ENGINE DRIVEN GENERATING SETS

PERFORMANCE STANDARD

EGSA 101P, 1995a

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1. SCOPE

This standard applies to the performance of engine driven generating sets, alternating current, primarily for commercial application. The term generator implies an alternating current generator. For other applications such as marine, off-shore, aircraft vehicular and military generating sets, there may be additional regulations of other classification societies and authorities to be observed.

The purpose of this standard is to provide performance criteria that can be expected from generating sets manufactured in accordance with EGSA Guideline Specification EGSA 101S.

2. REFERENCE STANDARDS AND PRACTICES AS APPLICABLE:

EGSA 100B-1992	Performance Standard for Engine Cranking Batteries
EGSA 100C-1992	Performance Standard for Battery Chargers
EGSA 100E-1992	Performance Standard for Governors on Engine Generator Sets
EGSA 100G-1992	Performance Standard for Electric Generator Set Instrumentation Control and Auxiliary Equipment
EGSA 100M-1992	Performance Standard for Multiple Engine Generator Set Control Systems
EGSA 100R-1992	Performance Standard for Voltage Regulators Used on Electric Generators
EGSA 100S-1989	Performance Standard for Transfer Switches for Use with Engine Generator Sets
EGSA 101S-1995	Engine Driven Generator Sets Guideline Specifications for Emergency or Standby
EGSA 109C-1995	Codes for Emergency Power by States and Major Cities
NFPA 37-1994	Stationary Combustion Engines & Gas Turbines
NFPA 70-1993	National Electrical Code, Articles 200, 250, 445, 517, 700, 701, 702, and 705

NFPA 99-1993	Health Care Facilities
NFPA 110-1993	Emergency and Standby Power Systems
IEEE 446-1987	IEEE Recommended Practice for Emergency and Standby Power System
SAE J1349	Engine Power Test Code-Spark Ignition and Diesel
ISO 8528	Reciprocating Internal Combustion Engine Driven Alternating Current Generator Sets
ISO 3046/1, Part II	Reciprocating Internal Combustion Engines-Performance
NEMA MG1-1994	Motors and Generators
SAE J726	Air Cleaner Test Code
CSA C282	Emergency Electrical Power Supply for Buildings
CSA-Z32.4-M86	Essential Electrical Systems for Hospitals

3. APPLICATIONS CRITERIA

3.1 **Modes of Operation.** Certain important characteristics of the generating set may be affected by its mode of operation and these must be taken into account by the purchaser when agreeing to the requirements with the manufacturer or dealer/distributor. For example: equipment intended for automatic standby duty will be different from that for manual prime duty. Particular attention should be given to the demands which the connected loads make on the power supply. The operating characteristics of the generating set must be matched to the demands made by the connected loads.

3.2 **Generator Set Rating Definitions**

3.2.1 **Emergency Standby Rating**. The power that the generator set will deliver continuously under normal varying load factors for the duration of a power outage.

3.2.2 **Limited Running Time Rating**. The power that the generator sets will deliver when used as a utility type power source, typically in load curtailment type service, for a limited number of hours, where there are non-varying load factors and / or constant dedicated loads.

Note: The customer should be apprised of the fact that operation at high level constant loads may have a detrimental effect on expected engine life.

3.2.3 **Prime Power Rating**. The power that the generator set will deliver when used as a utility type power plant under normal varying load factors to run continuously. This rating requires a minimum momentary overload capability of 10%.

3.2.4 **Industrial Rating**. The power that the generator set will deliver 24 hours per day when used as a utility type power plant where there are non-varying load factors and/or constant dedicated loads.

3.3 **Application Classes**

3.3.1 **Class 1**. Applications where the demands on the frequency, voltage and waveform characteristics are exceptionally severe. Example: Computer systems; and communications transmitters.

3.3.2 **Class 2**. Applications where the connected equipment may make demands on frequency, voltage and/or waveform characteristics approaching that of the public utility. Example: Hospitals, telecommunications and data processing equipment.

3.3.3 **Class 3**. Applications where the demands on frequency and voltage characteristics are somewhat less than the public utility electrical system. When load changes occur, there may be temporary but acceptable fluctuations of voltage and frequency. Example: resistance and motor loads, typical of a commercial or industrial facility.

3.3.4 **Class 4**. Applications where the connected loads are of such an undemanding nature that no special voltage or frequency regulation requirements need be specified. Example: General-purpose (lighting, heating and motor loads typical of a construction site.)

