST.

The purpose of this work was to develop a noise control modification kit, applicable to existing U.S. Army 30 KW, 400 HZ Department of Defense (DOD) diesel engine driven generator sets, as well as sets in production, and capable of meaningful performance in terms of current noise criteria.

"Offshore Turbine Power." Gas Turbine Int., March-April 1971, vol 12, no 2, p 44-46.

Eight gas turbine packages have been shipped to Australia for installation at the oil and gas development complex off the Southeastern coastline in Bass Strait. The new turbines will be installed on the Halibut platform, which is 47 miles offshore in 240 ft. deep water. Two of the Solar packages are 750 KW continuous duty generator sets, which are being fabricated in Australia into self-contained modules.

Okopinski, Charles P.. "Development and Test of the 1.5 KW, 60-cycle, Military-Design Engine-Driven Generator Set, Model SF-1.5-MD." Rept. No. AERDL-1860, Army Engineer Research and Development Labs, Fort Belvoir, Va., June 1966, 40 p.

The report covers the development and engineering design testing of the 1.5 KW, 60-cycle, Gasoline-Engine-Driven Generator Set.

Owen, W.T.. "Choosing a Diesel Generating Set for Standby and Peak-Topping Applications." Mirrlees Blackstone Ltd., Stockport, Ches. England, 1975.

This article covers some of the factors which may affect both the type of plant, and also the mode of operation, in standby diesel generating plants.

Pietrucha, W.J.. "Is There a Gas Turbine in Your Future?" Combustion, Oct. 1969, vol 41, no 4, p 35-38.

Equipment available to utilities interested in gas turbine generating unit which employs aircraft type gas turbines to drive an electrical generator through a pair of power turbines for power generation is described.

Plaxco, John D., and others. "Evaluation of Diesel-Driven Generators for Starting an Isolated System of Motor-Driven Equipment." Southern Services, Inc., Birmingham, Alabama, 1973.

This paper will describe a dynamic stability analysis of an emergency power system, containing a number of large induction motors, supplied by a diesel driven generator unit.

"Propane-Powered Generator." Electronic Engineering, Aug. 1974, p 4.

"Standby Generator Sets Provide Alternate Power Source." Water and Sewage Works, May 1975, p 105-108.

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It is shown that a mobile, 200 KW gas-turbogenerator is serving very well as a source of emergency power for small but important customers during reconstruction or during outages caused by faults.

Torpey, P.J., and W.L. Smith. "Performance Evaluation of a 2.1 MW Gas Turbine Generator Set Using Computerized Data Acquisition." Consolidated Edison Co., New York, N.Y., 1971.

A gas turbine generator set intended for use as an emergency power source has been evaluated and tested using a computer controlled data acquisition and processing system.

"Turbo-Generator Provides 2,000 Watts Remote Power." World Oil, Dec. 1972, vol 175, no 7, p 67-69.

Drawings, specifications and example applications describe a rugged, portable fuel burning power generator that produces between 200 and 2000 watts of power with the most economical cost per watt for its output range.

Wasdi, John T.. "Engineering Evaluation Report of the 5 and 10 KW, 60 HZ, Air-Cooled Diesel-Engine-Driven Generator Sets, Onan Contractor Model 6DJB-3E-2236/3820 and 12DJC-3E-2236/3820." Army Engineer Research and Development Labs, Fort Belvoir, Va., Dec. 1966, 44 p.

The report covers the engineering and performance tests of the above.

Yamada, Masaaki, and others. "10,000 KVA Gas Turbine Generator Plant for Standby." 1974.

The plant, which was developed for emergency power supply to the Tokyo Data Telecommunication Center Office, was installed inside the building. Pertinent details are presented.

Yang, R.T.M.. "Determination of the Dynamic Structural Response Characteristics of a Large Diesel Engine by Means of the Low Level Impedance Method." Delaval Turbine Inc., Oakland, Calif., 1976.

The application of diesel generators for nuclear standby power requires that the generator and its auxiliaries will survive seismic disturbances and remain functional whenever emergency power is called for.

FUEL CELLS

Callahan, Michael A.. "Catalytic Pyrolysis of Methane and Other Hydrocarbons." Proceedings of the 26th Annual Power Sources Conference, Ill. Inst. of Technol., April 29-30 and May 1-2, 1974.

USAMERDC's 1. 5 KW Fuel Cell Power Plant is designed to operate on any of a number of military fuels, including gasoline, JP4, and other hydrocarbon mixtures.

Engle, Merle. "1.5 KVA Hydrocarbon-Air Fuel Cell System." Allis-Chalmers Mfg. Co., Milwaukee, Wis., March 1965, 2 p.

Principal emphasis was placed upon the overall power plant analysis and design. The three major systems, the fuel cell reformer, and inverter, comprising the power plant are discussed.

Gillis, E.A.. "Acid Electrolyte Fuel Cell Stack Performance." Proceedings of the 23rd Annual Power Sources Conference, May 20-22, 1969.

To determine the extent of power plant simplifications that are practical, a test program was undertaken to define the permissible envelope of operating conditions for cells under steady state and transient conditions.

