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CARDOX

CO_2

Application Bulletin

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CARBON DIOXIDE FIRE SUPPRESSION —

Hydroelectric Generators

One of the more traditional applications of carbon dioxide as a fire extinguishant is in the protection of air cooled rotating electric machinery. This bulletin covers the protection of hydraulic turbine driven enclosed electric generators. Other bulletins will cover other electric motor/generator configurations.

The protection of hydroelectric generators has been covered by Standard No. 12 since its very inception (now an NFPA Standard.) It was recognized that if an adequate amount of CO_2 is introduced into the generator housing and held long enough, the fire would be completely extinguished, and the damage limited to the initial fire damage and whatever electrical problems initiated the fire. It was also recognized that CO_2, being an inert gas, is a nonconductor and could be introduced in the machine even if the power is not, or cannot be, shut off. In addition, CO_2 is three dimensional, making it capable of reaching all internal parts of the machine that the fire supporting air can reach.

Over the years, many improvements in electrical insulating materials have been made, resulting in reduced combustibility. These have caused some to believe that the need for fire protection has been eliminated. Not so!

The introduction of mica epoxy insulating materials has reduced the effects of aging, hopefully reducing the incidence of failure. Also, insulation materials have been tested to show they are self-extinguishing. But these tests do not evaluate the materials in the quantities and manner used in these machines, nor under the high energy conditions of an electrical fault. In addition, the materials making up the end turns are combustible and provide ample fuel for a disastrous fire. Numerous fires have demonstrated the need for protection of large value and key generator units.

Generally, the availability of the parts needed for repairs after a fire are limited. Rewinding requires a lengthy time period and ordering a new rotor or starter coils could represent a very long lead time.

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The National Fire Protection Association (NFPA) has issued a Recommended Practices, Fire Protection for Hydroelectric Generating Plants, (NFPA #851) and in paragraph 5-3.1, protection for the generator windings is recommended.

Machine Construction

As you can see from the drawing accompanying this bulletin, the dammed up water flows under gravity through a turbine of some type, to turn a shaft to which the rotor of an electric generator is attached. In contrast to the steam turbine, the speed of rotation is much less (usually under 360 rpm). To cool the unit, water is sometimes circulated in the windings; also, the recirculated cooling air is passed over cooling coils before being circulated through the windings. In some units, ducted air is used.

Water for driving the turbine is stored in a dammed up reservoir, with the water flowing from the reservoir down through the turbine to the river or stream below.

The turbine generator can be mounted in the vertical as shown, horizontally, or as a bulb type with water flowing through a bulb in which a generator is housed (access is through a strut to the inside of the bulb).

In the more commonly used vertical unit, one or more units are placed, usually in line, in a power house with at least part of the unit above the supporting concrete. The generator is separated from the turbine below by what is usually a water and air tight bulkhead. Access to the machine is by doors in the housing. These doors should be arranged to minimize the possibility of being blown open.

Above the generator housing is a small housing containing the collector rings, field exciter, and generator sensing elements. It is usually cooled by the same air as the generator and is included in the generator air volume when calculating CO_2 requirements.

Oil filled gear units may connect the turbine to the generator and require protection.

In some installations, the machine can be used as a pump as well as a generator. In this case, the electric machine functions as a motor with the turbine working as a pump, pumping water uphill into the power plant reservoir during the night, when the extra power generating capacity is available. During peak demand hours, water flows back down through the machine, now functioning as a generator, to generate the peak electric power needed. This is called pumpedstorage.

In recent years, many hydroelectric or pumped storage plants have been remotely operated, and therefore, most of the time they are unattended.

Some units are run of the river, or even tide operated. There are also wind driven or compressed air driven electric generators, all of which are similar in many ways.

The protection requirements for the enclosed electric generator portion of the machine are identical in all cases.

CO_2 Application

The established design for generator protection is per Table 2-4.2.1 and Paragraph 2-5.2.3 of NFPA Standard No. 12. Referring to these you will find that the design concentration for the generator CO_2 flooding is 50% by volume. Of this total, 30% is to be achieved in the first 2 minutes, with 50% achieved in 7 minutes, and 30% held until the unit shuts down (but not less than 20 minutes).