3.4 **Criteria of Use**

3.4.1 **Land Use**. This heading includes all generating sets, either fixed or transportable, which are used on land to supply power.

NOTE: Some installations may be land based but located adjacent to water making them subject to a marine environment and requiring special considerations.

3.4.2 **Marine Use**. This heading includes generating sets used on-board ships and in offshore installations. Land use units may or may not be acceptable for marine use.

3.5 **Classification of Operation**

3.5.1 **Single Unit Operation**. This classification includes all generating sets, irrespective of their configuration or mode of control, which operate independent of other electrical power sources.

3.5.2 **Parallel Operation**. This classification includes all generating sets, irrespective of their configuration or mode of control which will operate paralleled with another source of electric supply. (This may be another generating set(s) or a utility supply of the same voltage, frequency and phases.)

4. PRIME MOVER

4.1 **Engine Configuration**. The engine shall be configured for generator set service. Assurance shall be provided by the manufacturer or his dealer/distributor that it is compatible for use as a generator set prime mover. The engine shall conform to Standards EGSA 101S and ISO 3046.

4.2 **Engine Types**. The diesel engine is the predominant prime mover selected for generating set use and this standard is compiled with this in mind. It is, however, applicable in general terms to gas turbine, gasoline or natural gas engine powered sets.

5. GENERATORS (ALTERNATORS)

5.1 **Design Standards**. Generators shall be designed and constructed to meet the appropriate sections of NEMA MG1 and IEC34.

Maximum temperature rises of continuous and/or standby rated generators shall conform to the values specified in NEMA MG 1-16.40 and 16.85 or NEMA MG1-22.40 and 22.85 for the particular class of insulations based on a maximum ambient temperature of 40ºC (104ºF) and 1000 meters maximum altitude. If actual conditions are more severe, the machine rating must be correspondingly reduced.

Caution: It should be especially noted that both rectifier and thyristor-controlled loads may need special consideration with respect to their effect on generator voltage waveform.

The compatibility of engine crankshaft, flywheel, coupling and generator rotor combinations must be analyzed torsionally and analysis must be approved by the engine and generator manufacturer. The manufacturer of the generator set is responsible for the torsional and bending compatibility of rotating components per NEMA MG1-16.82 or NEMA MG1-22.82.

5.2 **Ratings**. Generators for use with most generating sets are rated in kW or kVA at an assumed minimum power factor of 0.8 lagging and at the specified output voltage and frequency.

5.3 **Transient Considerations**. Generating sets supplying industrial type loads frequently have to supply heavy overload currents of short duration which, although well within the thermal capabilities of the generator, may result in significant momentary voltage dip. Such cases need to be evaluated to assure that the generator selected has the capacity to limit the voltage dip to prescribed limits and is capable of recovering to normal voltage within a specified period of time. In some cases, this transient overload requirement may result in the selection of a larger size generator for the generator set than would be required based on average load demand.

5.4 **Generator Types**. Generators shall be rotating field type. They may have salient or non-salient poles on the rotor. They may be single or two bearing.

5.4.1 When slip rings are required, they must be designed to conduct the necessary current without excessive heating, wear, or other maintenance.

5.4.1.1 When radial brushes are used, each slip ring must have at least two brushes in parallel.

5.4.1.2 The materials used for slip rings and brushes should be selected so as to develop a low-resistance contact film at values of current densities over the operating range.

5.4.2 The excitation system may be static, brushless, or permanent magnet.

5.4.2.1 The excitation system must be capable of providing l.5 times the excitation required for the maximum rated full load condition.

6. VOLTAGE REGULATORS (SEE EGSA STD 100R)

6.1 **Application**. Some generators are inherently regulated or self regulated and do not require a voltage regulator. Externally regulated generators require a voltage regulator to control the voltage output.

6.2 **Voltage Sensing**. Voltage sensing may be single or three phase.

6.3 **Voltage Adjustment**. Externally regulated machines must incorporate a voltage adjusting means capable of a minimum adjustment of plus or minus 5% of the nominal rated voltage. The adjusting means may be either integral with or external to the voltage regulator.

6.4 **Voltage Regulator Accessories**

6.4.1 **Parallel Operation**. When required to operate in parallel, reactive droop compensation or reactive differential compensation (cross current compensation) shall be furnished.

When operating in parallel with a utility bus, the system shall have a means to limit reactive load.