_____, and others. "Open Cycle Hydrocarbon-Air Fuel Cell Power Plant." Army Mobility Equipment Research and Development Center, Fort Belvoir, Va., 1970, p 15.

Discussed are various types of fuel cells suitable for front line warfare communication systems. Mentioned is the hydrocarbon air fuel cell and various electrolytes including phosphoric acid.

"National Benefits Associated With Commercial Application of Fuel Cell Power Plants." Energy Research and Development Administration, Feb. 27, 1976, 67 p, NTIS ERDA-76-54.

The objective of this report is to outline and discuss the application opportunities for first generation fuel cell power plants, quantify improvements that these systems can offer in comparison with conventional electric generation techniques.

Nelson, S.H., and J.P. Ackerman. "Fuel Cell Benefit Analysis." ERDA, June 1976, 41 p, NTIS ANL/ES-51.

A study was performed to evaluate the potential benefits resulting from the commercialization of first-generation fuel cells in the early 1980's.

Onischak, M., and B.S. Baker. "30 Watt Hydride-Air Fuel Cell System." Energy Research Corp. Bethel, Conn., 1974.

Small portable fuel cell systems can be used by the military as power supplies for radio sets and other electronic equipment and as battery chargers. The source of fuel for such fuel cell systems is critical. Hydrogen is derived from the reaction between sodium aluminum hydride (NaAlH_4) and water. Air is the oxidant.

"Proceedings of the 16th Annual Power Sources Conference." May 22-24, 1962, 184 p.

Topics included are: Fuel cell materials and mechanisms; Fuel cell batteries and systems; Thermal energy conversion; Solar energy conversions; Secondary batteries; Primary batteries; Electrical to electrical energy conversion.

"Project Fuel Cell." Westinghouse Electric Corp., Pittsburg, Pa., Feb. 1971, 492 p, NTIS PB-236 188/9ST.

A solid electrolyte fuel cell designed to operate at approximately 1000C with a potential thermal efficiency of 60-70% for utility-size power plants is described.

White, H.F.. "Review and Evaluation of Project Fuel Cell." Jackson and Moreland, Inc., Boston, Mass., Dec. 2, 1966, 105 p.

This is a research project whose objective is the development of a high-efficiency, coal-oxidation, solid-electrolyte power plant.

GENERAL

Alich, John A. Jr., and others. "Suitability of Low-BTU Gas/Combined-Cycle Electric Power Generation for Intermediate Load Service." Stanford Research Institute, Calif., 1975.

This paper deals with the generalized concept of coal and oil gasification for electric power production. The requirements of intermediate load service are discussed. The suitability of gasification components and systems for this type service are summarized. The economics of low-BTU gas/combined-cycle power generation for intermediate load service are compared with alternatives.

Amberger, Hans. "Control of Emergency Diesel Generating Plants in Nuclear Power Stations." Siemens Review, April 1974, vol 41, n 4, p 157-160.

Discusses generating units equipped with automatic controls which take full account for all requirements relating to safety and availability.

Baldwin, Carl F.. "How To Specify Independent Power Systems Correctly." Actual Specifying Engineer, July 1975, vol 34, n 1, p 71-73.

One of the most recently developed emergency power systems is the dual-service or augmenting power system in which a switching circuit offers an operating option so that the power system can furnish power to either of two processes or sets of equipment.

Beatson, C.. "Insure Against the Losses Caused by Generation Gaps." Engineer, May 29, 1975, p 46.

_____. "There is Just Time To Install Vital Standby Generation." Engineer, Aug. 22-29, 1974, p 44.

Belt, Richard N.. "Silent, Electric Power Generators for Tactical Applications." Rept. No. USAMERDC-1954, Army Mobility Equipment Research and Development Center, Fort Belvoir, Va., June 1969, 153 p, NTIS AD-784 205/7.

The report is a study to evaluate candidate power-source technologies for near-term (2 to 5 year) and mid-term (10 to 20 year) tactical applications. The range of power ratings considered was from 0.5 KW to 15.0 KW.

Bluhm, D.D., and others. "Updating a Standby Power System." Plant Engineering, Nov. 30, 1972, vol 26, n 24, p 82-84.

Additions to a battery/motor/generation combination emergency power system included a 150 KW diesel generator, dummy load to permit generator load testing and modification of controls, monitoring and transfer equipment. Both diesel generators have similar speed-load characteristics for possible in-tandem operation.

Boers, G.H., and others. "Large No-Break System and Emergency Power Plant Installed at Netherlands Railways' Computer Centre." Holecpost (Eng. Ed.), Dec. 1972, vol 8, n 2, p 52-55.

The computer center is equipped with an extensive installation for emergency power supply, to satisfy the requirements as regards quality and continuity of the electric energy supply. Normal operation when line voltage is available is discussed, along with emergency operation when line power fails. The return to normal operation when line voltage is available again is also considered.

Boretz, J. E., and others. "Component Development of "TORES" For Artificial Heart Device." Proceedings of the Intersociety Energy Conversion Engineering Conference, IEEE, Newark, N.J., Aug. 18-22, 1975, p 1456-1465.

