Practical Guidelines for Electrical Area Classification in Combustion Turbine-Generator Power Plants

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1.0 INTRODUCTION

Combustion Turbine-Generator (CTG) power plants utilize flammable or combustible liquids and gases that pose fire or explosion hazards. It is essential to know the characteristics of all of the hazardous materials used in the power plant, define their locations and potential sources of leaks, and determine the extent of the Hazardous Area associated with each leak source. Each Hazardous Area should be classified according to applicable industry codes and standards. Such Area Classifications are used in the selection and installation of suitable electrical equipment, wiring devices, and wiring methods that prevent the ignition of flammable or explosion mixtures. This paper describes the approach being used by Burns and Roe Enterprises, Inc. in the classification of Hazardous Areas for a typical CTG power plant. Others may find this paper useful in developing their own guidelines for classifying Hazardous Areas in power plants. Burns and Roe Enterprises, Inc. takes no responsibility for classifications prepared by others using these guidelines.

2.0 DESIGN BASICS

The National Electrical Code (NEC), NFPA 70, defines Hazardous (Classified) Locations as those where fire or explosion hazards may exist due to the presence of flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings.

Electrical Area Classification is the process of determining the existence and extent of Hazardous (Classified) Locations in a facility handling any of the substances stated above. The result of such determination is usually called the Electrical Area Classification of the facility. The terms Area Classification, Hazardous Locations, Hazardous (Classified) Locations, and Classified Areas, when used in the context of electrical equipment, are all synonymous with the term "Electrical Area Classification," which is being used in these guidelines to avoid confusion with other non-electrical classifications.

For a fire or explosion to occur:

- Flammable or combustible material must be present,
- The material must be mixed with air in the proportions required to produce an ignitable mixture, and
- There must be sufficient release of energy to cause ignition of the mixture.

The above conditions constitute the well-known "fire triangle." Within the context of Electrical Area Classification, the source of energy is understood to be within the electrical system of the facility.

Areas are classified in accordance with material type, material properties, and the likelihood that an ignitable mixture will be present. The NEC permits categorization of hazardous locations in two ways:

- Class I, II and III, Division 1 and 2 concept (NEC Article 500)
- Class I, Zone 0, 1, and 2 locations concept (NEC Article 505)

The first method has traditionally been used in the United States, while the second method is in accordance with International Electrotechnical Commission standards and has been used in Europe. Since 2002, both methods have been accepted by the NEC.

This paper is based on the Class, Division concept (NEC Article 500) since it is most commonly used in U.S. power plants.

Hazardous Locations are then categorized as follows:

(a) Class (Material Type)

Class I - denotes areas where flammable gas, vapor or liquid is present.

Class II - denotes areas where combustible dust is present.

Class III - denotes areas where ignitable fibers or flyings are present. (Class III areas rarely exist in CTG facilities.)

(b) Group (Material Properties)

Hazardous chemicals are given group designations based on tests, which rate their explosion and fire characteristics. Grouping is a convenience for approving and listing equipment as suitable for use in such locations. National Fire Protection Association (NFPA) Recommended Practices 497 and 499 and other industry sources list chemicals by group. Groups and typical material types are:

Group A – Acetylene

Group B – Hydrogen

Group C – Cyclopropane, ethyl ether

Group D – Acetone, butane, hexane, natural gas, fuel oil

Group E – Combustible metals

Group F – Carbonaceous materials, including coal dust

Group G – Flour, starch, plastic

(c) Division (Likelihood of Hazardous Atmosphere**)**

Division 1 – denotes areas where flammable or combustible concentrations exist under normal operating conditions or have a high likelihood of presence.

Division 2 – denotes areas where flammable or combustible concentrations exist under abnormal operating conditions or have a low likelihood of presence.

Non-classified or unclassified – denotes areas where the presence of hazardous material is so infrequent that Electrical Area Classification is deemed unnecessary.

(d) Auto-Ignition Temperature

The Auto-Ignition Temperature (AIT) of the hazardous material must be known to properly complete the Area Classification since the temperature of electrical equipment must be checked to insure that ignition will not occur. NFPA 497 provides values of the AIT for various combustible substances.

