CHEMETRON
Fire Systems™

WATER MIST

Application Bulletin

CHEMETRON
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A World of Protection

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Water Mist Fire Suppression —

Compartmentized Gas Turbines

The newer high capacity cogeneration plants utilize compartmentized gas turbines – units that are housed in enclosures, shipped to the job site and quickly placed in service with little on-site construction. We choose to call these compartmentized turbines *packaged units*. Figure 2 illustrates a compartmentized gas turbine protected by a water mist fire protection system.

This bulletin presents a description of the recommended **Chemetron** Water Mist system protection, along with a background of the development work done to assure that this protection is properly designed to meet the unusual demands of this equipment.

This application can also include fire protection for auxiliary turbine rooms (which can house oil pumps, oil tanks, fuel filters, gear boxes, drive shafts and lubrication skids), diesel emergency rooms, and other similar machinery spaces.

The duration of the water mist discharge for gas turbines is a minimum of 20 minutes, except when the turbine wind-down time is specified as less than 20 minutes. All other hazards described shall be protected for a minimum of 10 minutes.

Description of Hazard

A gas turbine unit consists of an axial compressor section and an expansion turbine section on a common shaft, coupled to drive an electric generator or centrifugal compressor. A diesel starting engine, electric motor, or small separate turbine is utilized for starting.

Air is drawn into the compressor and compressed before entering the combustion chamber, where it is mixed with fuel and burned. The expanding burned gasses drive the turbine, which in turn powers the equipment being operated.

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The areas of protection considered for any gas turbine power facility are the Turbine Compartment, the Accessories Areas, the Electrical Control and Switchgear Areas, the Fuel Pump Area, and the Generator. Protection of the Accessories Areas, Control Room, and Pump House present no unique problems of protection. The protection of the Turbine Compartment is of primary concern in this presentation.

The most common fire hazard occurring in the turbine compartment is the failure of the fuel (natural gas, No. 2 fuel oil, or jet fuel) system, or by leakage of lubrication oils used on the shaft bearings. When the gas turbine is operating, it gets very hot, and when it is shut down, it cools rather slowly. Outer surface temperatures of the combustion chamber and turbine expander reach 850°F - 900°F, which is well above the approximate 494°F auto-ignition temperature of No. 2 fuel oil, or the approximate 700°F auto-ignition temperature of bearing lubricating oil. Therefore, if this fuel comes in contact with these hot surfaces in an air atmosphere, a fire can occur. Since these units are often unattended and not accessible to follow-up fire fighting, there is no way to effect total extinguishment except through the fire protection system itself. Shutting off the fuel to the gas turbine by closing a valve in the fuel line is a part of system design and should limit the fire producing material to the residue in the bottom of the unit. This residue may not be in contact with the hot turbine. However, contact could exist through failure of the fuel shutoff valve or other abnormal occurrence. The pressure in the bearing lubrication system is specifically designed to be maintained while the shaft is rotating so that a loss in the integrity of the lube oil system could force oil under pressure onto nearby hot metal parts.

Cool Down Time

The critical question in gas turbine protection is how long does it take for exposed hot surfaces to cool below the ignition temperature of the fuel involved. To answer this question, it was necessary to run a series of tests in which surface temperatures at suspected locations were recorded during operation and shutdown. These tests were conducted on actual installations on several different makes of turbines, one type of which is illustrated on the drawing accompanying this bulletin.

Recordings were made of surface temperatures at three locations, as illustrated by points A, B and C on the graph in Figure 1. Point A represents the external surface over the combustors. In industrial type turbines, the combustion chamber is separated from the exposed surface metal, allowing access to incoming cool air. Therefore, the temperature does not get as high as might be expected. The temperature may be higher downstream of the combustion chamber just before entering the expansion section of the turbine. In aircraft type turbines, the surface temperatures get somewhat higher.