The Turbine Organic Rankine Engine System (TORES) consists of a hybrid heat engine capable of generating both hydraulic and electric power.

Castenschield, Rene. "Obtaining Power Reliability With Multiple Utility Services and On-Site Generation." Electrical Construction and Maintenance, Jan. 1976, p 57-59.

_____. "Combining GFP and Emergency Power Systems." Electrical Construction and Maintenance, Dec. 1976, p 62-65.

Caunter, J.M.. "Low-Cost Emergency Power Generator." Wireless World, Feb. 1975, vol 81, n 1470, p 75-77.

Described is an emergency electric generator for home use. A gasoline-fueled lawnmower engine coupled to a scrap 12 volt automobile generator produces a 220 volt sinewave output. A 12 volt battery supplies the excitation current.

Cowart, Robert L.. "System Aspects of Standby Power." Cablecasting, July-Aug. 1973, vol 9, n 2, p 11-14.

The costs of emergency power supplies for cable TV systems are examined. Also the various kinds of standby power systems that are available are described.

Daley, James M.. "Emergency Power Systems For Computer Centers." Actual Specifying Engineer, July 1975, vol 34, n 1, p 57-62.

Presents steps to ensure the integrity and quality of the power system taken at the Merrill, Lynch, Pierce, Fenner & Smith's computer center in New York City.

"Electrical Power Generation Systems for Space Applications." Rept. No. NASA-TM-X-1089 (is superceded by NASA-SP-79), National Aeronautics and Space Administration, Wash., D.C., 1965, 42 p.

"Electrical System." Aircraft Engineering, June 1974, vol 46, n 6, p 24-26.

During flight operation two air-cooled brushless generators, engine-driven through a constant-speed drive (CSD), supply 120/208 volts, 400 cycles, three-phase AC power. A third generator, identical to the two-engine-driven ones, is driven by the APU to supply electric power during ground operation.

"Emergency Plus Standby Power Beats Utility Power Outages." Electrical Construction and Maintenance, Jan. 1976, p 64-66.

"Emergency Power Source Keeps HID Lamps Operating." Lighting Design and Application, May 1975, vol 5, n 5, p 52-53.

An emergency power system is described which is capable of switching over to full power fast enough to maintain an arc in HID lamps.

"Engineering Basics of Emergency/Standby Power." Actual Specifying Engineer, Dec. 1972, vol 28, n 6, p 103-108.

Four articles are presented reviewing engine/generator sets, turbine generators, unit-erruptible power supply systems, and stationary battery systems.

"Environmental Impacts of the Generation of Electricity in the Pacific Northwest. Volume I." Equitable Environmental Health, Inc., Woodbury, N.Y., Sept. 1976, 269 p, NTIS PB-257 096/8ST.

The report describes and quantifies the environmental impacts of all existing plants and various scenarios for planned thermal electrical generating facilities through 1995 in the Pacific Northwest.

Epler, E.P.. "Our Emergency Cooling Failure." Nuclear Safety, July-Aug. 1970, vol 11, n 4, p 323-327.

Three identical units that supply emergency power for afterheat protection of the Oak Ridge Research Reactor failed simultaneously, and the reactor was operated without emergency power for the afterheat removal system for 5 hours before the condition was discovered. The reactor was not endangered because a dissimilar unit of low reliability was activated.

Estes, E.M.. "Alternative Power Plants For Automotive Purposes." General Motors, N.Y., 1972.

General Motors' latest progress with alternative power plants and their relative feasibility in both the near and more distant future is discussed.

"Feeding Three Services From One Emergency Generator." Electrical Construction and Maintenance, July 1975, p 58-60.

Finney, D.. "Static-Inverter Systems For Emergency Supplies." Electronics and Power, Feb. 1973, vol 19, p 32-34.

Discusses matching the inverter to the battery's inherent characteristics, and the means of maintaining the battery in its correct state of readiness to cope with the loss of power.

Gerdes, R.H.. "Meeting Tomorrow's Electric Power Needs. New Method, New Concepts." Pacific Gas and Electric Co." San Francisco, Calif., 1968, Proceedings of the 7th World Energy Conference, Moscow, Aug. 20-24, 1968.

This discussion on meeting the growing need in the United States involves mainly the use of nuclear power plants, nuclear magneto-hydrodynamic generators.

"Get Standby Generation." Power, Jan. 1971, vol 115, n 1, p 32.

The steps that can be taken to better insure availability of emergency power when it is needed are reviewed.

Hagen, E.W.. "Standby Emergency Power Systems — The Early Plants." Nuclear Safety, May-June, 1973, vol 14, n 3, p 206-219.

Reviewed are the performance of standby systems for reactors commissioned from 1959-1967. Covered are on-site power, AC power and battery systems.

Hennigan, Thomas J., and others. "Proceedings of the 25th Annual Power Sources Symposium." Atlantic City, N.J., May 23-25, 1972, 198 p.

A continuation of the list of authors of 56 papers presented concerning battery generators.