A typical area classification for propane gas is: Class I, Division 2, Group D, 450^{o}C AIT, where:

Class I - indicates the presence of vapor,

Division 2 - indicates the presence under abnormal conditions only,

Group D - indicates the material is listed in this group, and

AIT - indicates the flammable concentration ignites at 450^{o} C.

Once an area has been classified, the NEC provides very specific and stringent requirements regarding the electrical equipment, associated wiring, and installation in such locations. These requirements are intended to prevent electrical equipment from being an ignition source in flammable or combustible atmospheres. Therefore, the electrical installation must be explosion proof in order to comply with these requirements.

Obviously, the Electrical Area Classification must be known before any electrical equipment can be specified, designed, or installed. In many CTG power plants, long lead-time, special purpose, mechanical equipment must be specified and ordered early in the project. Such equipment usually includes electrical motors, instrumentation, and controls, which are required to meet the Electrical Area Classification. Failure to correctly specify the Electrical Area Classification for such equipment can contribute to unsafe installations, rework, confusion, delays, and cost overruns.

3.0 DETERMINATION OF ELECTRICAL AREA CLASSIFICATION

An Electrical Area Classification is best performed by a project team consisting of members who are knowledgeable about classification, applicable codes and standards, electrical equipment and wiring, chemicals used, fire detection and protection systems, process operations and conditions, maintenance procedures, HVAC engineering, and plant safety.

A large number of variables must be considered in order to correctly determine Electrical Area Classification areas. These variables include properties and behaviors of materials, volumes, pressures, temperatures, flows, piping and equipment construction, weather, building arrangements, adequacy of mechanical ventilation and gas detection systems, operator interfaces, and, of course, experience. Careful evaluation of all data in accordance with established techniques, along with the application of sound engineering judgment, should result in a consistent and safe classification.

The NEC states that each room, section, or area shall be considered individually in determining its classification. The practice of classifying an entire facility using a broad-brush approach, instead of evaluating each individual area, sometimes referred to as “blanket classification,” usually leads to a less safe and more costly facility. This is especially true for a power plant, which normally contains several different process areas, support areas, and maintenance areas. A properly conducted Electrical Area Classification, in a well-designed and constructed facility, might result in a few Division 1 areas and several much larger Division 2 and non-classified areas.

While many other companies and industry organizations have written specific procedures for Area Classification, the NFPA Recommended Practices for Classification are most applicable to power plants. NFPA 497 covers Class I areas containing gases, vapors, and liquids, and NFPA 499 covers Class II areas containing dusts. These practices are based on identifying and locating sources of hazardous material. Sources can be necessary open process points or unintentional leaks in the process. Once sources are located, the practices provide guidance in determining the degree of the hazard (Division 1 or Division 2) and the extent of the hazard. Diagrams are provided for typical situations that give recommended distances from the source for the extent of Hazardous Locations. Although the diagrams take into account pressure, volume, flow rate, ventilation, building construction, and certain process operations, they are only typical and must be applied with sound engineering judgment to specific situations.

What follows is a brief outline of the NFPA practices. The actual practices and associated references should be consulted when performing any Electrical Area Classification.

To determine the Electrical Area Classification:

(a) Assemble pertinent information, such as:

- Codes, standards, practices, and references
- Process and operating descriptions
- Process flow diagrams (PFDs) and material and heat balance charts
- Piping and instrumentation diagrams (P&IDs)
- Equipment arrangement drawings and plot plans
- Commissioning, testing, operating, and safety procedures.

(b) List all flammable and combustible materials, along with their pertinent properties, such as ignition temperatures and flash points.

(c) Confirm the need for classification by assessing the likelihood of the presence of flammable and combustible materials.

(d) Locate material release sources, such as:

- Open process points
- Control valves
- Pump seals
- Drains
- Metering points
- Sampling points
- Vents.

See NFPA 497 and 499 for additional guidance in identifying sources.

As a practical matter, areas with large quantities of process equipment and piping that handle flammable/combustible materials can, as an area, be considered a release source.

(e) Determine an area's Class and Group from the chemicals present.

(f) Determine the degree of hazard, Division 1 or Division 2, by assessing the probability of presence.

(g) By reviewing the plant equipment layout drawings, determine the extent (or distance from the source) of Hazardous Areas.

(h) Consider utilizing recognizable boundaries for the extent of Classified Areas, such as walls, floors, ceilings, and column lines. This approach will greatly simplify both design and installation.

