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**Outline of Investigation for Controls For Stationary Engine Driven
Assemblies**

Issue No. 2

June 30, 2015

Summary of Topics:

This is the second issue of the Outline of Investigation for Controls for Stationary Engine Driven Assemblies.

This Outline of Investigation covers engine and engine generator or engine driven fire pumps and similar equipment control panels and assemblies that operate, control and supervise an engine or generator's operational functions. These units perform primary functions, such as engine control, overspeed control, fuel-flow control, ignition control, throttle control, engine temperature and low-oil indication, etc. These control panels and assemblies may additionally perform other secondary functions, such as battery charging, generator voltage regulation, transfer switch control, overcurrent (overload) protection, stand-alone and utility interactive controls (protective relay functionality example: over, under, voltage and frequency, phase loss, phase reversal), ground-fault protection, generator rotor and stator field control, and thermal protection.

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INTRODUCTION

1 Scope

1.1 These requirements apply to control panels, control units, and other various electrical circuits employed within a control circuit device intended for support functions, maintain operation and limiting safety control features for use in a Stationary Engine Driven Assembly or similar equipment applications.

1.2 These requirements cover controls operating at 600 Volts maximum with sensing and measurement circuits without the use of isolation devices and 36 kV a.c. or d.c. maximum with the use of isolation devices.

1.3 These requirements apply only to electrically operated control equipment.

1.4 These requirements apply to equipment intended to be operated and installed by skilled personnel in the field.

1.5 These requirements do not apply to devices in the power circuit, but may apply to pilot devices that would control switching devices in the power circuit and devices that include circuits that monitor a power circuit.

1.6 These requirements do not apply to controls for the propulsion engine of a vehicle.

1.7 These requirements apply to control equipment used in or with Movable engine driven assemblies that are otherwise constructed the same as Stationary engine driven assemblies.

1.8 These requirements do not apply to independent equipment that does not perform any control function of an engine driven assembly.

1.9 These requirements may supplement but do not cover equipment or devices for use in or connected to hazardous (Classified) locations.

2 General

2.1 Units of measurement

2.1.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

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2.2 Undated references

2.2.1 Any undated reference to a code or standard appearing in the requirements of this outline shall be interpreted as referring to the latest edition of that code or standard.

2.3 Verification

2.3.1 Labels and literature intended to accompany a product, such as installation, rating, operation, and user-maintenance instructions or manuals shall be reviewed in the investigation of the product.

2.4 Environmental conditions

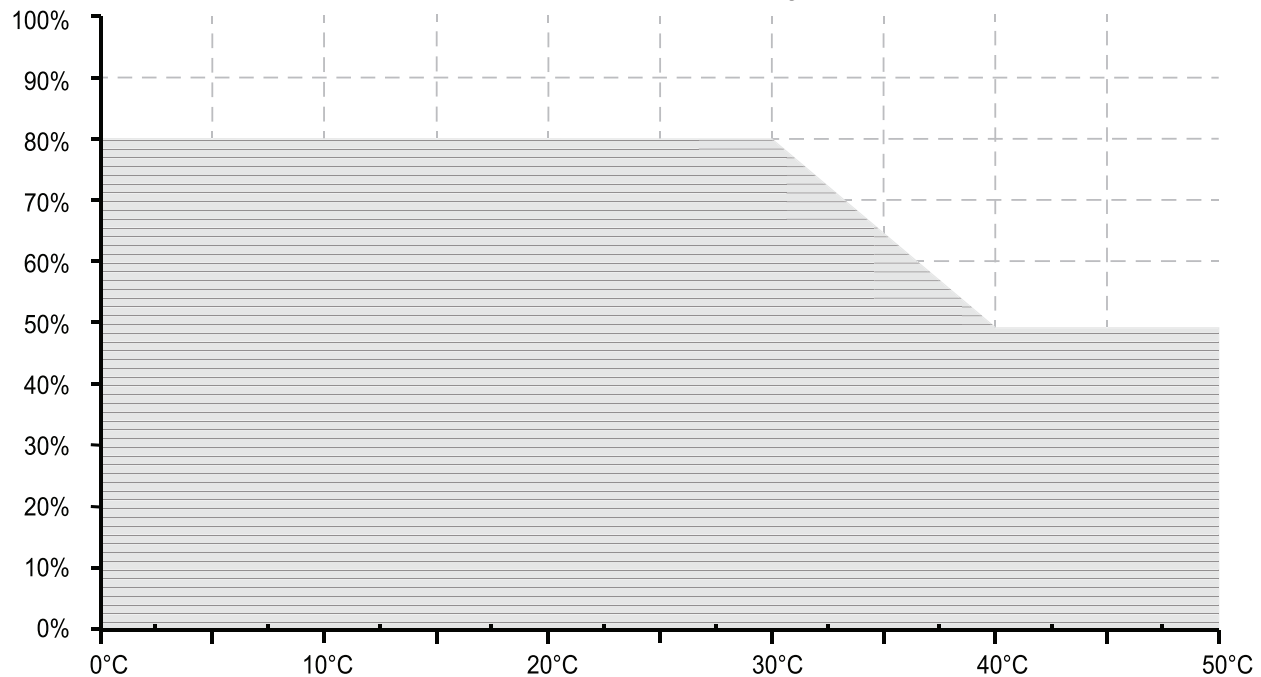
2.4.1 This standard applies to equipment designed for use under the following conditions:

- a) Indoor or outdoor use;
- b) Altitude 0 to 2000 m;
- c) Ambient temperature per Table 2.1;
- d) Maximum relative humidity in that does not exceed the levels charted in Figure 2.1;
- e) Voltage fluctuation of 90 percent to 110 percent of the nominal rated voltage for mains connected equipment and 75 percent to 120 percent of the nominal rated voltage for battery connected circuits;
- f) Overvoltage Level III based on direct connection to distribution circuits and local to the generator assembly; and
- g) Pollution degree 3 macro environment.

Table 2.1
Ambient temperatures

	Minimum		Maximum			
	Enclosed/open equipment		Enclosed equipment		Open equipment	
	°C	°F	°C	°F	°C	°F
Indoor	0	(32)	40	(104)	55	(131)
Outdoor	minus 35	(minus 31)	55	(131)	70	(158)

Figure 2.1
Maximum relative humidity



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2.5 Components

2.5.1 Except as indicated in 2.5.2, a component of a product covered by this outline shall comply with the requirements for that component. See Appendix A for a list of standards covering components typically used in the products covered by this standard.

2.5.2 A Component is not required to comply with a specific requirement that:

- a) Involves a feature or characteristic not required in the application of the component in the product covered by this document, or
- b) Is superseded by a requirement in this document.

2.5.3 A component shall be used in accordance with its rating established for the intended conditions of use.

2.5.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

2.5.5 If the manufacturer assigns a rating or an intended use to a component of a device (for example, an integral auxiliary switch intended to control an external circuit) the component is to be evaluated for that rating or use or both.

3 Glossary

3.1 General

3.1.1 AMBIENT TEMPERATURE – The temperature of the air medium into which the heat of the equipment is dissipated. See Table 1 for standard ambient temperature conditions.

3.1.2 SURROUNDING AIR TEMPERATURE RATING – A rating assigned to open type equipment that refers to the maximum ambient temperature of air immediately surrounding the equipment inside of the ultimate enclosure.

3.1.3 CONTROL CIRCUIT – A circuit that carries the electric signals directing the performance of a device, but which does not carry the main power. A control circuit is generally limited to 15 amperes.

3.1.4 PILOT DEVICE – An auxiliary mechanism that actuates, energizes, governs, or regulates another mechanism.

3.1.5 PILOT DUTY – The rating assigned to the output of a Pilot Device or similar circuit to control the energizing of the coil of a relay, contactor, solenoid, or similar coil operated mechanism.

3.1.6 PILOT LIGHT – A lamp that indicates when a pilot device is operating.

3.1.7 LOAD DEVICE – The solenoid, relay, contactor, circuit breaker, motor, heater, or other device controlled by the output circuit of a controller.

3.1.8 CONTROLLER – A device or group of devices that serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected.

3.1.9 CONTROL SYSTEM – An assembly of two or more engine and/or generators control circuit components such as engine control modules, paralleling modules, fuel control modules, and voltage regulators in combination with push-button, pilot lights, selector switches, timers, switches, and/or control relays. Generator Control Systems may be provided with a complete enclosure, partial enclosure for flat surface panel mounting, or open type for mounting totally within an ultimate enclosure such as the engine generator assembly enclosure.

3.1.10 SNUBBER CIRCUIT – A device or circuit used to suppress (“snub”) voltage transients in electrical systems. Snubber circuits are frequently used in electrical systems with an inductive load where the sudden interruption of current flow often leads to a sharp rise in voltage across the device creating the interruption. This sharp rise in voltage is a transient and can damage and lead to failure of the controlling device. A spark is likely to be generated (arcing), which can cause electrical breakdown of a switching device or electromagnetic interference in other circuits. The snubber prevents this undesired voltage by conducting transient current around the device.