Point B represents temperatures in the exhaust section not visible on the drawing. These surfaces are largely insulated; however, there are some thin, exposed sections in the exhaust bearing tunnel, and also some heavy support sections that have direct metallic contact with the inside of the exhaust passageway. Heavy support sections may not get as hot as thinner sections, but cooling will be slower because of the sheer mass of metal.

Point C represents the exhaust manifold of a diesel starting engine for those systems provided with this method of starting. The diesel engine runs only during the starting cycle. However, the exhaust manifold does get hot enough to ignite fuel oil before the diesel engine is shut down after starting.

The actual temperatures attained and the cool-down time depend upon operating conditions. The greater the load or output, the higher the gas temperature must be to drive the load. Therefore, maximum surface temperatures are developed when operating at maximum load with maximum ambient air temperature.

Cooling time will be influenced somewhat by the ambient temperature and also by the shutdown procedure. Normal shutdown procedure is to run the turbine under no load conditions for about five minutes before finally shutting off the fuel. The internal parts of the exhaust section cool down rapidly under these conditions because of the cooler gas flowing through the system. Emergency shutdown for fire extinguishing requires an immediate fuel cut off after load is removed so that the turbine slows down immediately and the air flow emergency shutdown conditions, there is no time for internal cooling and the exposed surfaces will not cool off as rapidly. Chemetron's water mist system has the capability to reduce the ambient temperatures in the enclosure almost instantly, thereby assisting in the reduction of surface temperatures of the involved equipment.

Figure 1 represents typical temperature curves during a test operating cycle for a turbine system with a diesel starting engine. It will be noted that the diesel exhaust manifold (C) reaches a temperature over 800°F during the starting cycle. The cooling time is based on cooling to 490°F, the auto-ignition temperature of diesel fuel.

Combustor surface temperatures (A) may not get as hot as the starting engine exhaust manifold, however, cool down time may be longer depending on the type of turbine. Highest surface temperatures were found in the exhaust section (B). Heavy metal sections required the longest cooling time. Where the only fuel exposure is turbine lubricating oil, the cooling time can be based on its auto-ignition temperature of 700°F. It is necessary to add a safety factor to all of these figures to compensate for the possible effect of operation at unduly high loads or high ambient temperatures.

Air Leakage

In any turbine installation, there must be a substantial flow of cooling air around the outside of the turbine to maintain reasonable ambient temperatures within the turbine compartment. This may be accomplished by aspirating air from the turbine enclosure into the exhaust duct. Alternately, fans or special eductors may be used. The cooling air often enters through openings on the side of the enclosure. The air inlets may be designed to bring the air in near the bottom of the turbine enclosure so that it must pass over the turbine before being exhausted to the outside. It is also necessary to cool the turbine lubricating oil by drawing air through a fin tube heat exchanger.

When the turbine is shut down, the flow rate of the secondary cooling air drops off rapidly; however, air leakage remains much too high to permit practical total flooding without prohibitive loss of water mist. The obvious leakage openings must be sealed or provided with dampers that can be closed when the water mist system is actuated. In some systems, there is an annular gap around the turbine air intake bell. In others, there may be bottom openings through which pipes and conduit are brought into the enclosure. Doors and panels must close tightly and have soft seals. Even so, the leakage rate will still be sufficient to dissipate the water mist atmosphere over a period of time. Therefore, protection should be provided until the completion of the turbine wind down time. Through testing, it has been determined that due to the cooling effect that water mist provides during suppression, the chance of reignition after extinguishment is minimal

Fire Detection

The high secondary air flow rate required for compartment cooling also makes it difficult to detect small fires with heat detectors located near the ceiling. It takes a substantially sized fire burning near the floor level to raise the temperature of the total air flow sufficiently to actuate the heat detectors. Heat detectors are obviously needed over the turbine sections to assure detection of a fire that may originate on the side or top of the turbine due to a broken fuel line. On the other hand, to detect a small fire near the floor level, it is desirable to install detectors below the turbine in critical areas where such fires might occur.

