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**Application
Bulletin**

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CARBON DIOXIDE FIRE SUPPRESSION —

Compartmentized Gas Turbines

Power Generation Bulletin #0020 covered the larger type gas turbines used in some of the newer high capacity cogeneration plants. This is the type of unit which is housed in a building built as a power station or as part of a combined cycle plant, wherein the station holds gas turbines and a steam turbine, with the exhaust gasses from the gas turbines used as a heat source for generating steam. However, many more gas turbines are built and 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*. This application bulletin covers these units.

The material contained herein is an update of the March, 1970 issue of **Hot Spots**, which was a technical publication of the Cardox Division of Chemetron Corporation.

We'll present a description of the recommended **Chemetron** Fire Systems 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.

Several basic considerations of carbon dioxide fire protection system design which are often overlooked, such as losses through unclosable openings and adequate cooling periods, are emphasized. We call these to your specific attention as they would apply to the design of protection of many other hazards.

Description of Hazard

A gas turbine unit essentially 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.

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. Protection of the generator, usually of the straight-through air cooled type, requires the same protection techniques developed by **Chemetron** for the protection of large rotating equipment in steel mills or similar facilities, and will not be discussed here. The protection of the Turbine Compartment is of primary concern in this presentation.

The fire problem in the turbine compartment is represented by 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. The problem is that 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 850EF - 900EF, which is well above the approximate 494EF auto-ignition temperature of No. 2 fuel oil, or the approximate 700EF 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. To put this fire out momentarily means nothing if, when the agent is dissipated, contact between the fuel and the ignition source still exists. 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 metal parts close by. If these parts are hot, and if this rotation is for an extended period, momentary fire extinguishment is of very little value.

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 shut-down. 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. Item 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.

Item 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.

Item 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 through the system falls off very rapidly. Under emergency shutdown conditions, there is no time for internal cooling and the exposed surfaces will not cool off as rapidly. On the other hand, the discharge of CO₂ for fire protection will be of some help in reducing surface temperatures.

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 800EF during the starting cycle. The cooling time is based on cooling to 490EF, 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 700EF. It's 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 educators 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 CO₂. The obvious leakage openings must be sealed or provided with dampers that can be closed when the CO₂ 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 any atmosphere of CO₂ in a couple of minutes or so, unless an extended discharge is used to compensate for losses. The extended discharge rate should be no higher than necessary to maintain a minimum of 30 to 35 percent CO₂ in the protected space for the cooling off period. Figure 2 represents typical CO₂ concentration curves recorded during the temperature cool down test illustrated in Figure 1. With this technique, it is possible to maintain an extinguishing concentration as long as necessary to permit proper cool down without risking reignition. CO₂ loss rates were established by separate discharge tests.

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 200EF and that therefore, a temperature setting of about 325EF should be satisfactory.

Because of their inherent simplicity and reliability, heat actuated detectors are considered best for automatic discharge of the CO₂ system. Flame or other special detectors may be used in critical units.

Carbon Dioxide System

The piping and nozzle arrangement of a CO₂ 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 in the event someone happens to be in one of the protected compartments, the discharge is started by the opening of both main and extended discharge valves (not shown). The turbine compartment is not normally occupied during operation, so delay of the discharge is not provided if provisions are made to lock out the discharge when the turbine compartment is occupied.

When opened, the valves at the central low pressure supply tank (not shown) permit the flow of carbon dioxide through the supply header into the hazard discharge piping. The flow through the main discharge line provides rapid total flooding for fast extinguishment. Pressure in this line also trips automatic damper closers to shut off major ventilation openings at the beginning of the discharge. The peak design concentration is attained in less than one minute to extinguish the fire.

The main discharge valve is then closed by means of the timing system. The extended discharge valve remains open as long as the concentration is to be maintained for protection against reignition. A simple orifice nozzle is used in each compartment on extended discharge to provide ample velocity for stirring the atmosphere. This action is designed to forestall stratification because of leakage. At the end of the

cooling period, the extended discharge valve is also closed, ending the discharge sequence.

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.

Of course, none of the lock out features would interfere with simultaneous or later automatic fire protection of another hazard protected by the same low pressure storage unit.