(i) Prepare the recommended documentation and have the project team review and come to an agreement.

4.0 APPLICABLE INDUSTRY CODES AND STANDARDS

The following codes and standards are particularly applicable to Hazardous Classified Areas in CTG power plants:

(a) United States Standards

National Fire Protection Association

NFPA 30-2003	Flammable and Combustible Liquids Code
NFPA 50A-1999	Standard for Gaseous Hydrogen Systems at Consumer Sites
NFPA 59-2001	Standard for the Production, Storage and Handling of Liquefied Natural Gas
NFPA 70-2005	National Electrical Code (Chapter 5)
NFPA 497-1997	Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

American National Standards Institute (ANSI)

ANSI K61.1-1999	Safety Requirements for the Storage and Handling of Anhydrous Ammonia
ANSI C2-2002	National Electrical Safety Code - Section 127
ANSI/ASHRAE 15	Safety Code for Mechanical Refrigeration (for ammonia)

Factory Mutual (FM)

Underwriters Laboratory (UL) Standards

Occupational Safety and Health Administration (OSHA) Standards

(b) European Standards

International Electrotechnical Commission (IEC) Standards

IEC 79-10 (Part 10)	Classification of Hazardous Areas
IEC 79-14 (Part 14)	Electrical Installations in Explosive Gas Atmospheres
IEC 79-15 (Part 15)	Electrical Apparatus With Type of Protection ”n”

(c) CTG Vendor Documentation

Major CTG vendors often supply Area Classification documents pertaining to their systems and equipment.

(d) Numerous other materials are available for reference through industry sources.

5.0 FIRE AND EXPLOSION RISK SYSTEMS AND EQUIPMENT

The main components and systems in a CTG power plant that pose fire or explosion risks are as follows:

- **Fuel Gas System** - Includes gas receiving station, gas analyzer system, gas compressor station, main shut-off valve, gas relief points, filter and scrubber station, gas pre-heater, gas control valve block, gas safety relief valve, gas flow metering, gas distribution piping, and turbine auxiliaries equipment/compartment.

- **Ignition Gas System** - Includes propane gas cylinders, piping to ignition burner and combustor, and gas relief points.

- **Fuel Oil System** -Includes fuel oil tanks, fuel oil unloading and forwarding pump station, fuel oil treatment system, fuel oil metering, fuel oil booster pump and leakage tank, fuel oil control valve block, and fuel oil piping to burners. The fuel oil becomes flammable when heated above its flash point.

- **Hydrogen Gas for Generator Cooling System** - Includes hydrogen gas cylinder station, gas unit, seal oil unit, control cubicle, and piping.

- **Plant Battery System** - Includes battery rooms.

- **Ammonia System** - Includes storage tanks, pumps, and diked areas.

Potential Leak Sources

The following are some of the most common potential leak sources in the fuel gas, propane gas (ignition), fuel oil, hydrogen gas, and ammonia gas systems. Some of these leak sources are identified by the CTG equipment vendor.

(a) Fuel Gas System

- Flange gasket connection points on local piping, tubing, or at equipment
- Flange gaskets or screwed connections in main headers
- Seals (unless seal-less) at pumps and control valves
- Pressure relief devices due to overpressure in the system
- Gas relief points located in the open air above the turbine building roof for equipment located within the turbine area.

(b) Propane Gas (Ignition) System

- Ignition gas cabinet at the turbine auxiliary equipment area with screwed couplings and glands
- Gas relief points above the turbine building roof.

(c) Fuel Oil System

- Fuel oil transfer pipe joints and coupling in the fuel oil unloading area and forwarding pump stations
- Fuel oil tanks piping, pump blocks, filling and suction valve blocks, vents, indicators, alarm switches, oil piping outdoor and at combustor, burners, and heaters
- Open process points, sample points, and sumps.

(d) Hydrogen Gas (H_2) System

- H_2 gas storage cylinders
- H_2 cooling unit and separator
- H_2 cooled generator
- Battery rooms - Hydrogen gas is released from lead-acid flooded cell batteries during battery charging operations.

(e) Anhydrous Ammonia System

- Storage tanks, vaporizer, and diked areas.

6.0 BOUNDARIES OF HAZARDOUS CLASSIFIED LOCATIONS

Using the references listed above, the extent of the Classified Area is established for each type of leak source as shown in Table A.