As the unit rotates, it is designed to move its own cooling air (which may be aided by fans). This air movement creates zones of increased and decreased pressure, which could cause loss of air/CO_2 after a discharge, or the introduction of fresh air. When the CO_2 is discharged and mixed with the air, the resulting mixture is heavier than air, so loss can also occur due to gravity flow out of low level leak points.

Some units require a prolonged run down after shutdown occurs. Others have braking systems which substantially shorten the run down period.

If the CO_2 is discharged in the quantities required to reach 50% and the cooling system is enclosed with air recirculating, it stands that it will hold a 30% concentration for 20 minutes unless there are some leak points. Experience has shown that housings are not tight and some CO_2 loss is to be expected. But in recent years, testing has shown losses on newer machines to be less than previously expected. In any case, the fire protection system designer must anticipate there will be some loss and design for same. The big question is how much? We must know how much CO_2 has to be added after the initial discharge to meet the design criteria of holding 30% until shutdown. For this we have been given a guide.

A table to determine the amount of CO_2 to be added (Table A-2-5.3 of Standard No. 12) has been used for years and has proven to give good, even conservative, results.

The initial discharge is calculated at 1 lb. for each 12 cubic feet of generator volume (50%) and the added, or make-up CO_2, is estimated from the table. For example, if the internal volume of the machine is 4,000 cubic feet and the shutdown time is 20 minutes, the added CO_2 needed is estimated to be 450 lbs.

It is normal practice to pipe both quantities of CO_2 into the machine independently. One set of discharge nozzles floods the machine to help achieve the initial design concentration (50%), while another set is used to add make-up CO_2 to hold the CO_2 level above 30%. We call these CO_2 discharges the Initial Discharge and the Extended Discharge. The initial discharge lasts for 2 minutes or more. The extended discharge continues throughout the complete holding period.

When a 50% CO_2 gas concentration is added to an enclosed volume, an internal pressure will be created. While the machine enclosure is designed to withstand some internal pressure, the protection must be designed so that the pressure level does not exceed design levels. This can mean the need to install pressure vents, which can be quite simple. The formula for calculating the need for venting and how much vent area is required is found in paragraph 2-6.2 of Standard No. 12.

System Arrangement

Referring to the arrangement diagram, you will note the CO_2 storage unit has two (2) control valves piped to two separate discharge lines and two separate sets of nozzles.

One line is the Initial Discharge line and the other the Extended Discharge line. The description of operation is as follows:

The unit is provided with an automatic detection system, usually consisting of an optical type smoke detection system, used in conjunction with a rate compensated heat actuated system. System actuation is by the detection system arranged as the operator prefers

This could be —

- CO_2 discharge and alarm upon either smoke or heat detection.

or

- Alarm only on smoke detection, and CO_2 discharge on heat detection.

or

- Discharge when both detectors operate together. Alarm is given when either operates.

The ability to abort the discharge, if necessary, is also a design option. A manual release is also available (usually in the control room) to initiate the CO_2 discharge. A second release can be by the machine.

Immediately on release by either automatic or manual operation, audible alarms sound in the machine, under the machine, and in the power house at the machine. Strobe or similar warning lights are also used. Usually, the machine CO_2 discharge starts immediately, but it must be delayed to allow for personnel evacuation if there is any possibility that anyone can be in the machine. Commonly, when the doors are opened, interlocks will switch the automatic mode to alarm only and lock out the machine so it cannot be started until the CO_2 system is in automatic operation and the doors closed.

Many machines are also arranged so that the CO_2 is tripped automatically by electric faults (differential relays, etc.)

At the start of the discharge, both valves open. The total CO_2 flow through the initial and extended discharge lines constitutes the initial discharge. For example, if the initial CO_2 required is 1,000 lbs/minute and the extended discharge is 100 lbs/minute, then the larger valve flows 900 lbs/minute and the smaller valve 100 lbs/minute to give the 1,000 lbs/minute total rate. After the initial discharge is over, the controls close the larger valve, with the smaller valve continuing to discharge for the full holding period.