Hnatek, Eugene R.. "Switching Power Supplies: Design Considerations." Computer Design, Feb. 1977, p 89-94.

Hogrebe, Lawrence F.. "Automatic Transfer Switches: Changing State of the Art." Specifying Engineer, Oct. 1975, vol 34, n 4, p 74-79.

A discussion of recent developments in the design of transfer switches to meet the needs of complex emergency power arrangements, is presented.

Koch, Wolf H.. "New Two-Phase Reluctance Generator For DC Loads." Tech Univ., Hannover, Germany, IEEE Transactions on Power Apparatus and Systems, Sept.-Oct. 1974, v PAS-93, n 5, p 1449-1457.

A new two-phase reluctance type generator, suitable for DC loads, is described.

Lehouchu, J.. "Power Supply of MOS RAM in Pulse Rating." Onde Electr., April 1971, vol 51, n 4, p 305-310.

This paper is concerned with the use of a pulsed power supply for MOS RAM'S, in order to decrease the power consumption. This principle is implemented in a test jig for a particular type of MOS RAM, and in emergency power supply which overcomes the drawback of semiconductor memory volatility. (In French with English abstract)

Long, Lawrence J., and Howard B. Hamilton. "Simplified Approach to Radial Flux Loss Calculation in Cylindrical Rotor Generators." Westinghouse Electric Corp., Pittsburgh, Pa., 1975.

This paper describes a technique developed to calculate the eddy current losses (radial flux losses) induced in the stator conductors of round rotor synchronous generators operating at any desired terminal conditions.

Marlow, J.C., Jr.. "Emergency Standby Power Systems for Pulp and Paper Mill Power Plants." J.E. Serrine Co., Greenville, S.C., 1970.

Self contained emergency lighting systems, station battery DC power systems, uninterruptible AC power systems, and startup AC power systems for standby power in pulp and paper mill power plants are discussed. Special emphasis is placed on startup power requirements for mills where in-plant generation provides 100% of mill electrical requirements. In pulp and paper mills, purchased power is normally the preferred source of energy for standby power requirements from 250 KW to 3500 KW. The economics of standby purchased power vs. engine generator and gas turbine power are discussed.

Meckler, Milton. "Options for on-Site Power." Power, March, 1976, p 33-35.

Murthy, K.S.N., and others. "Experience From Operational Testing Program Including Engineered Safeguards at Tarapur." Proceedings from the Symposium on Experiments From Operation and Fuelling Nuclear Power Plants, Vienna, Austria, Oct. 8-12, 1973, Int'l. Atomic Energy Agency.

The performance of the systems from the commissioning stages to date and the problems encountered and resolved are presented in the paper.

O'Keefe, William. "In-Plant Electric Generation." Power, April 1975, p 51-74.

Peach, Norman. "Get the Standby Power You Need." Power, May 1972, vol 116, n 5, p 23-26.

Emergency power is not, except in rare instances, provided for the whole plant (or commercial bldg.) load. Circuits separate from the rest of the system must be provided for those portions of the electrical which must remain energized when the main power source fails. Minimum requirements are for some lighting, one or two elevators, fire pumps, etc., necessary to assure the safe evacuation of people from the building.

Poetter, Hermann. "... Emergency Power Supply Equipment for Measurement and Control Installations in Gas and Water Supply ." Gas Wasserfach Gas Erdgas, March, 1975, vol 116, n 3, p 119-124.

The use of emergency and reserve power supply equipment in the monitoring and control of gas and water supply in case of an electric power failure is discussed.

Prokhovhik, D.N., and A.A. Arakelov. "Improvement of Transient Behavior in the Type UGP-24 Guaranteed Supply Circuits." Telecommunication Radio Engineer, Apr. 1974, vol 28-29, n 4, p 38-40.

The uninterruptible power supply for multichannel transmission equipment consists of control panels, a storage battery, a synchronous generator supplying the communications equipment, and two drives — an asynchronous motor and a DC motor.

Reichenstein, Hermann W., and Rene Castenschiold. "Coordinating Overcurrent Protective Devices With Automatic Transfer Switches in Commercial and Institutional Power Systems." IEEE Industrial and Commercial Power Systems Technology Conference, Denver, Colorado, June 2-6, 1974.

It is the purpose of this paper to define and analyze important transfer switch functions and application criteria.

Rutschow, Carl. "Simple CMOS Circuit Generates 3-Phase Signals." Aerojet Electrosyst, Azusa, Calif., 1976.

A micro-power, 3-phase generator, ideal for such applications as battery-powered inverters can be simply constructed using a CMOS 4-bit shift register and two CMOS inverter (only 1-1/3 total IC packages).

Schmied, Ernest. "Emergency Power For Hospitals." Syska and Hennessy Inc., New York, 1972.

While emergency standby generation has the basic purpose of serving a hospital during full power interruption, the engineer must also consider brownout periods, and he must adjust automatic start and throwover to the emergency system accordingly. The engineer must closely review local electrical and building codes for load types to be connected and for other requirements, including ventilation, cooling and exhaust of the generating unit.