6.4.2 **Motor Starting Applications**. When large motor starting or generator short circuit sustaining capabilities are required, consideration should be given to an excitation support system. (Refer to Paragraph 8.2.5)

6.4.3 **Underfrequency Protection**. In the event the engine can be operated at sub-synchronous speed, the excitation system, including the voltage regulator must be equipped with some form of excitation system underfrequency protection that limits regulator output and thereby generator excitation during underfrequency (under speed) conditions.

6.4.4 **Overvoltage Protection**. When overvoltage conditions could cause damage to the generating system or its load, consideration should be given to overvoltage protection equipment.

6.4.5 **Electromagnetic Interference**. On generator set applications involving, but not limited to, radio communications, radar, computers, etc., consideration should be given to electromagnetic interference suppression kits.

7. CONTROL AND MONITORING PANEL

7.1 **Configuration**. Refer to 101S Guideline Specification for Instrumentation Recommendation and Alternative Mounting Locations.

7.2 **Construction**. The control panel shall be constructed of materials conforming to NEMA and ANSI standards and shall be capable of withstanding the mechanical, electrical and thermal stresses, as well as the effects of any site environment which is likely to be encountered. The control panel shall be so arranged as to facilitate its operation and maintenance.

7.3 **Instrumentation**. The instruments shall be suitably scaled to enable the relevant electrical quantity to be observed. The A.C. electrical instruments shall be accurate within plus or minus 2% and the engine instruments/indicators must be accurate within plus or minus 10%, within the operating range.

7.4 **Current Rating**. Current carrying conductors and components shall have sufficient capacity for the duty and conditions specified.

7.5 **Identification of Components**. It shall be possible, physically, to identify individual electrical components in accordance with the relevant diagram supplied. Switch positions shall be clearly indicated.

7.6 **Electrical Protection**. Protective devices shall be provided to give protection against the consequences of short circuits in the control circuitry. Indicators are recommended for open protective devices for critical applications.

Where electrical apparatus is attached to lids or doors, steps shall be taken to assure continuity of the protective circuit in the form of a ground conductor of the appropriate size.

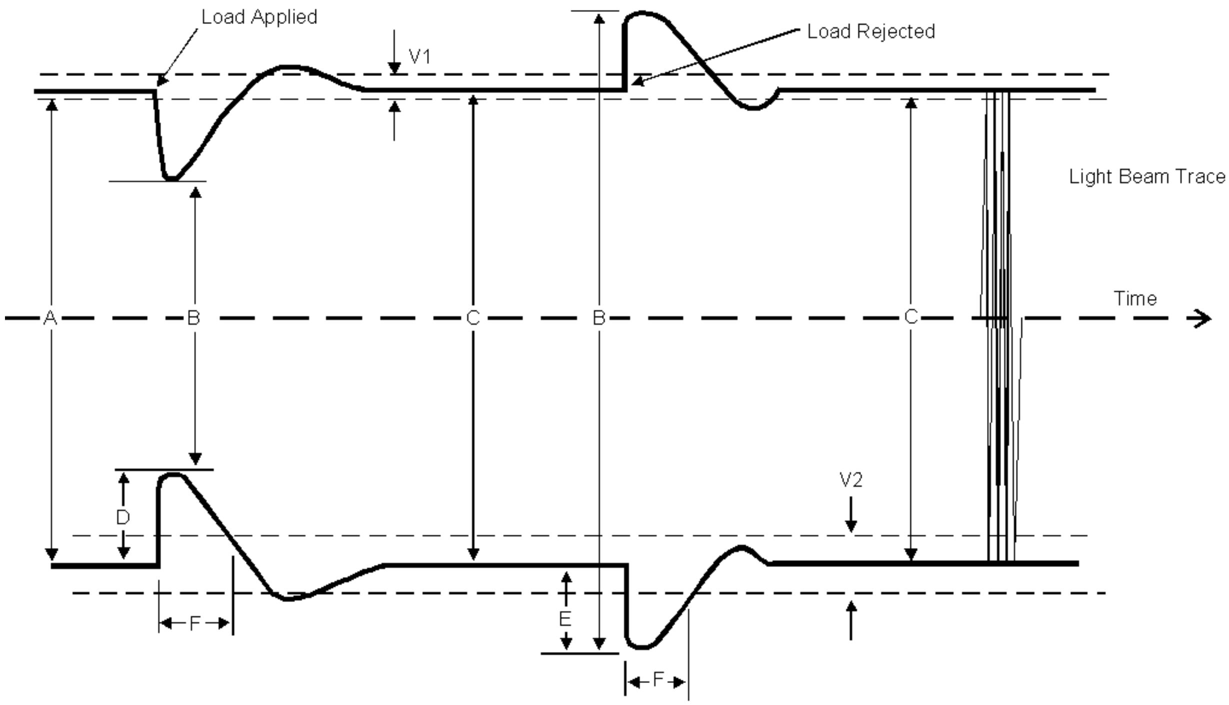
Conductors and Phases shall be identified by numbers or symbols and shall be in agreement with the indications on the supplied wiring diagrams. The ground conductor shall be properly identified and in compliance with National Electrical Code, Article 200 or other applicable code.