With the low pressure system, some installations have been made with one valve, one discharge line, and one set of nozzles. On discharge, the valve opens to give the required initial discharge to get 30% CO_2 in 2 minutes with the 50% design achieved within 7 minutes. Sometime after the initial discharge, if the CO_2 concentration in the machine drops near the 30% level, the valve is opened again for added CO_2. For long deceleration periods, it can be opened again later on. A full discharge test of the machine sets the length and frequency of the discharges. Care in design must be exercised so that too frequent discharges are not made. Frequent discharges of short duration can cause freezing problems due to dry ice build-up in the piping.

There may be a risk if CO_2 vapor is allowed to flow from the machine to areas where it is not expected. Therefore, proper sealing of the machine is not only beneficial for retaining the CO_2 for good fire protection, but it also makes for a safer installation as well. The system discharge test will usually identify housing leaks. Be sure to have adequate breathing apparatus available in the vicinity of the machine and in the control room.

It has become a common practice to odorize the CO_2 with oil of wintergreen during the discharge. Oil of wintergreen has a unique odor, can be smelled at very low CO_2 concentrations, and it doesn't hurt anything. Odorized CO_2 is detectable if it leaks from the machine and settles in low spots. All such potential areas should be equipped with alarms and be well ventilated.

NFPA Standard No. 12 should be consulted for recommendations on the safe use of CO_2 extinguishing systems.

On occasion, a generator fire has involved an explosion (vaporized combustible from the electrical fault suddenly igniting, or fault arc plasma). If this occurs, the access doors could be blown open. Proper placement of CO_2 discharge nozzles and increased CO_2 flow rates can be used to ensure adequate protection even if this happens (as we do protect straight through air flow machines which are not enclosed). If the low pressure type system is used, the provision for a worst case condition will probably not significantly increase the system cost.

If the cooling air of the machine is ducted and the ducts are provided with dampers, they should be arranged for closing upon CO_2 discharge. The volume of the ducts must be included in calculating CO_2 quantities. Fans are to be shut down and any expected air flow through the damper should be added in the CO_2 discharge calculation.

If there's a fire in the machine, it is expected that the machine will be shut down. The CO_2 system is designed on this basis. However, there are some articles recommending that the unit be kept running, with the air cooling the fire in the same way a burning match is cooled by blowing on it. If this is ever to be done, the CO_2 system must be designed accordingly.

High Pressure CO_2 System Arrangement

The accompanying diagram shows the arrangement of a high pressure CO_2 system for generator protection.

The calculated amount of CO_2 for the initial discharge is stored in a bank of cylinders, manifolded together and piped, in this case, to the extended discharge line.

The pilot cylinders, which are released to initiate the full discharge, are on the initial discharge bank. When they are tripped, the manifold pressure from the initial bank is piped through a check valve to the extended discharge manifold. Pressurization of this discharge manifold releases the extended discharge cylinders. The check valve prevents CO_2 flow from the extended discharge cylinders from entering into the initial discharge manifold and piping. The flow rate of each discharge is, of course, determined by the size of the discharge piping and the nozzle orifices on that line.

In plants where there are several generators in line, it's common practice to protect each generator with a separate cylinder arrangement. A third bank of cylinders, common to two adjacent generator systems, functions as a common reserve. In case either generator system discharges, this reserve can be switched into the position of the discharged cylinder bank, thus ensuring continuous protection until the other cylinders are recharged.

Conclusion

In conclusion, we'd like to discuss the common objections to the use of CO_2 in these machines.

Reliability — Enormous improvements in CO_2 system detection and control, along with full supervision of electrical and key mechanical operating controls, have been made in recent years. Recently published data and papers indicate gaseous agent systems to be comparable in reliability to water systems. Experience has shown that CO_2 gas supplies that are ample to ensure total fire extinguishment under worst case conditions can be provided and be cost effective.