The important limitation is to make sure that the temperature setting is high enough to avoid false actuation by radiant heat from the turbine itself. This point was actually tested by installing dummy thermostats with internal thermocouples for recording the temperature during a test cycle. It was found that such temperatures did not exceed 200°F and that therefore, a temperature setting of about 325°F should be satisfactory.

Because of their inherent simplicity and reliability, heat actuated detectors are considered best for automatic discharge of the water mist system. Flame or other special detectors may be used in critical units.

Water Mist System

The piping and nozzle arrangement of a water mist fire protection system for this application is illustrated on the drawing. When a fire is detected in any one of the protected compartments, the first action is to automatically shut down the turbine by shutting off the fuel supply and disconnecting the generator from the line. An alarm is also sounded to warn personnel of the impending discharge. After a brief delay to allow time for evacuation and the automatic charging of the water holding tank, discharge is initiated. The turbine compartment is not normally occupied during operation, so delay of the discharge is not required when the water mist system is operated.

When the water mist system is actuated and the flow of water through the nozzles is initiated, there will be an immediate reduction of temperature and displacement of oxygen within the enclosure, both of which are key components in the control, suppression or extinguishment of turbine fires by water mist. Water mist also has the capability to block radiant heat to further prevent the spread or propagation of fire.

Water mist provides a secondary function by partially scrubbing the air of products of combustion, thereby reducing the amount of toxic byproducts and/or contaminants in the air caused by a fire incident .

The water mist system is cycled on and off to more efficiently control the fire and to minimize the amount of water required for control.

The Chemetron Water Mist fire protection system follows this sequence of operation (reference Figure 4):

- The fire control panel initiates a signal to the solenoid located on a 2400 psi nitrogen cylinder valve, or the cylinder can be activated manually by a mechanical operator located on the cylinder valve. The nitrogen cylinder valve is equipped with a solenoid, fill port, pressure gauge and safety relief valve and is regulated through the primary regulator to a pressure established by hydraulic calculations, but not in excess of 500 psi. The control panel should also initiate a signal to close automatic dampers to shut off major ventilation openings before the discharge begins. In addition, all fuel and lubricant delivery systems into the hazard area will be stopped immediately after fire detection.

- Downstream of the primary regulator, the nitrogen splits at a tee to travel in two directions. On one side, the pressure established by hydraulic calculations is used to pressurize the water vessel (normally at atmospheric pressure). On the other side of the tee, the nitrogen will pass through a secondary regulator, where it will be regulated to a pressure (between 75 and 125 psi) suitable for the operation of the automatic water control valve.

- Water is pressurized in the water vessel up to the automatic water control valve, which is normally in the closed position. The water pressure vessel is provided with a nitrogen inlet, water (pressurized with nitrogen) discharge outlet, safety relief valve, water fill port, pressure indicator, and liquid level indicator. The water pressure vessel meets the requirements as established by DOT and/or ASME, section VIII.

- The water control valve is operated by nitrogen pressure between 75 and 125 psi. A solenoid mounted on the valve is energized open to permit nitrogen to open the closed water control valve. The solenoid is "time sequenced" to delay opening the valve until pressurized water has arrived at the water control valve. The timing is controlled by the fire control panel.

- When water arrives at the water valve, the solenoid controlling the nitrogen will open the water control valve, releasing pressurized water to the water mist nozzles located downstream. The valve will cycle on and off, based on the timing sequence established by fire tests performed at Factory Mutual.

- The water will be conveyed through the pipe to the individual water mist nozzles. A minimum pressure of 350 psi will be required at the most "hydraulically remote" nozzle.

Due to the very small diameter of the orifices in the nozzle, it is important to provide a strainer upstream of the nozzles to prevent orifice blockage. For ease of maintenance, the strainer will be located just downstream of the water vessel.