These guidelines should be used as a minimum requirement for Classification of Electrical Areas where such materials are located and processes are performed. Sound engineering judgment should be applied to determine if additional areas, not mentioned in Table A, should be identified. Equipment manufacturers' recommendations for the Area Classification of specific equipment should be followed, especially if they are more stringent than the guidelines provided in Table A.

When there is more than one leakage source in an area, such as in the case of a manifold having several instruments, valves, and flanges, or if there are several pieces of equipment with potential leak sources, the area should be boxed out as an overall three-dimensional shape covering the limits of the extreme leakage points.

In addition to the recommended distances from sources stated above, consideration should be given to using easily recognizable boundary limits when defining the horizontal and vertical limits of Classified Locations. Examples of recognizable boundaries are column lines, walls, ceilings, coordinates, equipment outlines, roads, dikes, etc. Areas identified by recognizable boundaries are helpful to plant installation, operations, and maintenance personnel.

To avoid undue expense, precaution should be taken to verify that boxing in overall areas or extending Classified Areas to recognizable boundaries does not include electrical equipment that would otherwise not be included in the hazardous area.

Table A
Extent of Classified Areas

Hazardous Material	Process Equipment	Location / Ventilation	Source of Leakage	Area Class / Division / Group/ AIT	Extent of Classified Area from Leakage Source (NFPA 497)
Fuel Gas (Natural Gas)	Gas Receiving Station	Outdoor / Natural	Possible release due to failure at meters, flange gaskets, or valve seal	I/2/D/ 457º C	Within 15 ft in all directions from leakage point
Fuel Gas (Natural Gas)	Gas Compressor Station	If not enclosed/ Natural If enclosed/ Artificial Forced	Possible release due to failure at meters, flange gaskets, or valve seal	I/2/D/ 457º C	Within 15 ft in all directions Entire Enclosure
Fuel Gas (Natural Gas)	Safety Valve Gas Relief Point(s)	Outdoor / Natural	Possible release due to overpressure in the system (abnormal) (Note 2)	I/1/D/ 457º C & I/2/D/ 457º C	Within 15 ft in all directions from a release point
Fuel Gas (Natural Gas)	Gas Filter/ Separator & Pre-heater Station	Outdoor / Natural	Possible release due to failure at meters, flange gaskets, or valve seals	I/2/D/ 457º C	Within 15 ft in all directions from leakage point
Fuel Gas (Natural Gas)	Gas Control Valve Module	Packaged Enclosure or Building/ Adequately Ventilated (Note 1)	Possible release due to failure at meters, flange gaskets, or valve seal, or door seals (abnormal)	I/2/D/ 457º C	Entire Enclosure or Building
Fuel Gas (Natural Gas)	Gas Control Valve Module Relief Point	Gas Turbine Building/ Enclosure Roof	Exhaust Vent	I/1/D/ 457º C	Within 18 ft radius from vent and 3 ft vertical from vent
Fuel Gas (Natural Gas)	Heat Recovery Steam Generator (HRSG) Supplemental Gas-Firing Duct Burner System	Outdoor / Natural	Possible release due to failure at flange gaskets or valve seal (abnormal)	I/1/D/ 457º C	15 ft radius from burner front, valve, and connections to burner grids
Fuel Gas (Natural Gas)	Fuel Gas Drain Tank	Outdoor / Natural (Above Ground)	Possible release due to failure at valve seal (abnormal)	I/1/D/ 457º C & I/2/D/ 457º C	Within 5 ft radius from relief valve and 10 ft radius from vent or relief valve

