Application of Catalytic Heating

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BACKGROUND

The use of a catalyst to speed combustion of gas-air mixtures was recorded as early as 1817 by Sir Humphrey Davy. He concluded that hot solids, particularly the platinum group, speed the combustion of gas at relatively low temperatures. Further research in 1912 by Bone and collaborators into the discovery by Davy determined that: (1) all surfaces possess the power (in varying degrees) to accelerate gaseous combustion at temperatures below the ignition point; (2) acceleration is dependent upon adsorption of gas by the surface; and (3) platinum, ferric oxide and nickel oxide are best catalysts for surface combustion.[1] The catalytic heater based upon the principle discovered by Davy, has been manufactured since the early 1900's. Development began as a result of the need for a heating apparatus that would eliminate the risk of fire or explosion when used around combustible fuels. During recent years catalytic heaters have been introduced to the oil industry with continuing success. These heaters use platinum as the catalyst because it has proven to be the most dependable.

THEORY

Catalytic combustion of gas at temperatures below the ignipoint is dependent upon the oxygen and gas coming in contact with the properly heated platinum catalyst. The catalyst must be at an initial temperature of 225° F and cannot exceed 762° F which is below the temperature which occurs in flame type combustion. The products of combustion are carbon dioxide, water vapor and heat. A typical reaction for a methane-air mixture would be:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

The reaction would be similar for other hydrocarbon fuels. Surface temperature of the heater can be controlled from between 225° F and 762° F. Temperatures are determined by the amount of oxygen and fuel supplied to the heater. Metering too much gas to the surface of the catalytic heater can stop the combustion process. The excess gas will push the available oxygen away from the catalyst and starve the reaction. This oxygen starvation does not occur unless a large amount of fuel is supplied to the heater. The optimum fuel rate is approximately 6500 BTU of fuel per hour for a square foot of heater surface. Slight increases of fuel input over the optimum rate will pass through the catalyst unburned and the heater will continue to operate at maximum temperature. If too little gas is supplied to the surface of the heater, the reaction will also stop when the temperature falls below minimum catalytic combustion temperature.

OPERATION

Catalytic heaters contain the basic components as illustrated in Fig. 1. The natural gas or fuel is introduced through a fixed orifice in the back of the heater where it is distributed through the adapter, distribution grid, and asbestos packing, all of which help diffuse the gas onto the catalyst packing. The catalytic reaction takes place just below the surface of the catalyst packing. The retainer screen simply holds the packing in place and serves no other purpose in the operation of the heater. The pre-heating element is used to electrically bring the surface temperature of the catalyst packing to approximately 225° F; then the catalytic reaction will begin. This surface temperature can be obtained by open flame heating, incandescence, or any reasonable means to produce enough surface heat to let the catalytic reaction support itself.

The amount of heat produced is regulated by changing the pressure on a fixed orifice or by the orifice size while leaving the pressure constant. It is not uncommon to vary both the pressure and orifice size when changing fuels that have a different BTU cu ft rating. BTU output of a catalytic heater is dependent upon the controllable factors of pressure and orifice size and can be determined using the following equation:

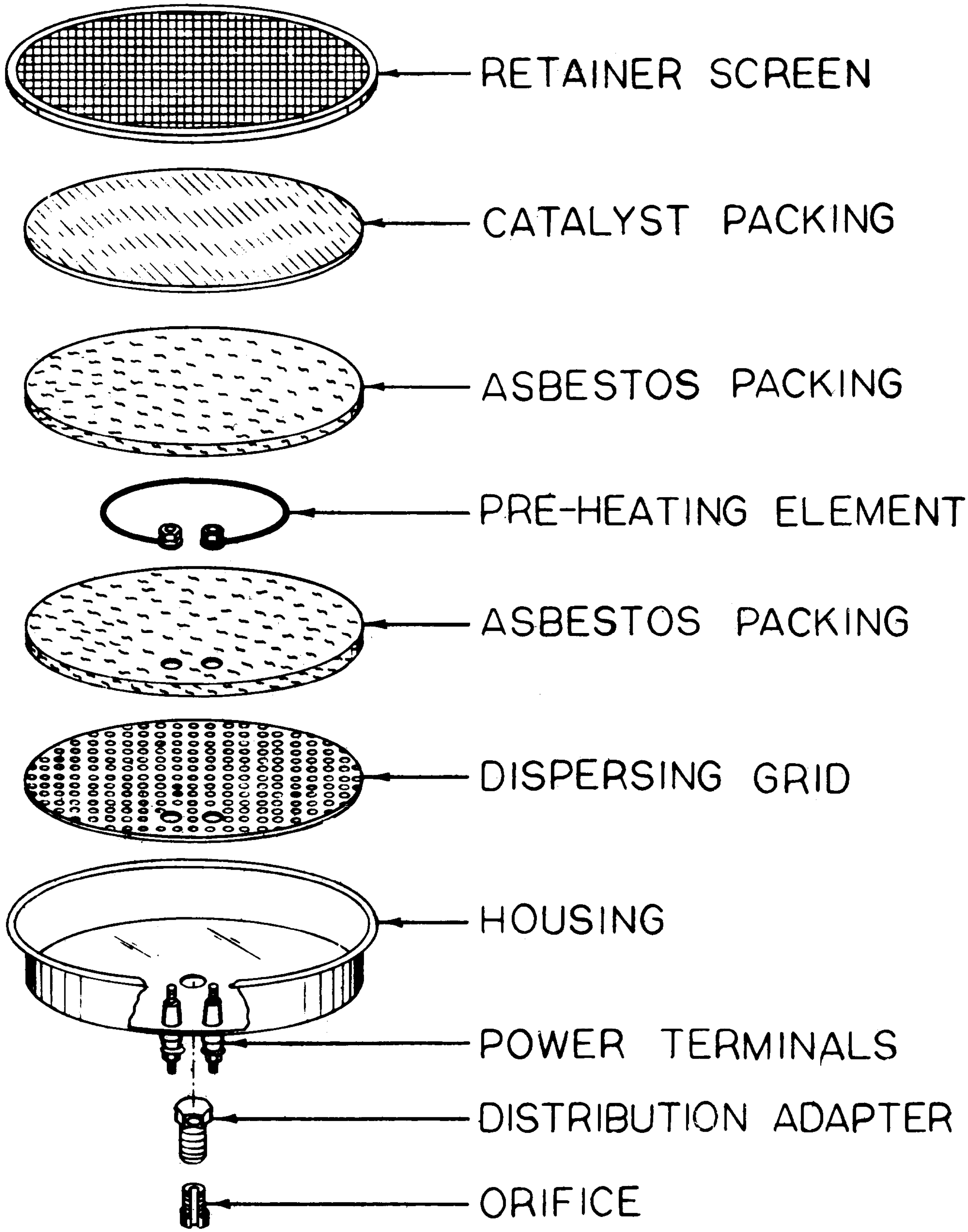

FIG. I CATALYTIC HEATER COMPONENTS

$$Q = cA\sqrt{\frac{p}{g}}$$

Where:

Q=gas flow rate in cu ft per hr

c=constant 1250 for natural gas
1330 for LPG

p=pressure in inches of water column

g=specific gravity of gas (air=1.0)

A=orifice area in square inches

Through rearrangement of the equation it is possible to solve for orifice area with a constant pressure and a desired flow rate. Also pressure can be determined after establishing a constant orifice area and flow rate. Figure 2 is a plot illustrating the change in BTU output versus changing pressure when orifice area is held constant. The fuel used is natural gas with a specific gravity of 0.65 and a heating value of 1000 BTU per cu ft. One curve in Fig. 2 is for gas flowing through a 71 drill size orifice while the other curve is for a 59 drill size orifice. It is interesting to note that a slight variance in the pressure will change the BTU output of the 59 orifice while it takes approximately five times as much variance in the 71 orifice to produce the same BTU change. The 59 drill size orifice is more than two times as large as the 71 drill size orifice; therefore, the 71 is more susceptible to clogging which will reduce the effectiveness of the catalytic heater.