The alarm circuit for the affected hazard must be manually reset to be certain that operating personnel are aware of the discharge. The fire detection circuit is also locked out until manually reset to avoid a possible second discharge in the event of a shorted detector or circuit. This does not prevent a second discharge by manual means if this should be needed.

After a fire, the turbine, itself, must obviously be checked to correct fuel leakage or whatever caused the fire in the first place.

Before the turbine can be operated, any dampers or other shutdowns tripped by the water mist system must be reset to allow a proper flow of cooling air or fuel, as the case may be.

Instances have occurred where the fire started with an explosion in the compartments and the doors were blown open. If this is to be a design basis, then it should be considered at the time of design, with water quantities and nozzle placement designed to ensure fire control, even with the doors open.

The 1992 (or later) edition of NFPA No. 850, **Fire Protection for Electric Generating Plants,** includes combustion turbines and is recommended as a reference source. Also recommended as a reference source is the 1996 (or later) edition of NFPA No. 750, **Installation of Water Mist Fire Protection.**

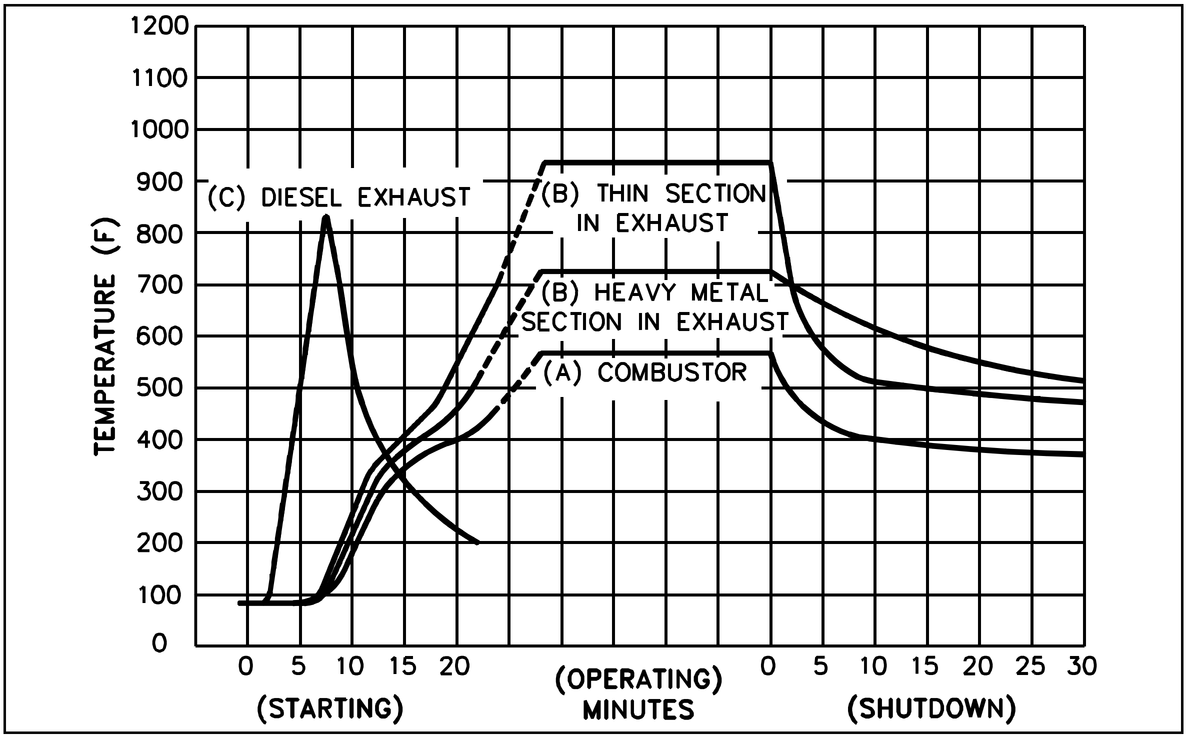
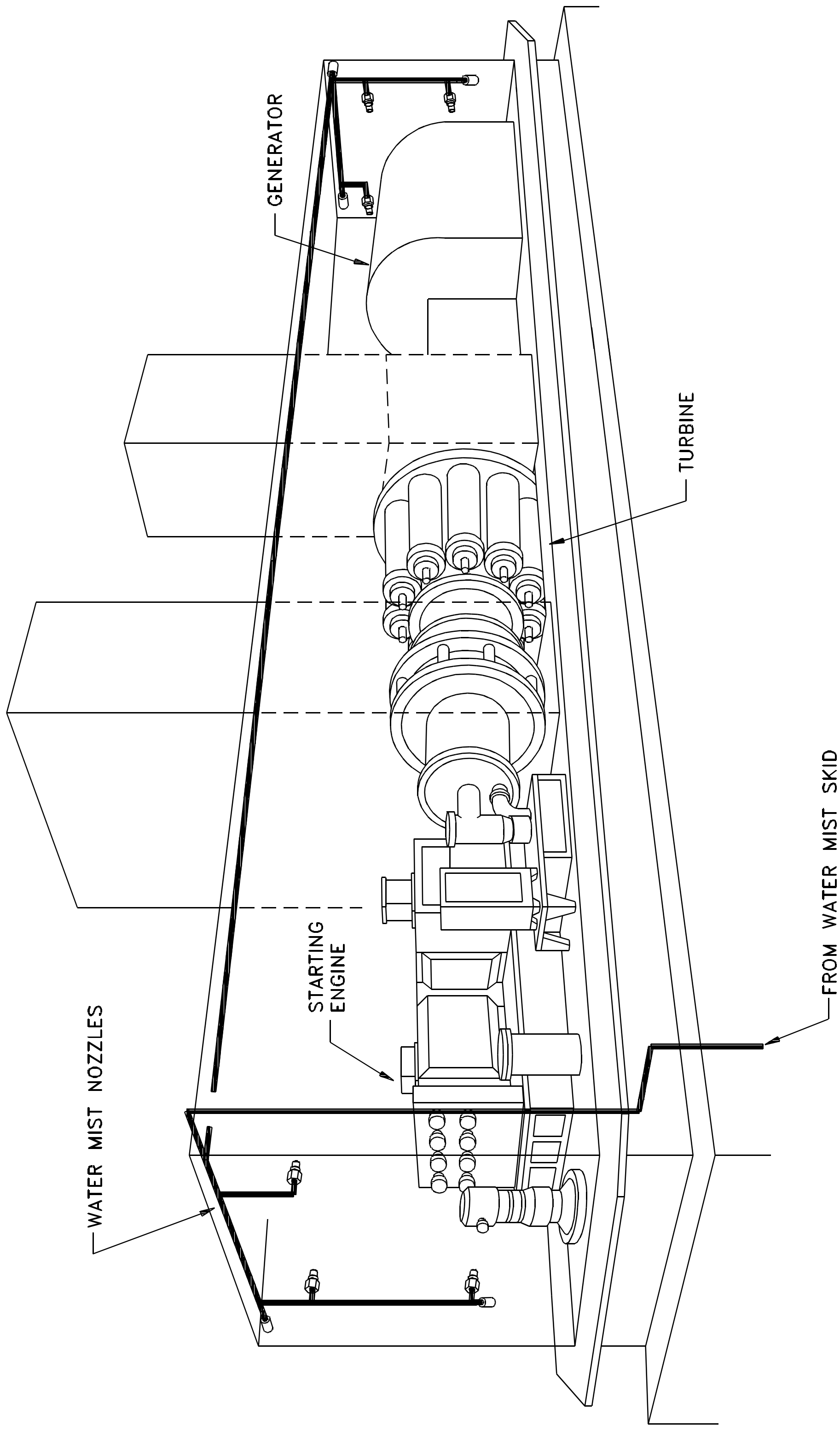
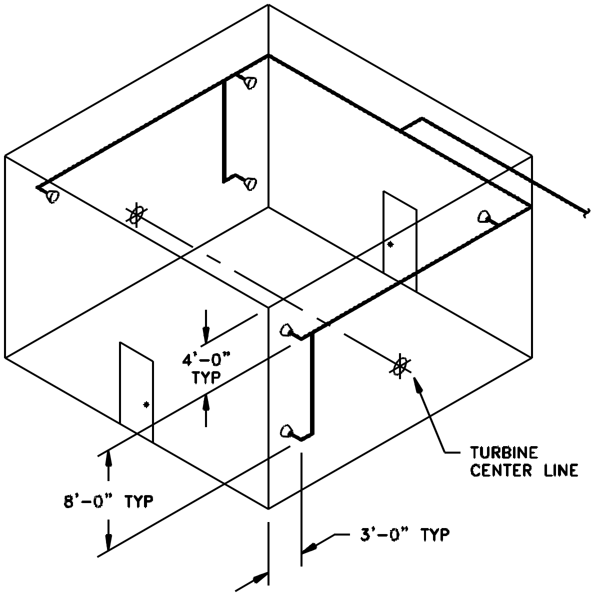