Hazardous Material	Process Equipment	Location / Ventilation	Source of Leakage	Area Class / Division / Group/ AIT	Extent of Classified Area from Leakage Source (NFPA 497)
Fuel Gas (Natural Gas)	Fuel Gas Drain Tank	Outdoor / Natural (Under Ground)	Possible release due to failure at instruments, flange gaskets, or valve seal	I/1/D/ 457º C & I/2/D/ 457º C	Within 5 ft radius from relief valve and 15 ft radius all around
Ignition Gas (Propane Gas)	Ignition Gas Cabinet	Turbine Auxiliary Equipment Area	Possible release due to failure at valve seal (abnormal)	I/2/D/ 450º C	Entire Cabinet
Fuel Oil	Fuel Oil Unloading & Pump Station	Outdoor Oil Unloading Shelter/ Natural	Possible release due to failure at oil transfer pipe coupling at the oil delivery truck	I/2/D/ 257º C	3 ft from the edge of the device extending in all directions and up to 18 inches above floor or grade level extending to a distance of 10 ft horizontally
Fuel Oil	Fuel Oil Tank	Outdoor Oil Tank Farm / Natural	Possible release of gas vapor from vent and sample points	I/1/D/ 257º C & I/2/D/ 257º C	Inside tank and within 5 ft in all directions from a point of discharge Beyond 5 ft but within 10 ft in all directions from a point of discharge
Fuel Oil	Fuel Oil Forwarding Station	Oil Tank Farm Area/ Adequately Ventilated (Note 1)	Possible release due to failure at valve seal (abnormal)	Non-classified if handled at less than the flash point temperature & I/2/D if handled at greater than the flash point temperature	Entire Compartment / Enclosure
Fuel Oil	Fuel Oil Control Valve Block	Turbine Auxiliary Equipment Compartment / Adequately Ventilated (Note 1)	Possible release due to failure at valve seal (abnormal)	Non-classified if handled at less than the flash point temperature & I/2/D if handled at greater than the flash point temperature	Entire Compartment / Enclosure
Hydrogen Gas	Hydrogen Gas Storage Cylinders	Outdoors / Natural	Possible release from valve packing, flange gasket, and relief valves vented or system over-pressure (abnormal) (Note 2)	I/2/B/ 520º C	Within 15 ft in all directions from a point of discharge
Hydrogen Gas	Hydrogen Manifold Equipment	Under Turbine Generator (TG) Pedestal – Open Bay / Adequately Ventilated (Note 1)	Possible release due to leaks in screwed joints	I/2/B/ 520º C	15 ft horizontal and vertical radius from leak source

Hazardous Material	Process Equipment	Location / Ventilation	Source of Leakage	Area Class / Division / Group/ AIT	Extent of Classified Area from Leakage Source (NFPA 497)
Hydrogen Gas	Hydrogen Cooled Generator	Turbine Building / Adequately Ventilated (Note 1)	Hydrogen oil seals	I/2/B/ 520º C	Within 5 ft in all directions from a point of leakage source
Hydrogen Gas	Hydrogen Seal Oil Unit	TG Building / Adequately Ventilated (Note 1)	Possible release due to failure at meters, flange gaskets, or valve seal (abnormal)	I/2/B/ 520º C	Within 5 ft in all directions from a point of leakage source
Hydrogen Gas	Hydrogen Gas Relief Points/Seal Oil Unit	Outdoor above TG Building Roof	Gas vents	I/1/B/ 520º C	Within 15 ft in all directions from a point of discharge
Hydrogen Gas	Plant Direct Current (DC) System Batteries	Battery Room / Adequately ventilated	Hydrogen gas during battery charging cycle. Failure of the continuously operated exhaust fan.	Non-Classified	See Note 3
Anhydrous Ammonia	Tank and Vaporizer	Outdoor Storage Tanks and Diked Areas	Ammonia concentrations in air are not likely to exceed 16% by volume.	Non-Classified	See Note 4

Note 1: Adequately ventilated per NFPA 497: A ventilation rate that affords either 6 air changes per hour, or 1 cfm per square foot of floor area, or other similar criterion that prevents the accumulation of significant quantities of vapor-air concentrations from exceeding 25% of the lower flammable limit.

Note 2: If vent pipes are being discharged in an otherwise non-hazardous area, they should be discharged outdoors at a minimum distance of 10 feet (for natural gas) and 15 feet (for hydrogen) from any electrical equipment, light fixture, etc.

Note 3: A continuously operated exhaust fan in the battery room is required to remove the hydrogen gas discharged from the batteries. The exhaust fan will prevent accumulation of the hydrogen gas explosive mixture. Loss of electrical power to the fan should be alarmed in the Plant Control Room.

Note 4: Ammonia detectors should be installed around the diked area that send a signal to the Plant DCS. A deluge water spray system should be installed for automatic/manual actuation and an alarm signal should be sent to the Fire Alarm Panel located in the Plant Control Room.

