by the active support of all levels of management, should produce the optimum in safety.

In mathematics, there is a basic principle that if you take any number, however small, and divide it by two and then in succession divide the answer by two, you will never reach zero. I submit that if the dividing principle is continued long enough you will get close enough for all practical purposes.

Let us think of this job of ours in somewhat the same fashion. Recognizing the frailties of human nature, the limitations of material things, we cannot hope to reduce our accident occurrences to zero. Let it be sufficient for us to know that, by the ever-lasting continuation of our progress in the field of control, we, too, can continue the process until we can get close enough for all practical purposes.

Application of Safety Control Devices to Fuel Gases in Industry

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The uses of gaseous fuels in industry are many and diverse. The range of applications varies from small furnaces that heat soldering irons to large furnaces that heat ten ton steel ingots; and from ovens in the foundry that dry sand to ovens in the assembly plant that dry the finishes of new automobiles.

Several different gases are used; among these are coke oven gas, natural gas, propane and acetylene. These gases differ somewhat in chemical composition and have different burning characteristics. There is one thing that they all have in common. They will burn, and, under certain conditions, they will become an explosive hazard.

In the past, the handling of gases was rather haphazard. Gas was piped to an oven or furnace through one hand-operated valve. Lighting a furnace safely was purely a matter of experience. Accidents happened. To prevent explosions, and to make lighting and operating safe and foolproof, safety controls were devised.

For the safety of personnel and for protection against fire or explosion, careful consideration has been given to the hazards of each project. It has been said that the best safety apparatus is a *safety-conscious* man. This statement may be true, but no man can be a substitute for the constant attention which properly designed automatic safety apparatus will provide. The final test of safety apparatus is that it fails safe in the event of the interruption of the safety sequence or the development of unsafe conditions in operation. Partial protection is more dangerous than no protection at all. Insufficient, poorly installed, or poorly maintained equipment could cause operators to lapse into carelessness by *supposed safety not actually present.*

Safety controls should be understood to mean automatic supervising devices of sufficient number, properly constructed and so arranged that they will maintain the required conditions of safety for the purpose of preventing the development of any fire or explosive hazard. One type of equipment is a paint-drying oven.

If flammable vapors are permitted to accumulate within an oven enclosure, their concentration may come within the explosive range; experience has shown that such an accumulation in the presence of an ignition source may be ignited and exploded, or result in a serious fire.

A study of industrial heating equipment shows that it is unwise to depend for safety on elimination of a course of ignition. The only reasonable solution is to introduce a sufficient quantity of air into the oven in order to dilute any possible flammable vapor-air mixture to a safe concentration below the lower explosion limit. Another type of hazard which can be created is an explosive fuel mixture which necessitates other types of safety controls.

Fuel Safety Controls. These are devices much as safety shut-off valves, combustion safeguards, pressure switches, temperature, and over-temperature controls. These are interlocked and arranged in control circuits to minimize the possibility of dangerous accumulation of explosive air fuel mixture in a heating system operating at 1200°F. and below.

Safety shut-off valves are normally closed *(closed when de-energized)* automatic valves installed in the fuel piping to shut off the fuel in the event of unsafe conditions or during shut-down periods. The safety shut-off valve may be considered as the key unit of all the safety controls used to guard against the explosion or fire hazards which could result from accidental interruption to the various services or operations, such as flame failure, failure of fuel pressure, failure of combustion air pressure, failure of exhaust or recirculating fans, excessive temperature or power failure. Safety shut-off valves should be installed in such manner that they cannot be by-passed or blocked in the open position. A safety-shut-off valve should be used for safety shut-off service only, and not subject to the wear and tear of a temperature control valve.

Combustion (flame failure) safeguards are devices which detect the presence or absence of flame. In the event of flame failure, they will automatically shut off the supply of fuel, and if so arranged, they will also sound an alarm.

Pressure switches maintain an electric circuit when the pressure in fuel or combustion air supply line is above the proper minimum setting for correct combustion. The circuit is interrupted if the pressure drops below the minimum setting. The safety shut-off valve controlled by pressure switches does not automatically reopen when pressure is restored to normal. *All safety shut-off valves must be reset manually.* This is important.

Temperature control devices are instruments for automatically controlling the heat of the furnace or oven. Over-temperature controls shut off the fuel supply if a safe operating temperature is exceeded.

To these controls, we should add timing devices and other power operated valves.

A typical example is the system of controls used for drying ovens and draw furnaces. A drying oven or draw furnace may be described as a heated enclosure operating at approximately atmosphere pressure, and below 1200°F. It is used for the processing of materials and finishes. The safety equipment may be itemized as follows:

1. *Purging timer.* This times the pre-ventilization of the oven. It is not considered necessary to purge small enclosures if they have an interlock to insure that all doors are open, and blowers are operating before the gas can be admitted to the burners.
2. *Flame protective device.* This may be either the flame rectification type or the infra-red photo electric type.
3. Safety-shut-off valve.
4. Pilot gas solenoid.
5. Normally closed valve. Power-operated type for coke oven gas.
6. Normally open valve, same as above. The normally closed valve is installed in the system between the safety shut-off valve and the burners. The normally open valve is installed in a vent line between the safety shut-off valve and the normally closed valve.
7. Air pressure switch.
8. Gas pressure switch.

These controls are arranged in an interlocking system that assures that each event in lighting a furnace shall happen in proper sequence. After the purging cycle has begun, nothing can happen until the timer indicates that the purge period is completed. Then the pilot may be lighted. When the pilot burner is lighted, the main burners may be lighted.

The safety shut-off valve, the key unit of the system, can be opened only if all of the following exist:

1. Presence of pilot flame is established through the flame protective device.
2. Gas pressure within the range established by pressure switches is available.
3. Compressed air used for temperature control and dampers is available as required.
4. Temperature of oven or furnace is below the point established by the over temperature control.

The safety shut-off valve will automatically close if any of the following occur:

1. Pilot flame is extinguished.
2. Power failure has occurred.