3.1.11 ENGINE DRIVEN ASSEMBLY – Includes the engine and any machine designed to convert energy; thermal energy, rotating mechanical work, electrical power generation.

3.1.12 WET LOCATIONS – Location where occasional or continuous exposure to water or other liquids is anticipated. Circuits, including wiring and connections, exposed to outdoor environments or spraying, splashing, or dripping water, oil, or coolant (such as within the engine compartment) are considered to be in wet locations.

3.2 Personnel

3.2.1 OPERATOR – Trained Personnel responsible for day to day operation of the system.

3.2.2 SKILLED – Having undergone formal instruction and/or educational program related to the specified tasks.

3.3 Enclosures

3.3.1 ENCLOSURE – The portion of a unit that:

- a) Reduces the accessibility of a part that involves a risk of fire, electric shock or injury to persons, or
- b) Reduces the risk of propagation of flame, sparks, and molten metal initiated by an electrical disturbance occurring within.

3.3.2 ENCLOSURE TYPE RATINGS – Enclosed control equipment is identified with an enclosure type designation and is intended for use as indicated in Table 110.28 of NFPA 70.

3.3.3 ASSEMBLY ENCLOSURE – The enclosure provided and evaluated with the end product assembly that houses the generator, prime mover, and associated electrical equipment. Engine and generator controls may be housed in the engine or generator assembly enclosure or in a separate attached or remote enclosure.

3.3.4 WEATHER ENCLOSURE – An Assembly Enclosure that is intended to protect from exposure to environmental conditions of an outdoor application. Weather Enclosures are normally rated “rainproof”, which is equivalent to the ingress protection provided by the Enclosure Type rating of 3R, and “raintight”, which is the same as rainproof excepted no entrance of water is allowed under the rain test.

3.3.5 ENCLOSED EQUIPMENT – Equipment provided with complete enclosures and marked with one or more specific Enclosure Type ratings.

3.3.6 PANEL MOUNT – Equipment with partial or incomplete enclosures intended for mounting through the exterior wall in an opening provided in an enclosure. Panel mount equipment investigated for mounting through the wall specific enclosure types are marked “Suitable for use on a flat surface of a Type ____ enclosure,” or the equivalent, and are provided with instructions and mounting hardware. Panel mount equipment has aspects of both enclosed and open type equipment.

3.3.7 OPEN-TYPE – Unless otherwise specified in the instructions or markings on the product, open-type equipment is intended for installation completely within enclosures supplied in the field.

3.4 Power

3.4.1 OVERVOLTAGE – Any voltage that exceeds its rated or intended value. A continuous overvoltage condition on generator system that is connected in parallel with other power sources can cause reverse power to other sources.

3.5 Insulation coordination

3.5.1 ELECTRICAL INSULATION – That part of an electrotechnical product that separates the conducting parts at different electrical potentials.

3.5.2 SPACINGS – Any combination of clearance distances, creepage distances, and distances through insulation.

3.5.3 CLEARANCES - through-air spacing – The shortest distance measured through air between conductive parts.

3.5.4 CREEPAGE DISTANCES (CREEPAGE) - over-surface spacings – The shortest distance measured over the surface of insulation between conductive parts.

3.6 Wiring methods

3.6.1 FIELD WIRING – The connection of a wire, which is made in the field and that is subjected to the requirements for a terminal for field wiring as specified in this standard and the National Electrical Code (NEC), NFPA 70.

3.7 Ground

3.7.1 GROUND – The earth, unless otherwise specified.

3.7.2 GROUNDING – The act of establishing a conductive connection, whether intentional or otherwise, between an electrical circuit or electrical equipment and earth.

3.7.3 GROUNDED CONDUCTOR – A system or circuit conductor intentionally connected to ground at the building supply source, also referred to as "common" or "neutral."

3.7.4 GROUNDING CONDUCTOR, EQUIPMENT (EGC) – The definition is in Article 110 of the National Electrical Code (NEC), NFPA 70.

3.8 Circuits – general

3.8.1 LIVE PART – Denotes metal or conductive parts that, during intended use, have a potential difference with respect to ground or any other conductive part.

3.8.2 DEAD METAL – A conductive part that has Galvanic Isolation to Live Parts, Grounded Parts, and accessible conductive parts.

3.8.3 HAZARDOUS LIVE – A circuit capable of rendering an electric shock or electric burn in normal condition or single-fault condition.