8. COMPLETE GENERATOR SET

8.1 Terms and Expressions

8.1.1 **Voltage Strip Chart**. Figure 1 is an illustration of a typical oscillograph voltage strip chart showing both steady state, and transient conditions of loading. For purposes of clarity, the trace has been removed for the majority of the chart so that the various conditions could be detailed. At the extreme right of the chart, we have inserted several cycles of trace as it could be throughout the entire chart.

FIGURE 1. VOLTAGE STRIP CHART



- *A. No Load Voltage.*
- *B. Maximum Voltage Excursion During Transient.*
- *C. Steady State Load Voltage (100%).*
- *D. Maximum Transient Voltage Dip.*
- *E. Maximum Transient Voltage Overshoot.*
- *F. Recovery Time to Re-enter Transient Voltage Envelope.*
- *V1. Steady State Voltage Envelope.*
- *V2. ±% Transient Voltage Envelope.*

8.1.1.1 **Steady State Voltage Envelope (V1)**. This is the "band width" within which the alternator will maintain its output voltage during conditions of steady state loading.

8.1.1.2 **Transient Voltage Envelope (V2)**. Following a load change, (transient) the alternator voltage shall recover to a band width somewhat wider than that allowed for steady state within a specified period of time following the onset of the change.

8.1.1.3 **Recovery Time (F)**. Recovery time is the length of time from the instant of transient to the time the voltage reenters and remains within the transient voltage envelope.

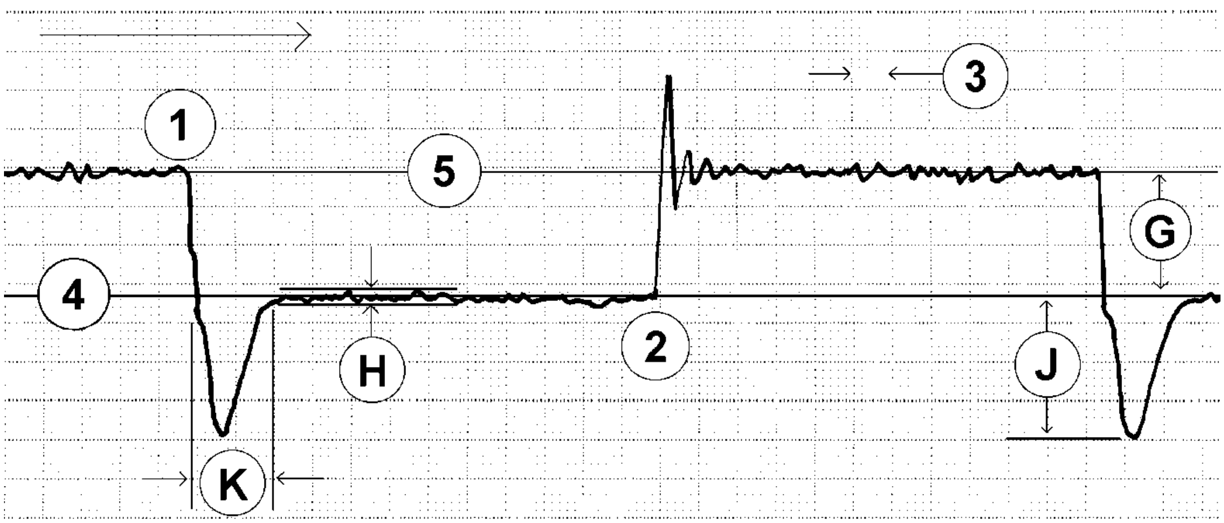
8.1.1.4 **Transient Voltage Dip (D)**. Transient dip is the total amount of voltage drop due to acceptance of load, expressed as a percent of full (100%) steady state voltage.