Figure 1: *Represents typical temperature curves during a test operating cycle for a turbine system with a diesel starting engine.*



NOTE: The nozzles have been carefully positioned to avoid direct impingement of water on the turbine casing.

Figure 2
Water Mist Fire Protection System for a Compartmentized Gas Turbine



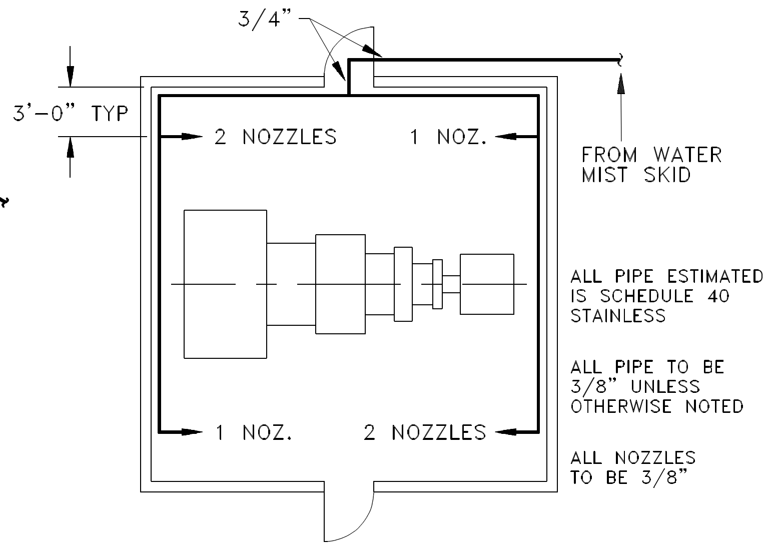


Figure 3

Isometric View Plan View

260 cubic meter (9,175 cu. ft.) turbine enclosure. Room size: 24 feet square x 16 feet high.

This typical turbine enclosure has a 20 minute wind-down time and requires approximately 94 gallons of water and six nozzles as shown in the above diagram. The required flow rate for each nozzle would be 1.87 GPM @ 350 psi. The complete on/off cycle time to extinguish this type of fire is 4.25 minutes and requires a minimum of approximately 30 gallons of water.

Factory Mutual requires 20 minutes of fire protection to maintain the fire protection for the duration of the wind-down period, but will allow the amount of water to be reduced if the wind-down time of a specific turbine is identified to be less than 20 minutes.