The catalytic heater is designed to operate in areas where open flame or harmful fumes cannot be tolerated. The surface temperature of the heater is limited to 762° F while flame temperatures usually exceed 1200° F. The autoignition temperature, conducted under laboratory test conditions, is approximately 1000° F for methane, 950° F for ethane, 880° F for propane, and 810° F for butane.[2/3/4] Therefore, catalytic heaters can safely operate in atmospheres where these gases are present. While catalytic heaters are safe, it could be possible to bring a substance such as carbon disulfide (AIT=90C) in contact with the heated surface, causing ignition.

APPLICATION

Catalytic heating applications are numerous and new ideas for their use are evolved every day. A primary requirement for choosing a catalytic heater is determining the BTU rating required. A 2500 or 5000 BTU heater should not be expected to do the same job as a million BTU direct or indirect-fired heater. Some other requirements for producing the most efficiency from a catalytic heater are optimum fuel supply, wind shielding, insulation, and the heater position.

As mentioned earlier, different size orifices and pressure settings can be utilized to produce a desired heat output from the catalytic heater. It is important to follow manufacturers' recommended settings for maximum heat output. The heat output can be reduced by varying either pressure, orifice size, or both. The equation explained in the Operation section of this paper will serve as a guide for orifice and pressure sizing. Too much fuel directed to the heater will suppress the reaction temperature due to oxygen starvation. The maximum temperature which can be attained is self limiting by this phenomenon.

Wind shielding or enclosures should be used if the full benefit of the heater is to be obtained. Exposing the heater surface to cold wind greatly reduces the surface heat and could, over a prolonged period, reduce the surface temperature enough to extinguish the combustion process. The minimum enclosure for a catalytic heater is a windbreak. Unlike open flame heaters the catalytic heater will not be extinguished by gusts of wind. Usually the heaters are placed in sheet metal enclosures in order to concentrate and utilize available heat. A large portion of the heat produced is low energy radiant heat and is readily absorbed by metals, painted surfaces and water. Without an enclosure or windbreak the heat absorbed by an object could be given up by the heat transfer to the cold wind. It should be mentioned at this point that enough ventilation has to be available to replenish the oxygen used in the combustion reaction. Heat transfer calculations that are encountered in predicting the heat required to heat an enclosure depends upon many variables such as film coefficient and conductivities. To calculate this heat requirement precisely, using these variables, would be time consuming and in most cases impractical. An approximate calculation for small sheet metal buildings can be made from the following equation:

$$Q = U\ A\ \Delta T$$

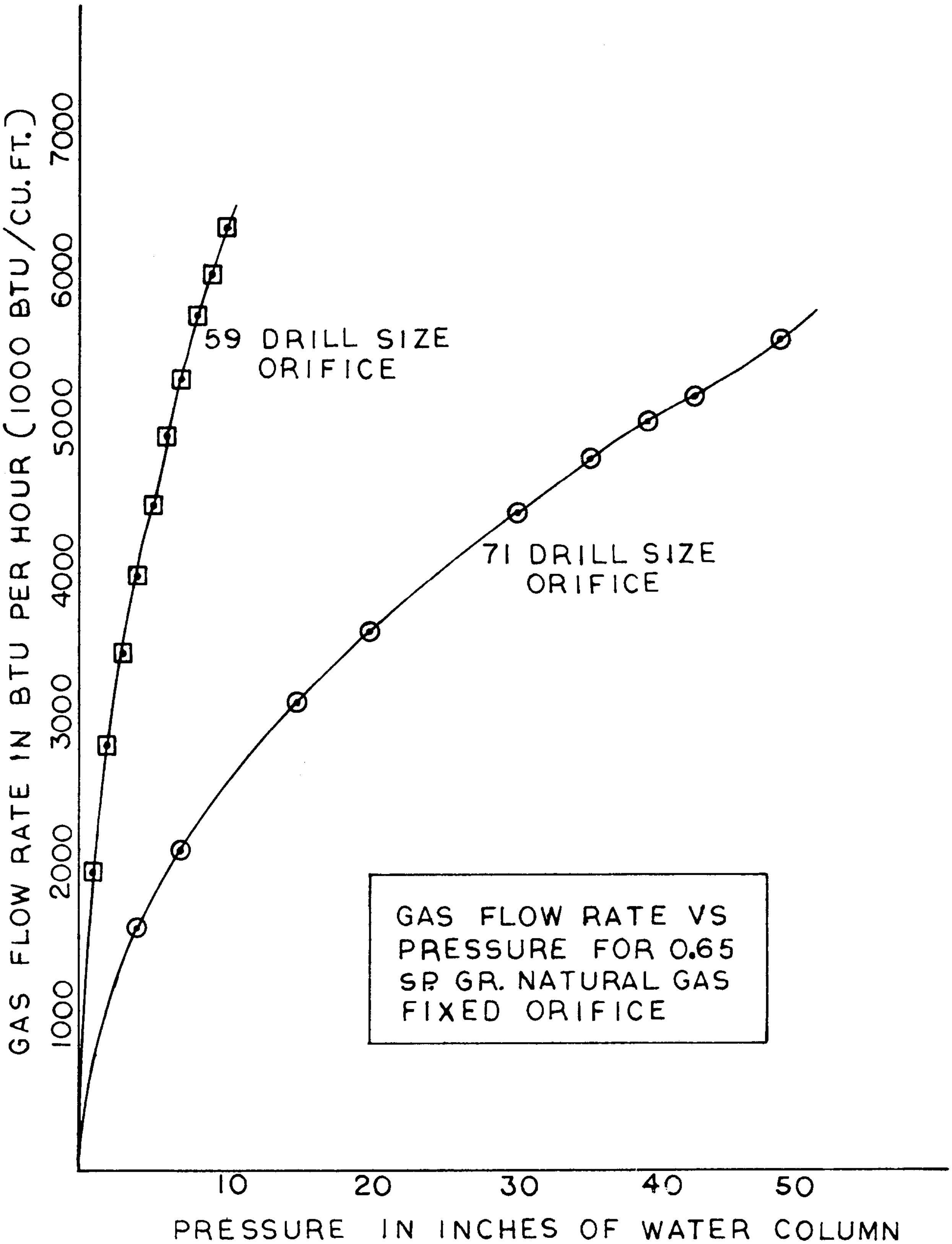

FIG.2 FLOW VS PRESSURE FOR FIXED ORIFICE

Where:

Q=heat required in BTU per hour

U=heat transmission coefficient

A=surface area of enclosure in square feet

ΔT=temperature differential (design inside temperature minus design outside temperature)

Insulation is important in the above equation. The value of U (heat transmission coefficient) for a sheet metal building with no insulation is 1.1 while U for the same building with 1/2-in. thickness of Fiberglas insulation is 0.3. This indicates that a building with insulation will require approximately 1/3 the heat needed for an uninsulated building.

Position of the catalytic heater must be considered for proper operation. Placing the heater with the catalyst packing facing upward will allow dust, sand, and other foreign material to collect, reducing the efficiency of the heater. Placing the catalyst packing facing straight down traps the products of combustion on the surface and also reduces efficiency. Any other position is generally acceptable; however, some positions, depending upon the object being heated, are more effective than others. Freeze protection of a pump or orifice flange inside a building would be more effective if the heater were positioned close to and facing the pump or flange. There is no need to use the heat output to warm the surrounding atmosphere.