8.1.1.5 **Transient Voltage Overshoot (E)**. Voltage overshoot is the total amount of voltage increase upon sudden rejection of load, and is expressed as a percent of full (100%) steady state voltage.

8.1.2 **Frequency Strip Chart**. Figure 2 is a copy of a frequency strip chart showing both steady state and load application/rejection modes of operation. The numerals represent events and the letters represent performance parameters.

Reading from left to right, the chart illustrates the frequency change that occurred when load was applied to a generator set operating at no load, followed by a rejection of the load and then another load application.

FIGURE 2. FREQUENCY STRIP CHART



1. Load Application
2. Load Rejection
3. Time
4. Rated Frequency
5. No Load Frequency

G. Frequency Regulation
H. Steady State Stability
J. Frequency Dip
K. Recovery Time

8.1.2.1 **Load Application (1)**. A single step application of a specified load

8.1.2.2 **Load Rejection (2)**. A single step removal of the specified load, 8.1.2.1.

8.1.2.3 **Time (3)**. The time, measured in seconds, for the pen, brush, light beam, etc. to pass a unit distance on the chart.

8.1.2.4 **Rated Frequency (4)**. The nominal frequency for which the generator set is designed and set to operate.

8.1.2.5 **No Load Frequency (5)**. The frequency at which the unit operates at full throttle and without any electrical load.

8.1.2.6 **Frequency Regulation (G)**. Defined by the equation:

$$\text{Regulation} = \frac{\text{No Load Frequency} - \text{Rated Load Frequency}}{\text{Rated Load Frequency}}$$

8.1.2.7 **Steady State Stability (H)**. The random speed variation experienced when the generator set is operating under stabilized conditions.

8.1.2.8 **Frequency Dip (J)**. The difference between the lowest recorded frequency and the rated frequency that is experienced as the result of a load application per 8.1.2.1.

8.1.2.9 **Recovery Time (K)**. The time required for the frequency to reenter the specified steady state envelope following a load application per 8.1.2.1.

8.2 **Performance**. The assembled generator set shall provide the following performance characteristics:

8.2.1 **Unit Starting and Load Acceptance**

8.2.1.1 **Emergency.** The emergency generator set shall be capable of starting and being on line, under load, in ten seconds or less.

8.2.1.2 **Standby.** The standby generator set shall be capable of starting and being on line, under rated load in one minute or less.

8.2.1.3 **Additional Starting Aids.** Under severe conditions, engine coolant and cranking battery temperature control may be required to accomplish the above starting performance. For some engines glow plugs and/or oil heating may be beneficial.

8.2.2 **Rated Power.** The generator set must be capable of producing its rated power (see paragraph 3.2) at the rated frequency, voltage and electrical power factor. The measurement is corrected to standard ambient condition per SAE J1349.

8.2.3 **Governor Performance For Application Classifications**

8.2.3.1 **Frequency Regulation (G)**

Classification 1 (Precise Power Operation). The steady state frequency at no load is the same steady state frequency as at the emergency standby load, subject to the steady state stability specified in 8.2.3.2. The governor also includes a compensating network that anticipates engine fuel setting changes as a function of changes in electrical load to reduce frequency transient.

Classification 2 (Isochronous Operation). The steady state frequency at no load is the same steady state frequency as at the emergency standby load, subject to the steady state stability specified in 8.2.3.2.

Classification 3 (Droop Operation). The steady state frequency difference between the no load frequency and the rated emergency standby load frequency shall not be more than 5%.

Classification 4 (Droop Operation). The steady state frequency difference between the no load frequency and the rated emergency standby load frequency shall not be more than 7%.

8.2.3.2 **Steady State Stability (H).** When the generator set is operating under stabilized conditions, the random speed variation shall not exceed plus or minus 0.25% for application classification 1 or 2 and plus or minus 0.5% for classifications 3 and 4. The generator set shall not hunt or surge in a regular or cyclical manner under any steady state condition.

8.2.3.3 **Block Loading (J).** When operating at no load, the generator set shall be capable of accepting a one step block load of a minimum of 80% of rated emergency standby load, at 0.8 lagging power factor with a maximum transient frequency dip (J) of 5 HZ, a maximum transient voltage dip (D) of 20% and frequency recover (K) to steady state conditions within three (3) seconds.