Schwartz, H.J., and L.I. Shure. "Survey of Electric Power Plants for Space Applications." National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio, Rept. No. NASA -MM-X-52158, 1965, 39 p.

Presented at the 58th Aiche National Meeting in Philadelphia, on Dec. 1965, it covers the Brayton cycle, Rankine cycle, spacecraft power supply, thermionic converters, batteries, cells, chemicals, converters, fuel cells, fuels, generators, solar energy, spacecrafts, supplies, thermionics, and thermoelectric systems.

Sharma, G.N., and G.N. Acharya. "Standby Power Source Uses Diodes and Battery." Central Electronic Engineering Research Inst., Pilani, India, 1970.

A way to provide an instantaneous emergency power supply for small electronic devices normally operated from a battery eliminator is described. A simple combination of two

diodes, properly rated for the maximum current drain, provides automatic changeover from AC mains to a battery supply.

Sheets, Marvin W.. "Are We Asking Too Much In Qualifying Tests of Electric Motors for Nuclear Power Stations?" Power, Jan. 1975, p 48-49.

Simmons, Henry E.. "Consider the Tradeoffs." E.E. Incorp. Long Beach, Calif., 1974.

Wall mounted battery supply units of sufficient capacity to handle full branch circuits, ranging in size from 400 to 1200 watts, and operating at 208/120 volts are discussed.

Sommer, Peter. "... Design Requirements for the Emergency Power Supply of Nuclear Power Plants ." Tech Ueberwach-Ver Rheini, Germany, 1975.

The design requirements for emergency power supply of nuclear power plants are discussed on the basis of operational experience with emergency power diesel units. (In German with English Abs.)

"Standby Power Assures Residential Service Continuity." Electrical Construction and Maintenance, July 1975, p 53-54.

Takahashi, Patrick K., and others. "State-of-the-Art of Geothermal Reservoir Engineering." ASCE Journal, (Power Div.), July 1975, vol 101, n 1, p 111-126.

This paper is a comprehensive survey into the state-of-the-art in geothermal reservoir engineering.

Teets, Rex M.. "Protecting Minicomputers from Power Line Perturbations." Computer Design, June 1976, p 99-104.

"Thermo-Mechanical Generator." Engineering, Sept. 1974, p 730.

Thorpe, L.J., and W.J. Cosgrove. "Portable Camera Unit For the TKP-45 Color Television Camera." RCA Corp., Camden, N.J., 1976.

A new self-contained camera control unit (CCU) for a portable color television camera head has been designed. It can be readily carried into the field for portable production applications or for electronic newsgathering.

Wentz, Jill P.. "Emergency and Standby Power: 10 Years After the Blackout." Electrical Construction and Maintenance, Jan. 1976, p 51-56, 126-131.

Wiss, J.W., and others. "Military Ground Power." Proceedings of the 7th Intersociety Energy Conversion Engineering Conference, San Diego, Calif., Sept. 25-29, 1972, p 1073-1111.

Woods, D.E., and others. "IEEE Industrial and Commercial Power Systems Technical Conference." IEEE, Atlanta, Georgia, May 13-16, 1972, 127 p.

List of titles and authors presented at this conference.

Zung, Joseph T. (Ed.). "Energy Resources and Management." University of Rolla, Rolla, Missouri, April 24-26, 1974, 260 p.

Includes 42 papers on energy resources and new methods of conserving increasingly scarce supplies of energy.

HYDROELECTRIC SYSTEMS

Angelini, A. M.. "The Utilization of Hydraulic Resources Still Available in the World." 9th World Energy Conference, Detroit, Sept. 1974.

Davis, C.V., and K.E. Sorenson. Handbook of Applied Hydraulics. 3rd Edition, 1969.

"Hydroelectric Power Resources of the United States, Developed and Undeveloped." Federal Power Commission, FPC P-42, Jan. 1, 1972.

Pffenninger, H.. "Hydroelectric and Compressed Air Pumped-Storage Shemes." Brown Boveri Review, July-Aug. 1975, v 62, n 7-8, p 327-331.

Storage power plants store mechanical energy during periods of low power demand and supply this energy in the form of electric power when peak loads occur.

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Cormack, A. III., and others. "Design and Test of a Flywheel Energy Storage Unit for Spacecraft Application." Rockwell Int'l, Downey, Calif., IEEE, 1974.

This paper summarizes the design and test of a development flywheel energy storage device intended for spacecraft application.

NUCLEAR SYSTEMS

Brunings, J.E., and others. "Compact Reactor Power Systems." Nuclear Technology, May 1974, v 22, n 2, p 237-251.

The snap zirconium hydride reactor developed by the U.S. Atomic Energy Commission for space applications can also be used for the generation of power in marine applications.

Kahn, Alan R., and others. "Three-Year's Clinical Experience with Radiosotope Powered Cardiac Pacemakers." Medtronic Inc., Minneapolis, Minn., IEEE Transactions of Bio-Medical Engineering, Sept. 1973, v BME-20, n 5, p 326-331.