3.8.4 HAZARDOUS VOLTAGE – A Hazardous Live circuit exceeding 30 V r.m.s., 42.4 V peak, or 60 V d.c. and the available current exceeds 0.5 mA r.m.s., 0.7 mA peak, or 2 mA d.c., in normal condition or single-fault condition.

3.8.5 NON-HAZARDOUS SECONDARY CIRCUIT – A circuit that is not capable of rendering an electric shock, electric burn, or fire in normal condition and single-fault condition.

3.8.6 ACCESSIBLE CIRCUIT – A circuit that is subject to inadvertent user contact or does not meet spacings requirements to exposed conductive parts.

3.8.7 ACCESSIBLE NON-HAZARDOUS SECONDARY CIRCUIT – An Accessible Circuit that meets the requirements of Non-Hazardous Secondary Circuit to the extent that directly touching any Live Part has no risk of rendering an electric shock, electric burn under both open or short circuit conditions and there is no risk of fire when a direct short is applied across the circuit or to conductive and/or grounded parts.

3.8.8 ISOLATED CIRCUIT – A circuit having an isolation transformer or isolating components such as optically or magnetically coupled devices.

3.8.9 OPPOSITE POLARITY – The relationship between two Live Parts such that an interconnection between them allows a flow of current which is limited by the impedance of the electrical supply circuit.

3.8.10 SUPPLY MAINS – Permanently installed power source which may also be used to supply electrical apparatus that is outside the scope of this outline.

3.8.11 PRIMARY CIRCUIT – Circuit that is directly connected to the external supply mains or other equivalent source (such as a motor-generator set) that supplies the electric power. It includes the primary windings of transformers, motors, other loading devices, and the means of connection to supply mains.

3.8.12 SECONDARY CIRCUITS – Those circuits supplied from transformer secondary windings or the output of a power supply that are electrically separated from the primary windings or input to a power supply.

3.9 Generators

3.9.1 GENERATOR – A machine by which mechanical energy is changed into electrical energy usually by electromagnetic induction. Generators are often referred to as DC machines while alternators are AC machines. In the context of this document, the term generators shall be understood to apply to both AC and DC machines.

3.9.2 EXCITATION CONTROLLER – Controls the output voltage of a generator by controlling its excitation (field) current. The excitation current is directly proportional to the magnetic field strength of the stator windings. The terminal voltage of the generator is proportional to the magnetic field strength until the stator field coil nears saturation.

3.9.3 AUTOMATIC VOLTAGE REGULATOR (AVR) – An excitation controller that is provided with voltage feedback from the output of a generator output and directly controls the field coil current.

3.9.4 EXCITATION – The process of generating a magnetic field by means of an electric current. An electric generator that uses field coils rather than permanent magnets will require a current flow to be present in the field coils for the device to be able to work. This construction is often referred to as an alternator. If the field coils are not powered, the rotor in a generator can spin without producing any usable electrical energy.

3.9.5 FIELD COIL – The magnetic field component of an alternator, generator, dynamo, motor, or rotary converter. The phrase is also often used in the plural form, as field coils. The field coils can be mounted on either the rotor or the stator, depending on whichever method is the most cost-effective for the device design.

3.9.6 FIELD CURRENT REGULATOR (FCR) – A controller that maintains a constant field current independent of the generator output voltage.

3.10 Equipment – general

3.10.1 TERMINAL VOLTAGE – The potential difference measured across the terminals of the generator under an open circuit condition.

3.10.2 POWER CIRCUIT – Conductors and components of branch and feeder circuits.

3.10.3 SAFETY CIRCUIT – A primary or secondary circuit that is relied upon to reduce the risk of fire, electric shock, injury to persons, operation of controlled equipment that is capable of resulting in a risk of fire, electric shock, or injury to persons. Examples include an interlock circuit, a circuit which limits leakage current to accessible parts, a circuit which limits the wattage to a limited-energy circuit, or a phase control or other circuit designed to limit temperatures or fault current in the end-use product to acceptable levels.

3.10.4 TRANSFER SWITCH – A switching device that disconnects a load from a primary source and connects the load to another separately derived source. Automatic Transfer Switches operate without human intervention when power is lost in the primary source.

3.10.5 TRANSFER SWITCH CONTROLLER – A device that remotely causes an Automatic Transfer Switch to operate.

3.10.6 INTERNAL POWER TRANSFER – A circuit allowing more than one source to power an internal circuit but only one source is connected at a time. See also Transfer Switch.