8.2.3.4 **Motor Starting.** The generator set shall be capable of starting a motor, across the line, having a minimum of 2.7 inrush kVA per the generator set's rated electrical prime power kW. The transient voltage dip (D) shall not exceed 35% and the transient frequency dip (J) shall not exceed 5 HZ below rated frequency.

8.2.4 **Voltage Regulation.**

8.2.4.1 **Voltage Regulator Performance (see EGSA Std 100R).** The steady state voltage difference between no load and full rated emergency standby load shall not be more than 2%.

When the generator set is operating under stable load and temperature conditions, the random voltage variation shall not exceed 0.25% for classifications 1 or 2 and 0.50% for classifications 3 and 4.

The steady state voltage shall not vary more than 1% with a 25ºC (77ºF) ambient temperature change within the generator sets operating temperature range.

8.2.4.2 **Self Regulated Alternator Voltage Characteristics.** Self regulated generator sets are generally tailored to the specific application. Close liaison with the set manufacturer is necessary to assure proper performance in the application.

8.2.5 **Excitation Support System (Optional).** An Excitation Support System is a dedicated source of power for the Exciter Field of a brushless AC generator, which is not dependent on the output voltage of the generator. This source may be a device which utilizes output current, such as current transformers, current feedback through the exciter or a permanent magnet generator. It is used to supply exciter field power during a fault or to assist voltage recovery during heavy motor starting requirements.

An Excitation Support System increases the probability of acceptable main line circuit breaker operation for fault clearance and can significantly assist in motor starting by maintaining a higher voltage to the regulator during the starting cycle.

When specified, the Excitation Support System shall furnish sufficient exciter field power to sustain a minimum of 2.5 per unit output current into a balanced three phase short circuit.

An Excitation Support System requires overcurrent protection against generator winding damage.

8.2.6 **Unbalanced Loads.** It is recommended that efforts are made to balance system loads between phases within approximately 20% in order to eliminate difficulties which could result due to the deterioration in output voltage regulation and its possible effect on other connected loads.

The maximum load which should be connected to any one phase of a three phase machine should not exceed one third of the nominal kVA rating.

Single phase rating for delta, delta-delta or open delta (zigzag) connections shall be a minimum of 60% of the 3 phase rating.

Voltage unbalance with 25% of rated current on one phase and no other load on the generator shall not exceed 5%. Alternator temperatures shall be consistent with Paragraph 5.1.

8.2.7 **Wave Form and Telephone Influence Factor.** The maximum wave form harmonic content at no load condition (line to line or line to neutral) and telephone influence factor (frequency, per NEMA MG 1-22.43C weighting) shall be as shown in Table 1. for the application classifications in Paragraph 3.3:

TABLE 1. WAVE FORM AND TELEPHONE INFLUENCE FACTOR

CLASS	HARMONIC TOTAL	HARMONIC INDIVIDUAL	TELEPHONE INFLUENCE FACTOR
1	5%	3%	50
2	5%	3%	75
3	5%	3%	100
4	10%	5%	250

8.2.8 **Overspeed.** The generator set shall be capable of operating at no load and at an overspeed condition of 25% above its maximum rated synchronous speed for 10 seconds without incurring any damage.

Any overspeed protective device shall be set to shut the generator set down in the event the unit's speed exceeds the maximum rated synchronous speed by 20%, maximum.

8.2.9 **Engine Cooling System.** If the drive engine is a liquid cooled type, the engine cooling system on a new unit must ensure that the engine manufacturer's maximum engine water outlet temperature is not exceeded when the generator set is operating with a 50% ethylene glycol/water solution at the emergency standby rating, 38°C (100°F) ambient temperature and 152 meters (500 feet) altitude with 12.7 mm (1/2 inch) of water column radiator air flow restriction.

A lower or higher ambient capability cooling system can be utilized when specified by the customer.

Ambient temperature is defined as the temperature of the cooling air as it enters the generator.

Care should be taken to ensure that the engine and/or generator cooling air is not recirculated thereby affecting the ambient operating temperature. All cooling system and engine components must be compatible with ethylene glycol antifreeze, if drive engine is a liquid cooled type.

8.2.10 **Engine Air Cleaner.** The engine air induction system must be equipped with a dry-type air cleaner.

As a minimum performance, the air cleaner assembly must provide 99.2% efficiency as measured by Section 8.1 of SAE Test Code J726 at any air flow between 10% and 100% of the air flow experienced at the generator set's standby rating, at the applied frequency.