7.0 SUPPORT DRAWINGS AND DOCUMENTS

Like any engineering study or analysis, Electrical Area Classification must be carefully documented since it serves as the basis for electrical equipment requirements in such Classified Areas. Such documentation, along with properly implemented protective measures, inhibits the possibility of an explosion or fire. The documentation also provides the necessary guidance to engineers working on facility design, as well as to insurance and inspection personnel. The protective measures ensure the safety of the operations and maintenance personnel working in the facility.

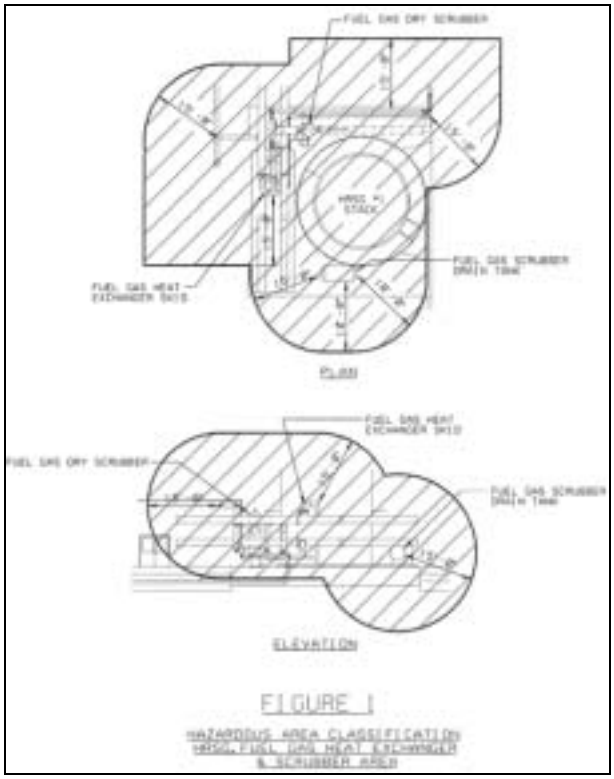
The Design Engineer should prepare a Hazardous Location Design Basis Document defining the plant hazards, the potential leakage sources, and the extent of the Classified Areas. The Design Basis Document and the associated plant drawings that show the extent of the horizontal and vertical boundaries of each Classified Area should be

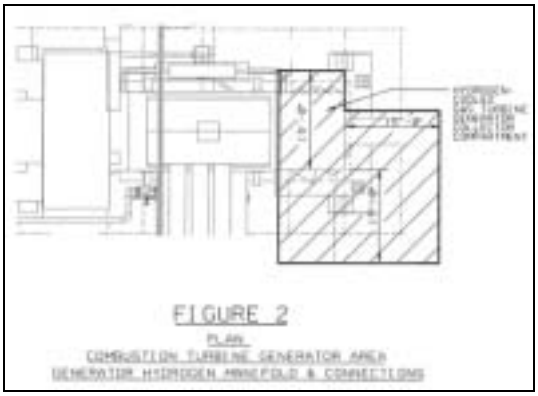
discussed with the Owner, the Construction Contractor, and the Plant Operators to ensure their understanding of the affected areas.

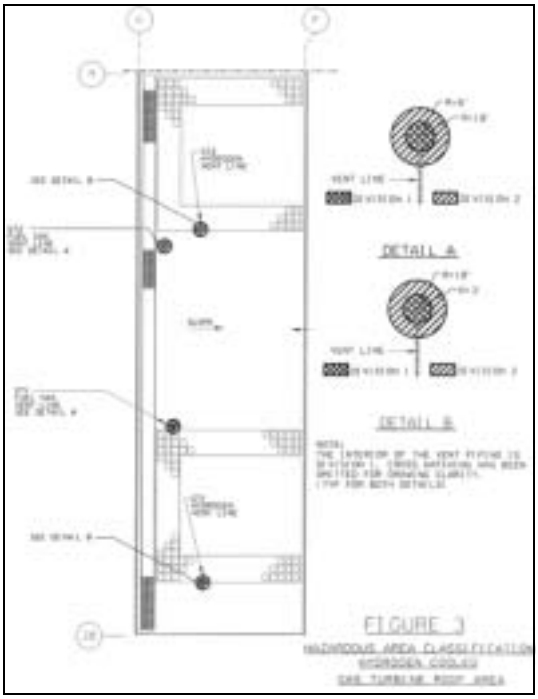
Figures 1, 2, and 3 show typical details of Classified Hazardous Areas for equipment associated with a combustion turbine and generator, Figure 4 for an auxiliary boiler, and Figure 5 for an ammonia vaporizer skid area associated with a combined cycle power plant. Hazardous Area Classification drawings should be prepared for each plant and should include similar details for the use of the Plant Construction Contractor and the Operations staff.