3.10.7 SURGE PROTECTIVE DEVICE – A component or assembly that limits the transient voltage such as an overvoltage protective device, a transformer with isolated windings, or damping impedance suitably located.

3.11 Engine controls

3.11.1 PRIME MOVER – The engine or rotating equipment driving the generator, pump, or other mechanical load. Typical examples of prime movers are, internal combustion and external combustion engines, wind and water driven turbines, and electric motors.

3.11.2 ENGINE – A machine for converting energy (in such forms as heat, chemical energy, radiation energy, and potential energy) into mechanical force and motion.

3.11.3 INTERNAL COMBUSTION ENGINE – Any heat driven engine in which the working medium consists of the products of combustion of the air and fuel supplied. This combustion usually is affected within the working cylinder but can take place in an external chamber. Typical examples of internal combustion engines are auto cycle, diesel cycle, and brayton cycle (gas turbine engines.) Engine controls for internal combustion engines control the engine starting motor, air flow, and fuel flow.

3.11.4 STARTER CONTACTOR – A high current battery contactor used to energize the Starter Solenoid. Typical starter contactor coil power is 8 to 25 watts.

3.11.5 STARTER SOLENOID – A dual function, two coil operated device used to mechanically engage the starter motor to the engine and to energize the windings of the starter motor. The two coils will have the same number of turns. However the positioning coil has larger winding conductors and will typically draw up to 25 Amps. The holding coil has smaller winding conductors and will typically draw up to 10 Amps. The two coils operate in parallel for 50 ms for a total current draw of up to 35 Amps. After 50 ms the positioning coil circuit will open and the holding coil continues to be energized with the current reduced to 10 Amps maximum.

3.11.6 CRANKING – The energizing of an electric (or hydraulic, or pneumatic) starter motor (or starter) for rotating an internal-combustion engine so as to initiate the engine's operation under its own power. The cranking operation in engine driven assemblies is usually initiated by manually actuating a momentary switch or automatically energizing a relay coil that controls the operation of the starter contactor. The term originated from the hand operated crank mechanism used to start internal combustion engines used in early automobiles.

3.11.7 ENGINE CRANKING SEQUENCE – The sequence of Cranking Cycles repeated until the Crank Limit time is reached or the engine has started. Also includes the sequence of continuously cranking the engine until the Crank Limit time is reached or the engine has started.

3.11.8 CRANK (DUTY) CYCLE – The part of the engine cranking sequence that consists of single iteration of crank time plus the rest time. A cranking duty cycle for emergency standby applications per NFPA 110 and fire pump applications per NFPA 20 is 15 seconds crank time followed by 15 seconds rest time.

3.11.9 CRANKING TIME LIMIT (CRANK LIMIT) – The maximum time that the engine cranking sequence is allowed to operate without the engine starting. A failure to start is indicated after the crank limit has been reached.

3.11.10 ENGINE CONTROLLER – Device, such as governor device and engine control unit that control the operation of the prime mover.

3.12 Annunciators

3.12.1 ANNUNCIATOR – An audio or visual indicator that announces which electrical circuit has become active. For the purposes of this outline the electrical circuits typically being monitored include engine sensors, engine starting battery, transfer switch, air damper control, and/or generator output. The visual indicators range from pilot lights and panel meters to panel mounted displays.

3.13 Cogeneration controls

3.13.1 Reserved.

3.14 Parallel generation systems

3.14.1 SYNCHRONIZATION – Matching the voltage amplitude, phase angle, and frequency of the output of a generator with the amplitude, phase angle, and frequency of the local area system bus or utility.

3.14.2 DESIGN TEST – Test of one or more devices made to a certain design to demonstrate that the design meets certain specifications. Also referred to as Type Test.

3.14.3 PRODUCTION TEST – A test conducted on every unit of equipment prior to shipment.

3.15 Protective controls

3.15.1 ELECTRONIC PROTECTION – Equipment that provide various types of electronic protection by detecting abnormal conditions and isolating them from the rest of the electrical system. For the purpose of this document, this term may apply to equipment that causes the circuit breaker to open, disconnect to open, engine to shut down, or generator to stop production of power.

3.15.2 INTERRUPTING DEVICE – A device capable of being opened and reclosed whose purpose is to interrupt faults and restore service or disconnect loads. These devices can be manual, automatic, or motor-operated. Examples include circuit breakers, motor-operated switches, and electronic switches.