The air induction system restriction, measured at the engine inlet, shall not exceed the limit established by the engine manufacturer.

The air cleaner capacity will vary between generator set applications depending on the installation and the operating environment. The air cleaner must be sized to provide acceptable element service life which is considered to be exhausted when the air induction system restriction reaches the maximum value as specified by the engine manufacturer.

The use of a unit-mounted air restriction indicator is recommended to advise the operator when the element needs replacement.

9. LITERATURE SUPPORT PACKAGE

The following information shall be supplied with the generator set to ensure proper installation, operation and maintenance of the unit:

9.1 **Operating Instruction**. Detailed Operating Instructions shall be included in the instruction manual and, as a minimum, should cover starting, stopping, protection of circuits, automatic controls, battery charging, safety considerations, etc.

Method of adjustment of speed, output voltage, control timers, etc. shall be detailed in the manual.

Performance Parameters of the plant shall be detailed for the operator's guidance and as a minimum should cover Output Voltage, Frequency, Load, Engine Temperature and Oil Pressure nominal values and acceptable limits. Circuit drawings with component identifications shall be included for reference purposes.

9.2 **Maintenance Instructions**. A section shall be included in the manual to outline maintenance procedures for all the equipment supplied. Schedules for maintenance to be effected on a daily, weekly, monthly/e.c. or on an hours run basis should be included.

This section shall include guidance with respect to selection of fuel oil, lubricating oil, use of water treatment additives and anti-freeze.

The availability of any contract maintenance services should be detailed in the manual.

9.3 **Troubleshooting**. A troubleshooting procedure shall be available to enable the timely diagnosis of any defect considered likely to occur in service.

Reference outputs and conditions shall be quoted to facilitate diagnosis.

9.4 **Spare Parts**. Adequate information to allow identification of spares shall be available.

APPENDIX A

ADDITIONAL ENGINEERING CONSIDERATION

Although these items are beyond the scope of this Performance Standard, the committee members recommend they be considered when designing the generator set to ensure the desired performance.

POWER FACTOR CORRECTION

Power factor correction equipment can have serious effects on the output characteristics of the alternator if connected to the system without its associated load due to the possibility of the system then operating at a leading power factor.

FLUORESCENT LIGHTING

For large areas of illumination, it is normal practice on 3 phase mains installations to connect adjacent fluorescent lamp fittings to different phases of the supply in order to minimize the effect of the double supply frequency flicker of the lamps. This practice should be maintained for installations supplied by 3 phase generating sets. When considering single phase installations; however, this obviously is unacceptable lighting conditions. The effect is likely to be further accentuated if single or twin cylinder engines are incorporated in the generating set. Although most modern fluorescent lighting fittings have their own power factor correction capacitors incorporated in them, this point should be checked when installing generating sets as with 'un-corrected' fittings the power factor may be as low as 0.5 lagging.

Another effect of fluorescent lamp loading is that it gives rise to a significant third harmonic circulating current in the neutral conductor of the system. It is essential, therefore, that the rating of the neutral conductor and the neutral contacts of 4 pole changeover contactors are adequately rated. If fluorescent lighting forms a major proportion of the load, the above rating should be equal to the line conductor and contactor contact rating.

ELEVATORS, HOISTS, AND CRANES

As with all major motor starting applications, it is essential that the kVA rating of the generating set A.C. generator is sufficient to start and run the motor driving the hoisting machinery while still supplying the maximum load likely to be connected to the system.

A problem can arise, however, if the generating set is installed solely to operate the hoist; i.e. the motor forms the major item of load. Due to the regenerative action of the motor when the load is descending, the A.C. generator can act as a motor. The result is that the generator set speed increases and may exceed rated speed. With some regulation systems, an excessively high voltage may be applied to the load circuit.

LOADS WITH BUILT-IN CLOSED LOOP CONTROL

A. Certain types of industrial load (e.g. automatic battery chargers and automatic thyristor speed control) use a closed loop control system involving a reference element, an error detector and error correction circuit. Such circuits may be prone to self-oscillation and it is then customary to fit some form of stabilization network to ensure satisfactory operation.

The voltage regulating system of most generating sets also works on a closed loop system of the type referred to above and when the generator is supplying this type of load it is possible for the two control systems to interact to produce a new condition of instability. The cure for this situation usually involves altering the time constants of one of the control systems so that the two natural frequencies of oscillation do not coincide. Since the generator time constants are large and generally difficult to adjust, it is much easier to adjust time constants in the electronic circuits of the load equipment.