Documentation should include:

- A listing of all the flammable and combustible materials used in the facility, along with their pertinent properties, such as flash point, ignition temperature, density, and how and where handled.
- Brief process, operating, maintenance, and cleaning descriptions.
- A list, including dates and/or editions, of all the codes, standards, references, practices, and other data used to prepare the classification.
- A discussion of all the assumptions made during the analysis.
- A listing of each room or area and its determined Area Classification, along with the rationale for making such determination.
- A complete set of Electrical Area Classification Drawings, which indicate all of the process equipment, the normal or leakage sources, and the boundaries of the Area Classifications.







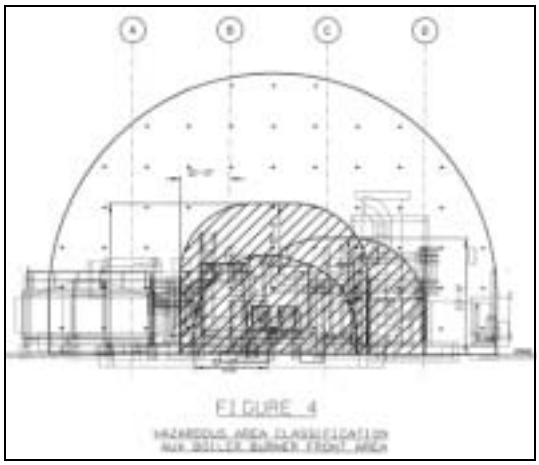


FIGURE 4

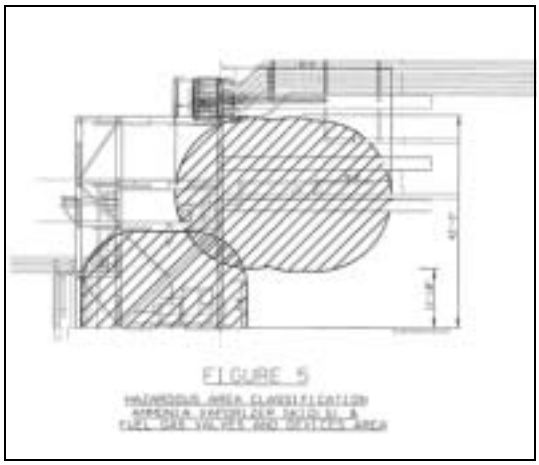


FIGURE 5

8.0 ELECTRICAL EQUIPMENT AND DESIGN IN HAZARDOUS (CLASSIFIED) LOCATIONS

Once the Electrical Area Classification has been determined, the NEC provides stringent requirements for electrical equipment and design in hazardous locations. These requirements are intended to prevent or minimize the potential for electrical equipment and wiring being the ignition energy source to a hazardous atmosphere. The NEC rules should be very carefully followed and exceptions taken only if absolutely necessary. Rather than providing specific design guidelines, the following brief list of NEC rules is intended only to convey an awareness of the complexity of electrical design in hazardous areas. Experienced and knowledgeable engineers must apply the NEC rules to the specific situations.

- Explosion proof and dust-ignition proof equipment is required in Division 1 areas and for certain types of equipment in Division 2 areas.
- Approved (by UL or other appropriate agency) equipment is preferred in Hazardous Locations.
- It is preferable to locate electrical equipment outside the Hazardous Area.
- General purpose equipment is permitted for certain applications in Division 2 areas.
- Purging and pressurization of enclosures are permitted to prevent the entrance of flammable and combustible material, provided that specific rules in NFPA 496 are followed.
- Instrumentation enclosures may be the general purpose type if they are part of Intrinsically Safe Systems and if they are installed per NEC Article 504.
- Rigid metal conduit is the allowable wiring method in Division 1 areas.
- Cable tray and cable, under certain conditions, are permitted in Division 2 areas.
- Electrical equipment must have temperature ratings or operating surface temperatures below the AIT of the hazardous substance present.