The uses for heating with catalytic heaters are practically unlimited and depend upon the imagination of the user. Perhaps one of the more common uses is meter runs. Some users apply heat to the orifice flange, while still others apply heat both to the instrument and orifice flange. The basic intent is to eliminate the formation of hydrates in the equipment. Instrumentation heating such as H_2S analyzers and some flow instruments require regulated temperatures. When the design outside temperature is -30° F and the design inside temperature is 40° F, it is apparent that if the outside temperature is 60° F, there will be overheating without temperature regulation. This type of regulation is usually done with an on-off temperature controller which closes the main gas flow stream to the heater when the temperature reaches a preset limit. A fixed orifice or needle valve adjustment is used to bypass the thermostate and keep the surface of the heater supplied with enough fuel to support minimum combustion temperature of approximately 225° F. At 225° F surface temperature, a small amount of heat is produced, thereby regulating the temperature. Common uses of catalytic heating, which require little more than mounting the heater and starting it, are crankcase heating, paraffin prevention in valves, freeze protection of valves, and hydrate prevention. Crankcase heating applies heat to the crankcase of small battery start engines so lubrication oil will be warm for start-up, thereby reducing the drain on the battery. Paraffin prevention and freeze prevention in valves, pilots, and regulators require relatively small amounts of heat for their protection. This protection is accomplished by the simple application of catalytic heaters. One of the more interesting uses of catalytic heaters is for treating products which require heat within the capability of the catalytic heater such as de-ethanizers for treating compressor condensates. This is done by first flashing the methane by pressure drop and then allowing the heavier products to enter a packed tower. At the bottom of the tower enough heat is applied by catalytic heating to boil the product and strip the ethane out of the entering product. The ethane along with the flashed methane is returned to the gas sales line and the stabilized heavy products can be stored and transported at lower pressure. This description of the basic function of a condensate de-ethanizer illustrates the ever increasing application of flameless catalytic heat application to some of the unthought of problems.

Two basic principles should be observed when catalytic heaters are used to produce heat for human use. First, the catalytic heater does consume oxygen from the air supply and enough ventilation to replenish the supply should be assured. The ventilation rate depends upon the exact fuel being used. The amount of air required for combustion of methane is 9.53 cubic feet per cubic foot of methane, 23.82 cubic feet per cubic foot of propane, and 30.97 cubic feet per cubic foot of butane.[5] It would be safe to predict that for combustion of natural gas a ventilation rate of 20 cubic feet of air per cubic foot of gas is sufficient. The second principle is the possible presence of contaminants in the fuel which could prove harmful. A test was conducted on a catalytic heater to determine the presence of carbon monoxide using a Mine Safety Appliance carbon monoxide detector. There was no detectable carbon monoxide in the catalytic heater's gases of combustion. Several cigarettes were tested in the same manner using the same equipment and they indicated concentrations of 0.01 per cent carbon monoxide in their gases of combustion. Even though the catalytic heater will fully combust its fuel with no harmful by-products in its gases of combustion, there is the possibility of putting a harmful product into the heater and getting that same product out.

Field operation of catalytic heaters often requires the use of sour gas for its fuel. As with other equipment, sour gas is not the best service in which the heaters can operate. While life expectancy of the catalytic heater is reduced because of the sulfide content of the fuel, it is possible to operate in this service. Higher concentrations of sulfides cause a coating to be formed on the platinum catalyst which in turn prevents the reaction from taking place. This coating is not instantaneous but takes a period of time depending upon the sulfide concentration. Since gas consumption is slight, it is possible to bubble this small amount of gas through a monoethanolamine or caustic solution before it goes to the heater, thereby stripping the sulfides and extending the life of the heater. When normal field conditions prevail, there will be an accumulation of liquids in the supply fuel. These liquids can normally be disposed of by conventional drip pots which require periodic maintenance. The drip pot is not practical for large slugs of liquids which could destroy the heating surface. If more liquid than the heater can combust or evaporate enters through the orifice, the heater will be extinguished and possibly matted allowing channelling of the fuel gas. This channelling will permit the fuel to be vented and no combustion can take place. The packing can sometimes be fluffed, dried, and redistributed to form a combustible surface. A new surface can be installed if the packing is no longer serviceable.

SUMMARY

Following basic operation and application guides will produce long and trouble-free service life from catalytic heaters. These guides are simple and logical requiring little more than forethought. The use of these heaters will produce better results from instruments, save downtime, avoid loss of product, and prevent needless repair of equipment. Catalytic heating applications are in their infancy and are restricted only by the imagination of the user.

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