B. Rectifier and Thyristor Controlled Loads have an adverse effect upon the wave form of the A.C. generator, the effect becoming progressively worse as the percentage of the rectified load (including SCR's) increases.

C. The critical percentage depends upon the type and design of the generator and voltage regulator. As a guide, thyristor load should not exceed approximately 40% for standard commercial type generators. Above this figure it is usually recommended that specially designed generators with low reactance are used. This results in a larger machine for a given kVA output.

GROUND FAULT PROTECTION

Defined as monitoring the effectiveness of the generator stator insulation system and of the connected load and providing an alarm or disconnect when it reaches a specified minimum.

Ground Fault Protection may be incorporated in the generating set design to provide protection in a zone from the generator to sub-circuit protection circuits, or if not defined, the equipment outgoing load terminals.

For stationary installations of a permanent nature, it is advisable to have the benefit of ground fault protection.

The variety of duties for which generating sets can be employed make it necessary to discuss the particular circumstances of the installation with the manufacturer or other competent authority to decide the best method.

For semi-portable generating sets, grounding providing as high a level of protection as possible complementary to the satisfactory normal operation of the set should be mandatory.

RESTRICTION OF ACCESS TO LIVE PARTS:

(a) Live parts within a secure enclosure need not be separately covered providing internal access is not required to effect day-to-day adjustment of controls.

(b) It is recommended that for automatic transfer switch applications, a means should be provided to facilitate maintenance of contactors, breakers and other control equipment. If bypass circuitry is selected, such facilities should preferably be located at a separate feeder panel. It should also be noted that separate auxiliary/maintained supplies may require isolating separately and a notice to this effect should be affixed to the panel when applicable. All potentially live parts must be provided with an adequate protective cover and warning note.

LOCATION OF CONTROLS AND ADJUSTMENT DEVICES:

Adjustment devices not required on a regular daily basis shall be located to permit safe operation.

APPENDIX B

APPLICATION CONSIDERATIONS

The generator set is not self-contained. In order for the generator set to perform satisfactorily, at least nine elements of the installation must meet minimum criteria. Some of these require attention only when the line installation is planned and completed. Some will require maintenance throughout the life of the equipment.

Support or Foundation: The support or foundation for the generator set may be any flat surface sufficiently dense to support the weight and withstand the linear vibrations. The surface must be leveled within the set manufacturer's specifications.
Fuel System: The rating and performance of the generator set are predicated on fuel meeting the manufacturer's specification as to energy content, viscosity, cetane number, etc., and a supply system which delivers adequate fuel to the set in all operating conditions.

Air Supply: The generator set is able to start and deliver rated output if the air supply and temperature meet manufacturer's specifications. If it is too cold, the set cannot be started; if it is too hot, the set cannot attain rating.

Exhaust System: Exhaust gas must be carried away from the generator set and dispersed to the atmosphere in such a way as to prevent recirculation to the air pickup points. The system must be sized so that the back pressure falls within the manufacturer's recommendation.

Cooling System: The medium by which the generator set is cooled may be air or liquid. In the short term, inadequate cooling may not adversely affect performance but sooner or later inadequate cooling will detract from performance, abuse the equipment, and possibly endanger personnel.

Controls, Governors, and Protection System: This system controls speed of the generator set regardless of load and protects the equipment from malfunction within the set. No subsystem of the generator set is more vital to the proper performance than the governor. The correct governor for the application must be selected and maintained in order to attain top performance.

Electrical Power Connections: Electrical power is taken from the generator set by means of power leads and circuit breaker. The current carrying capacity of this system must be adequate for the rating of the generator set, plus overload capability, while conforming to national and local codes. If these components are undersized, they may overheat which will both detract from performance and endanger equipment and personnel.

Shelter: The generator set must be provided with a means to shelter it from the elements in order for it to perform satisfactorily and safely. As the degree of shelter needed varies among manufacturers, those choosing the equipment should become familiar with site conditions and the equipment being considered.

Routine Maintenance: The generator set will perform per the manufacturer's specifications if all auxiliary systems are maintained as described in the operation and maintenance manual. Renewing the air, fuel, and lubricating oil filters is a vital part of this as is changing oil at the intervals recommended by the manufacturer. The means to start the engine should be maintained diligently because this function is fundamental. Care should be given in the planning stage of the installation to both encourage and ease servicing of the generator set and auxiliary systems.