The power supply of these units was developed in response to the need for pulse generators with longer lifetimes and more predictable performance characteristics than the conventional pulse generators which are powered by chemical cells.

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Beale, W., and others. "Design Details and Performance Characteristics of Some Free-Piston Stirling Engines." Proceedings of the 8th Intersociety Energy Conversion Engineers Conference, Univ. of Pa., Philadelphia, Aug. 13-17, 1973, p 190-193, AIAA.

The concentric piston-displacer type of free-piston Stirling engine is being developed for use as a solar-powered water pump, a gas-fired air conditioner, an isotope-powered electric generator.

Daniels, F.. "Direct Use of the Sun's Energy." 1965.

Duffie, J.A., and W.A. Beckman. "Solar Energy Processes." 1974.

Durand, H., and G. J. Naaier. "Water Pumps Driven by Photovoltaic Modules." Proceedings of the International Conference on Heliotech. and Dev., Drahan, Saudi Arabia, Dev Anal Assoc., Nov. 2-6, 1975, vol 2, p 315-330.

Two water pumping systems including a KW-size photovoltaic generator combined with a short-term storage battery are described.

Gnau, L. H.. "Solar Thermoelectric Generator Design and Panel Development Program Fabrication Report." Rept. No. NASA-CR-72386, Radio Corp. of America, Harrison, N.J., March 20, 1968, 65 p.

Contains information on flat plates, germanium, silicon, solar cells, thermoelectric generators, beryllium, engineering drawings, metal bonding, panels, and thermal insulation.

Ehricke, K.A.. "Space Industrial Productivity: New Options for the Future." Future Space Programs, Hearings of the House Subcommittee on Space Science and Applications, 1975.

Jordan, R.C.. "Solar Energy Powered Systems; History and Current Status." ASTM Standardization News, Aug. 1975, p 13.

Landsman, A.P., and N.V. Pulmanov. "Low-Powered Photoelectric Generators For the Terrestrial Application." Central National d'Etud Spatiales, Paris, France, 1973.

For terrestrial applications, solar cells, especially thin-film cells, must be protected against environmental effects (e.g. humidity, chemical action, particulate matter, etc.). Research in the USSR has led to the practice of sealing the modules into glass or organic glass (for the larger modules).

Loesch, Helmut R. (Ed.). "Photovoltaic Power Generation." Dtsch Ges Fuer Luft-und Raumfahrt, Cologne, Germany, 1974, 731 p.

Solar radiation has been successfully used for power generation in space and one session of this conference dealt with the field of space application. However, emphasis of the meeting was on terrestrial application of solar energy.

Ramakumar, R., and others. "Solar Energy Conversion and Storage Systems for the Future." IEEE Transactions on Power Apparatus and Systems, Nov.-Dec. 1975, vol PAS-94, n 6, p 1926-1934.

Research and development at Oklahoma State Univ. has resulted in the evolution of several components required to engineer a continuous duty power system running on nonexpendable energy sources, namely the sun and the wind. This paper presents the system and discusses its applicability to the energy systems of the future.

"Reliability Analysis of the Solar Generator of the ESRO 1 Satellite." National Aeronautics and Space Administration, Wash., D.C., Rept. No. NASA-TT-F-14498, Sept. 1972, 24 p, NTIS N73-10051.

The reliability of the solar generator of ESRO is studied by investigating the reliability of its components.

Synder, Robert E.. "Solar Power Generator Cuts Offshore Operating Cost." World Oil, May 1973, v 176, n 6, p 81-83.

Solar cells, or photovoltaic systems are discussed in the article.

"Solar Thermionic Generator Development Quarterly Report. 1 Dec. 1967 - 29 Feb. 1968." Rept. No. NASA-CR-94402, TE4055-145-68, Jet Propulsion Lab., Calif. Institute of Technology, Pasadena, Calif., April 1968, 35 p.

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Adam, A. Warren, and John Monahan. "100 KW Organic Rankine Cycle Total Energy System." AIAA, New York, 1973.

Preliminary results of an extensive development program of an organic Rankine cycle total energy system concept for on-site commercial power up to several hundred DW are presented.

Angello, Joseph P.. "Static, Silent, Thermoelectric Power Sources: Session on Thermal Energy Conversion." Proceedings of the 23rd Annual Power Sources Conference, May 20-22, 1969, 4 p.

The 10 and 20 ampere units were developed and proved to be fully feasible for Army field operation.

Beard, George L.. "1.4 GW Centralia Power Plant." 8th World Energy Conference, Bucharest, Hungary, June 28 - July 2, 1971, vol 3, 17 p.

The Centralia thermal-electric generating station is described.

Campana, Robert J., and others. "Thermoelectric Generator." Rept. No. PAT-APPL-451 367, Energy Research and Development Administration, April 1965, NTIS PATENT-3 388-008.

A thermoelectric generator comprising an elongated thermopile formed of a plurality of interlaced thermoelectric elements adapted to generate electricity when opposite ends thereof are subjected to different temperatures, means maintaining said opposite ends at different temperatures, and means minimizing the difference in the time rates of change of temperature of said ends of said thermopile incident to ambient temperature changes so as to stabilize the power produced by the generator.