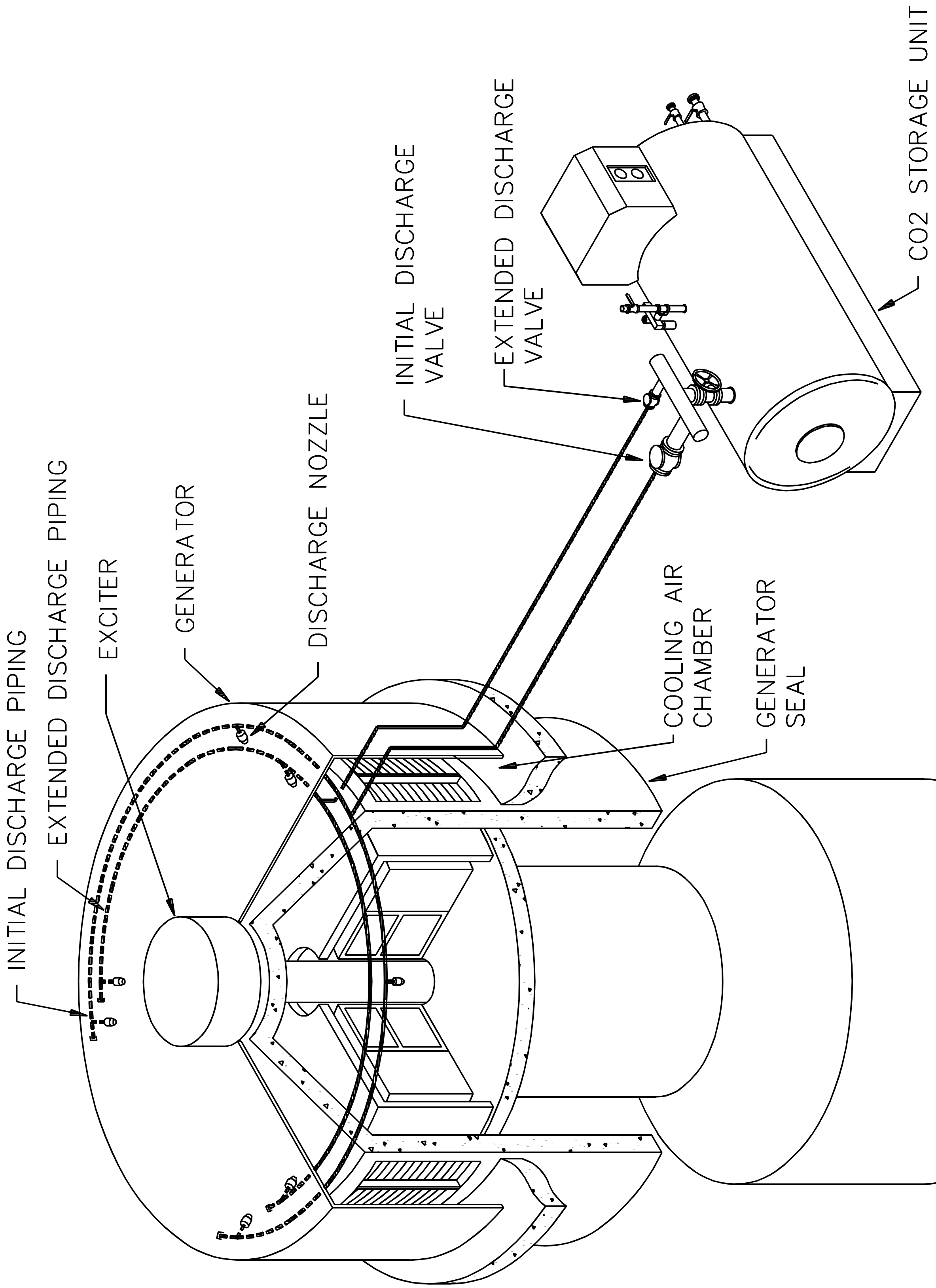
Since CO_2 systems are almost always automatic, and most water systems are manual (to prevent discharge when the unit is energized), seems to give the edge to CO_2, especially at an unattended, remotely controlled plant.

Safety — The safety engineering of the system must be just as important as the fire protection engineering. History has shown that accidents do not occur when the equipment and system are well maintained and personnel are familiar with what they have and how it operates.