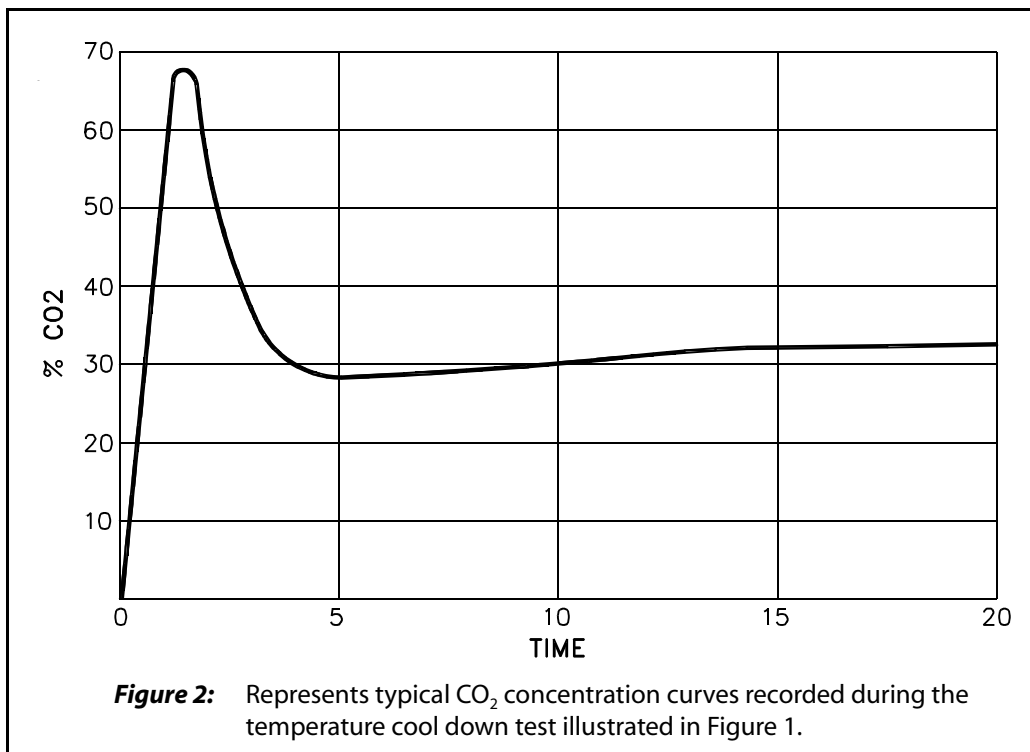
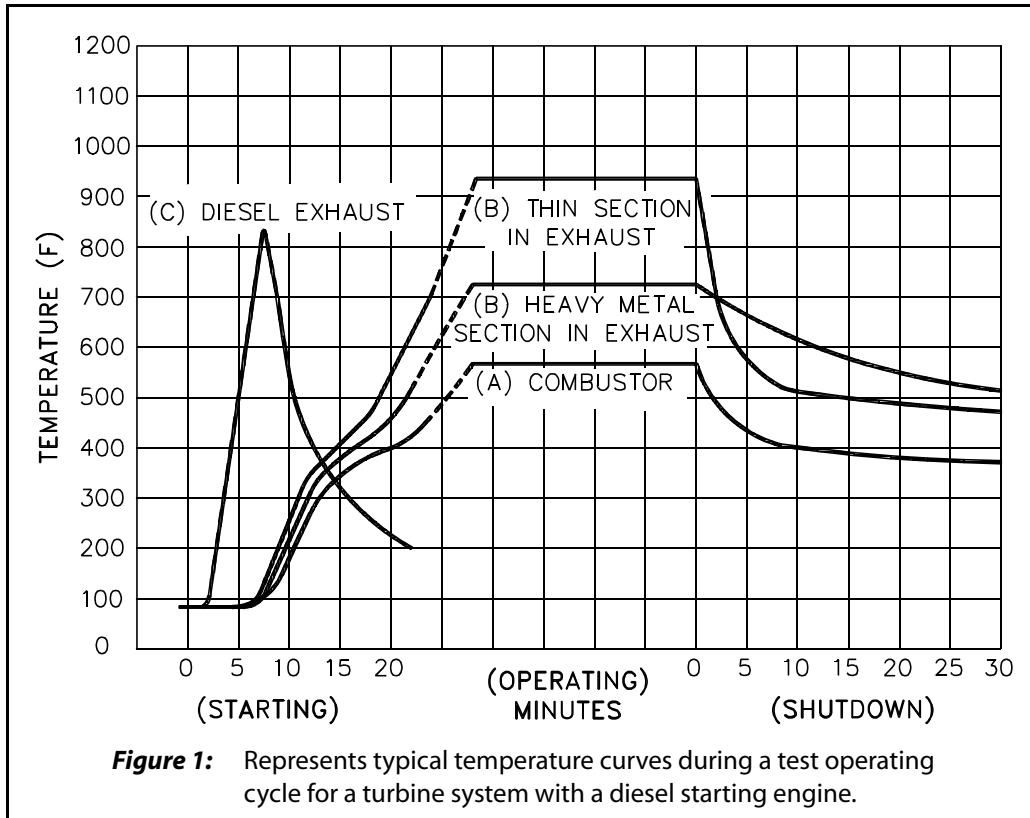
After a fire, the turbine, itself, must obviously be checked to correct fuel leakage or whatever caused the fire in the first place. Before the turbine can be operated, any dampers or other shutdowns tripped by the CO₂ system must be reset to allow proper flow of cooling air or fuel, as the case may be.