Christenbury, T., and others. "Thermoelectric Generator Design Manual." Rept. No. NASA-CR-109637, INSD-7089-1, Jet Propulsion Lab, California Institute of Technology, Pasadena, Calif., Feb. 20, 1970, 120 p.

Cooke-Yarborough, E.H., and others. "Thermomechanical Generator: An efficient Means of Converting Heat To Electricity at Low Power Levels." Atomic Energy Research Establishment, Harwell, Berks, England, 1974.

Research results are reported on thermal energy conversion, which has led to the successful development of an efficient heat engine/alternator system capable of delivering several tens of watts of alternating current.

LaPorte, Alfred H.. "Design and Testing of a 150 Watt SNAP 19 High Performance Generator." AIAA, New York, N.Y., 1973.

The role of heat pipe technology in enabling the growth of Pioneer and Viking class SNAP 19 radioisotope thermoelectric generators (RTG's) to multi-hundred watt capacity is described.

Magnuson, K., and others. "Manportable Thermoelectric Generator." Minnesota Mining and Mfg. Co., St. Paul, Army Electronics Command, Fort Monmouth, N.J., Nov. 1974, 42 p, NTIS AD/A-002 042/OST.

The report describes the design, fabrication, and test of the 120 watt Manportable Thermoelectric Generator (exploratory development model).

Malevskii, Yu. N., "Performance Reliability Calculation for a Modular Solar Thermoelectric Generator." Rept. No. FSTC-HT-23-1434-72, Army Foreign Science and Technology Center, Charlottesville, Va., Jan. 10, 1973, 8 p, NTIS AD-757 087.

Analysis is given of the overall reliability of a solar energy converter unit composed of thermoelectric modules, as a function of the reliability of individual photocells and component modules.

Messerle, H.K.. "Electric Power Generation By M. H. D. - Recent Developments." Institute of Engineering, Sidney, Australia, 1975.

A survey of the status in a magnetohydrodynamic generator design, flow dynamics and of experimental results is given.

Miller, D.F., and A.H. Mayala. "Man-Pack 250 Watt Thermoelectric Generator (Rebuild)." Minnesota Mining and Mfg. Co., St. Paul. Thermoelectric Products, March 24, 1964, 37 p.

The mode of failure of the 3M-5B1 generator after only 500 hours operation was due to overheating the cold-end solder-type hermetic seal, leading to oxidation of the PbTe thermoelectric material.

Miller, N.C., and R.A. Lockwood. "Portable Thermoelectric Generator." Rept. No. AI-7642, Atomics International, Canoga Park, Calif., Aug. 29, 1962, 26 p, NTIS AD-764 277.

Neild, Alton B., Jr.. "Arrangement of Thermoelectric Elements for Improved Generator Efficiency." Available from Commissioner of Patents, Wash., D.C., July 27, 1965.

A plurality of thermoelectric generator banks or rows are connected in parallel, each containing a group of series connected thermoelectric elements which are placed between a heat source and a heat sink.

"Operating Report for Radiosotopic Thermoelectric Generators of the U.S. Navy. Volume 9. Number 1." Naval Nuclear Power Unit, Fort Belvoir, Va., Dec. 31, 1975, 106 p, NTIS AD-A024 531/6ST.

The objective of this Operating Report is to serve as a vehicle for the accumulation and dissemination of information concerning the application and operation of radioisotopic thermoelectric generator (RTGs) within the Navy.

Prosser, D.L.. "SNAP-27 On The Moon." Isotope Radiation Technology, Summer 1970, vol 7, n 4, p 443-447.

A SNAP-27 thermoelectric generator left on the moon by the Apollo 12 astronauts were designed to provide electric power for five experiments on the lunar surface. The source is fueled with 3735 g (8.36 lb) of Pu-238 dioxide microspheres, which produce 63 W(e) ! 1480 W(th) ! of power.

Rosell, Fred E., Jr.. "Navy Half-Watt RTG — A Super-Battery Becomes Reality." IEEE, New York, N.Y., 1975.

A half-watt radioisotope thermoelectric generator (RTG) being procured by the Navy for use as distributed power sources for remote undersea applications is described.

Russo, Frank A.. "Operational Testing of the High Performance Thermoelectric Generator (HPG-02)." ASME, New York, 1974.

This paper describes the activities and observations leading to the successful development of the HPG-02, a thermoelectric generator of 165 watts output and specific power of greater than 2 watts per pound.

Serksnis, Anthony W.. "Thermoelectric Generator For an Automotive Charging System." AICHE, New York, N.Y., 1976, vol 2, p 1614-1618.

Outlines of the basic parameters to be considered and of a proposed design are given.

"SNAP-15A Thermoelectric Generator." Gulf General Atomic, Inc., San Diego, Calif., Sept. 3, 1968, 60 p.

Discusses nuclear power plants, thermoelectricity, auxiliary power plants, and environmental tests, and contains information on radioisotope thermoelectric devices, SNAP and SNAP-15 isotopic generators.