3.15.3 OVER EXCITATION – A condition when the excitation system is providing too much field current and as a result, the rotor of the generator will over heat. If the excitation system is equipped with an over excitation limiter, this limiter acts to reduce the excitation current if this condition exists.

3.15.4 UNDER EXCITATION – A condition where the generator is not getting enough excitation current. If the generator does not get enough excitation current, it can be un-synchronized with the grid. This is referred to as slipping a pole. If this occurs, the generator can be severely damaged.

3.15.5 MOTORING – The rotation of a generator from reverse electrical power instead from the prime mover.

3.15.6 OVERCURRENT – Any current in excess of the rated current of the equipment, generator, or ampacity of the conductors. It may result from overloads, short circuits, and faults to ground.

3.15.7 CURRENT LIMITING – Equipment designed to limit the current to a predetermined value. Current limiting may be accomplished by controlling the prime mover speed or the excitation field current.

3.15.8 OVERLOAD – The definition is in Article 110 of the National Electrical Code (NEC), NFPA 70.

3.15.9 GROUND FAULT – Denotes an unintentional electrical path between a part operating normally at some potential to ground, and ground. Ground fault protection of a generator is intended to interrupt equipment damaging line-to-ground currents. Ground fault protection of personnel is intended to interrupt excessive leakage currents to protect from risk of electric shock. Ground fault protection will operate at current levels lower than current levels required to protect from overload or short circuit conditions.

3.15.10 REVERSE POWER – Electrical power provided to the generator from the electric power system or load that causes motoring of the generator after loss or reduction of rotational power from the prime mover.

3.15.11 SHORT CIRCUIT – A fault current is caused by direct line-to-line short across a load or the generator terminals. The symmetrical short circuit fault current is a function of the terminal voltage divided by the sum of transformer or generator impedance, line-side series equipment impedance, and the conductor impedance at the location of the fault.

3.15.12 TYPE 1 ACTION – Automatic action of an operating control for which the manufacturing deviation and the drift of its operating value, operating time or operating sequence have not been declared and evaluated.

3.16 Current sensing

3.16.1 CURRENT TRANSFORMER – A type of instrument transformer used to measure AC current. It is intended to be able to measure the current through an isolated secondary winding where the ratio of primary turns to secondary turns is inversely proportional to the ratio of the primary current to the secondary current up to the knee-point. A burden resistor is connected across the secondary winding to convert the current measurement to a voltage measurement in a similar way as a current shunt. The burden resistor is sized so that all the secondary current passes through it.

3.16.2 PASS-THROUGH TYPE CURRENT TRANSFORMER – A bushing or window type current transformer in which the primary conductor is passed through an opening in the core of the transformer and the secondary windings. The pass-through type CT is not provided with primary terminals. The secondary may be provided with terminals or leads.

3.16.3 KNEE-POINT – The point that indicates saturation of the current transformer. The knee-point voltage of a current transformer is the magnitude of the secondary voltage after which the output current ceases to follow linearly the input current. This means that the one-to-one or proportional relationship between the input and output is no longer within declared accuracy.

3.17 Fire detection and alarm systems

3.17.1 FIRE DETECTION AND ALARM SYSTEMS – A system that includes smoke flame detectors intended to activate an alarm when a fire is detected. For engines installed in a building NFPA 37 requires fuel shut-off valves to be installed that close when the fire detection system activates the alarm.

3.18 Functional safety

3.18.1 FUNCTIONAL SAFETY – Functional safety applied to the overall safety of a system or piece of equipment that depends on the system or equipment operating correctly in response to its inputs, including the safe management of likely operator errors, hardware failures, and environmental changes. The objective of functional safety is freedom from unacceptable risk of physical injury or of damage to the health of people either directly or indirectly (through damage to property or to the environment). For the purposes of these guidelines, this applies to functions that:

- a) Limit the effects abnormal voltage, frequency, and/or power;
- b) Limit the effects of an overcurrent condition;
- c) Maintain line pressure of an engine driven fire pump system;
- d) Monitor critical system sensors for safety indications and shutdowns in emergency power systems and fire pump applications;
- e) Control the detection time of a transfer switch or paralleling device controller;
- f) Control the detection time of electronic protection of the engine, generator, pump, and other components of the system;
- g) Provide a means to remove output power from a generator system from the load upon actuation of an emergency stop device;
- h) Provide a means to shut down the prime mover upon actuation of an emergency stop device;
- i) Control the synchronization of a generator system of a distributed resource to an electric power system; and
- j) Incorporate signal and communication circuits that interconnect systems or devices to provide the functions described above.