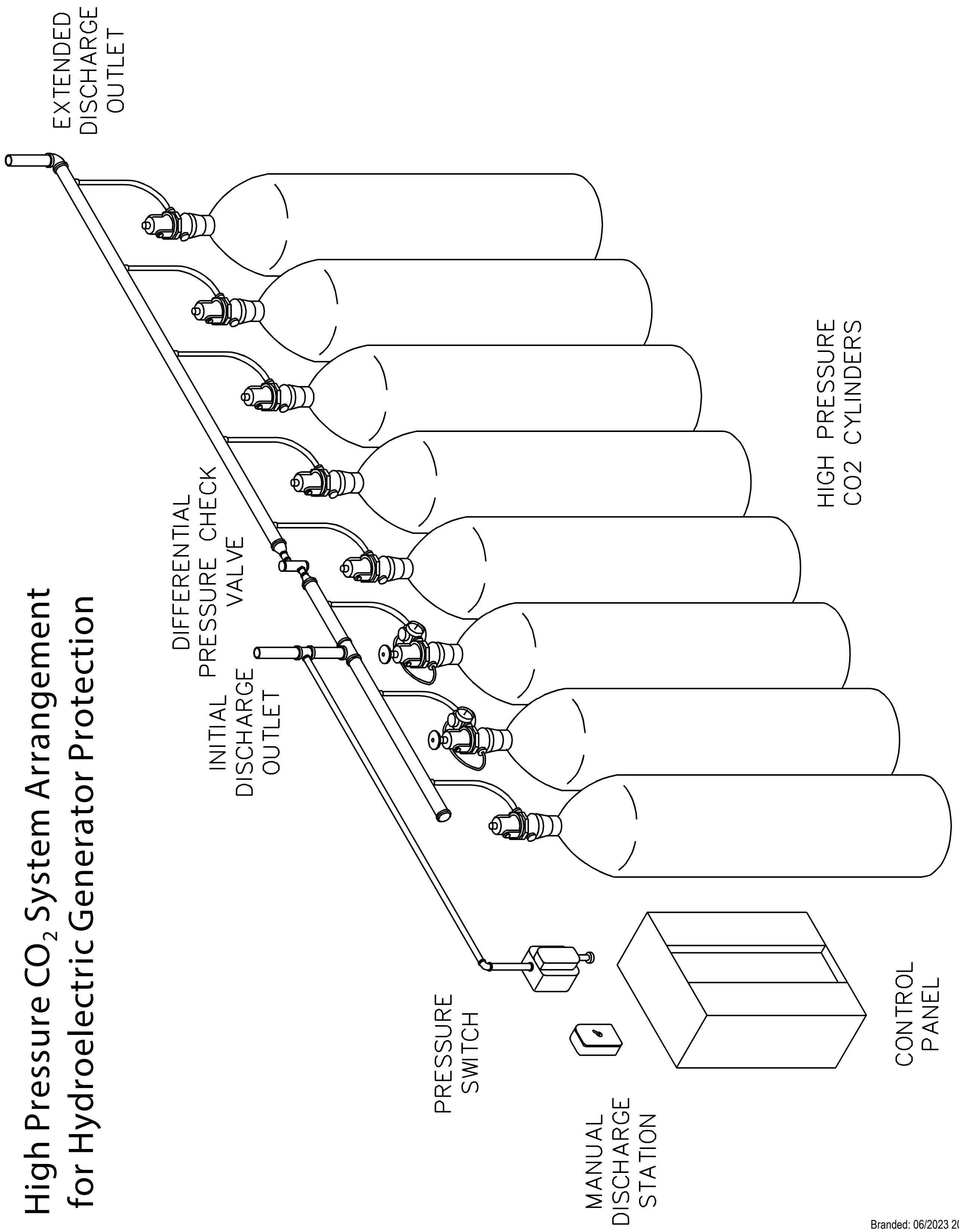
Cost — You have to analyze what you are protecting and how important it is to you. Assuming a fire is always a possibility, you should do a fire risk analysis to determine your protection needs and get expert help in estimating costs before selecting the type and scope of protection. The thousands of CO_2 systems in service testify to the cost effectiveness of CO_2 on key units.

In addition to the generator protection, the consideration of CO_2 for protection of regulator cabinets, oil rooms, transformers, cable vaults, switchgear, and spaces beneath raised floors should be made. Normally, one system can be used to protect all.

Other bulletins will cover the protection of nonenclosed electric machines and the other hazards mentioned above.



Low Pressure CO$_2$ Extinguishing System for Hydroelectric Generator



High Pressure CO$_2$ System Arrangement for Hydroelectric Generator Protection

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