Steen, Donald B.. "Development of a Thermoelectric Generator-Powered Solid State 100-Watt Beacon System." Rept. No. MEL-83/66, Navy Marine Engineering Lab, Annapolis, Md., April 1966, 2 p.

A solid-state 100-watt navigational beacon power system employing a propane-fired, 30-watt, thermoelectric power supply, a capacitor energy storage bank; and a 5-second, one-quarter duty cycle, solid-state flasher has been developed for possible replacement of present Coast Guard battery-powered systems using mechanical flashers.

UPS

Best, C.A.. "Uninterruptible Power Supplies." Westinghouse Electric Corp., Buffalo, N.Y., 1969.

Advantages derived from installing an uninterruptible power supply (UPS) in industrial plants are outlined. Three types of interruptible power supplies are discussed.

Budzilovich, Peter N.. "Thinking of Buying a UPS?" Computer Decisions, May 1977, p 84-86, 88-90.

Edwards, Ted. "Scheduled Exercising Keeps Merrill-Lynch Alternate Power Systems Ready to Take Over." Sawyers Gas Turbine Int., Sept. - Oct. 1976, vol 17, n 5, p 34-35.

The operational data for an integrated, alternate power system for computer facility are given.

George, Michael L.. "How to Weigh Variables for UPS." Power, March 1974, p 68-69.

Holscher, J.N.. "Uninterruptible Power System, A Progress Report." Advances in Instrumentation, vol 24, Pt. 4, 1969.

There is a generalized discussion of various inverter installations which are useful for providing uninterrupted sources of emergency power.

Krieger, Charles H.. "UPS and M-G Sets Combine to Protect Major Computer Center." Electrical Construction and Maintenance, Jan. 1976, p 67-69.

Lambert, F.J.. "Understanding Uninterrupted Power Systems." Instruments and Control Systems, Oct. 1974, p 75-78, Nov. 1974, p 53-54.

McGregor, John E.. "Specifying Power Line Buffer Equipment for Computer Systems." Computer Design, Nov. 1973, vol 12, n 11, p 96, 98, 100-101.

Long-term savings in uninterrupted, error-free operation of a larger computer system can more than offset the initial cost of a buffer designed to isolate the computer from power line disturbances and outages.

"Modern UPS Power Utility Control Center." Electrical Construction and Maintenance, Jan. 1976, p 60-63.

"UPS Assures No-Break Power." Power, Jan. 1976, p 50-51.

Wiener, Hesh. "A User's View of UPS." Computer Decisions, June 1976, p 52-53.

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Clark, R.H.. Energy Int., Nov. 1972, vol 9, n 11, p 21-26.

Cotillon, J.. Water Power, Oct. 1974, vol 26, n 10, p 314-322.

Fuglister, F.C.. "Atlantic Ocean Atlas of Temperature and Salinity Profiles and Data from the International Geophysical Year of 1957-58." Woods Hole Oceanographic Institute, 1960.

Jeffs, E.. Energy Int., Dec. 1974, vol 11, n 12, p 19-21.

Lavi, Abraham, and Clarence Zener. "Plumbing the Ocean Depths: A New Source of Power." Carnegie-Mellon Univ., Pittsburgh, Pa., IEEE Spectrum, Oct. 1973, vol 10, n 10, p 22-27.

Temperature differences between surface and deep waters of tropical oceans are a potential source of relatively cheap power. These differences probably do not exceed 20 C, but serious consideration is being given to using part of this differential in a boiler containing a working fluid such as ammonia, freon, or propane that will produce a moderately high pressure to operate a turboelectric generator.

"Tide Tables, East Coast, North and South America (including Greenland), West Coast of North and South America (including the Hawaiian Islands)." U.S. Department of Commerce, National Oceanic Survey.

Wilson., E.M.. Underwater Journal, Aug. 1973, vol 5, n 4, p 175-186.

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Betz, A.. "Windmills in the Light of Modern Research." National Advisory Committee, National Member, n 474, 1928, NTIS.

Eldridge, F.R. (ed.). Proceedings of the 2nd Workshop on Wind Energy Conversion Systems, Washington, D.C., 1975.

Glauert, H.. "Windmills and Fans." Aerodynamic Theory, vol 4, 1935.

Golding, E.W.. "Generation of Electricity by Windpower." 1955.

Heronemus, W.R.. "Preprints of the 8th Annual Conference and Exposition, Marine Technology Society." Washington, D.C., Sept. 1972.

Concerns pollution free energy from offshore winds.

McGowan, J.G., and others. "Wind and Solar Thermal Combinations for Space Heating." IEEE, New York, N.Y., 1975.

This paper presents the results of an analytical study that was carried out to model and to determine the feasibility of a residential heating system for the Northeastern section of the U.S., designed to be powered or augmented by a wind generator system. In addition to windpowered electrical resistance heating systems (with and without thermal energy storage), the possibility of combining these systems with a flat plate solar collector is investigated.

Putnam, P.C.. "Power from the Wind." 1948.

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