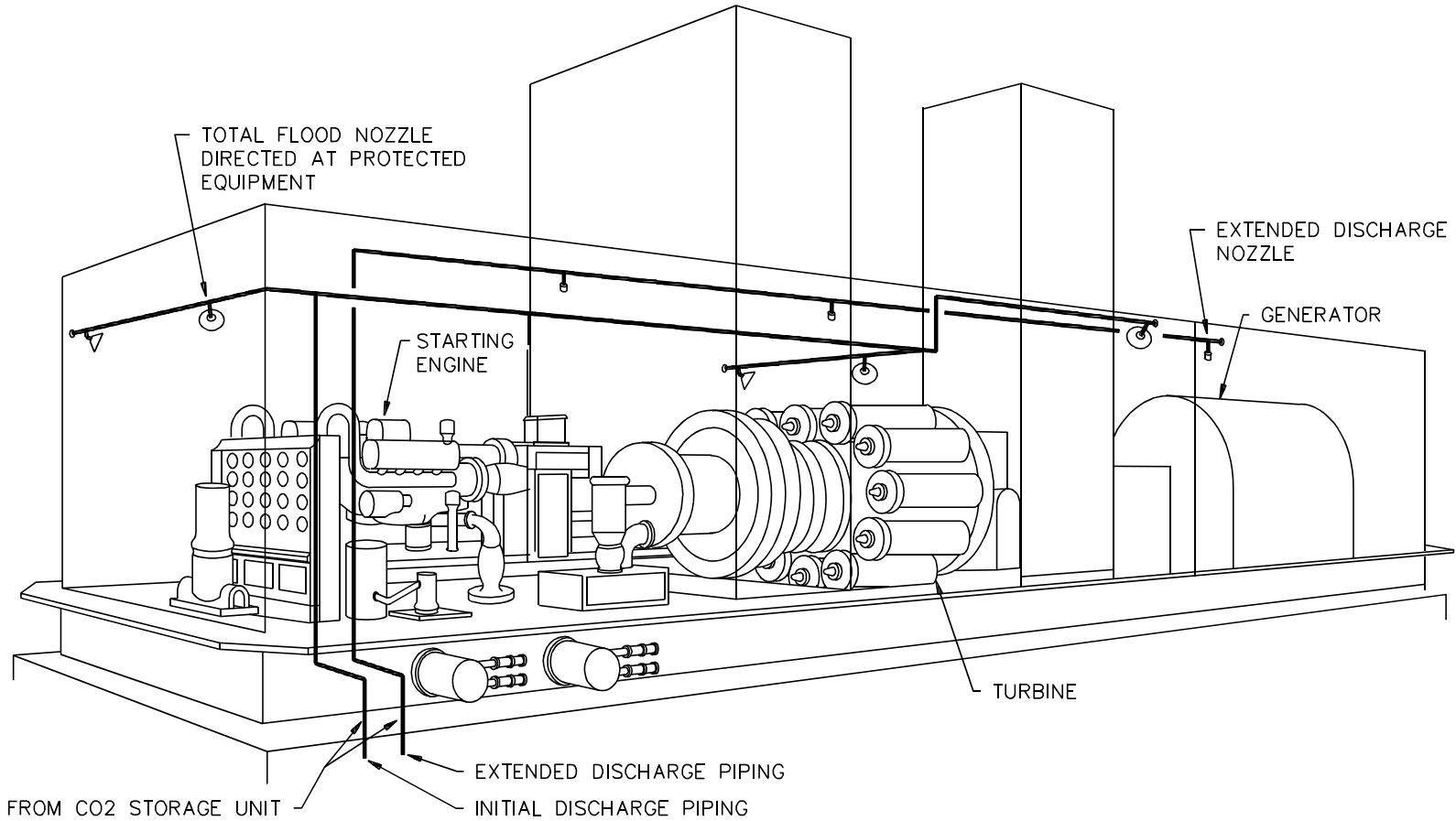
Instances have occurred where the fire started with an explosion in the compartments and the doors were blown open. If this is to be a design basis, then it should be considered at the time of design and CO₂ quantities and nozzle placement designed to ensure flooding, even with the doors open.

Some have used foam to supplement CO₂ protection by covering any fuel or lubricant in the bottom of the unit. High expansion foam is the usual choice for this.

The CO₂ will quickly flood the unit to the ceiling and from wall to wall. Foam will not do this, so the foam is considered a supplement.

The 1990 edition of NFPA No. 850 Recommended Practices: **Fire Protection for Fossil Fueled Steam Electric Generating Plants** (to be renamed), will include combustion turbines and is recommended as a reference source.





Compartmentized Gas Turbine