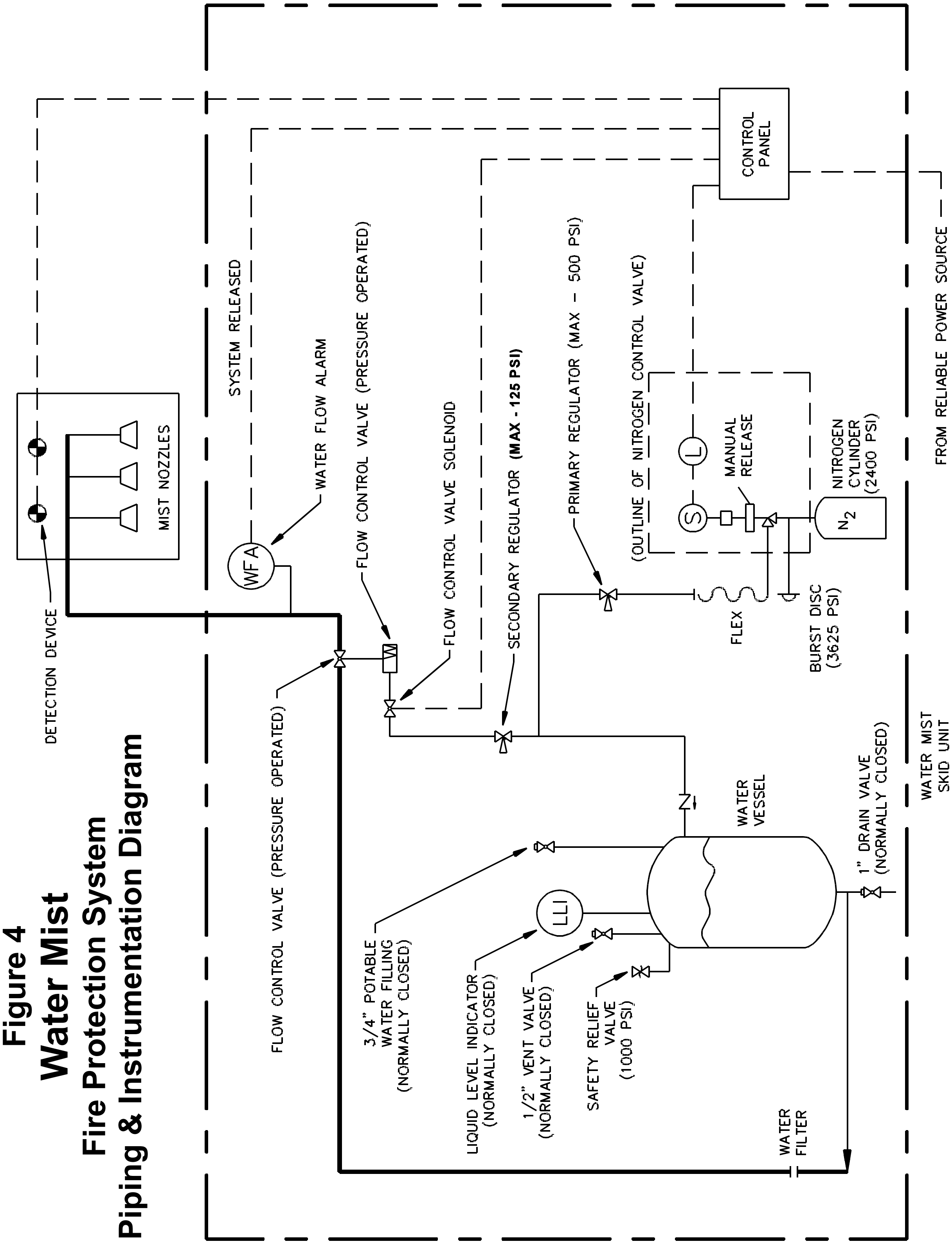


Figure 4
Water Mist
Fire Protection System
Piping & Instrumentation Diagram