Energy Recovery Through Incineration in Paint Drying Process

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The conventional oven-incinerator system in paint drying process requires considerable amount of auxiliary fuel. The fuel consumption can be reduced drastically by using a new drying process. In this process, drying is achieved by using inert gases. A special incinerator design, which utilizes chemical energy of the solvents to bring the fumes to the incineration temperature, is used to incinerate oxygen-free fumes from the oven and produce high temperature inert gases. Part of these inert gases can be recycled to the oven, while additional gases can be used as a source of heat for other processes. This paper describes the process, development work, and the incinerator design and performance.

INTRODUCTION

The widespread concern about the quality of our environment has resulted in enforcement of strict pollution control regulations. These regulations are forcing many industries to install pollution abatement equipment on their existing and new processing lines. Incineration has been accepted and used as the most efficient method of air pollution abatement. The use of incineration, however, requires auxiliary energy normally supplied in the form of natural gas. The present shortage of clean fuels and the increasing cost for all types of fuels has become a grave concern for the industry.

The paint drying industry is an example where the combined effects of safety requirements, pollution control regulations and the current fuel shortage have created serious supply and cost problems. To solve these problems the industry is looking for alternative coating materials and processes which are safe, pollution free and reduce the process energy requirements. Powder coating and use of water-based paints are the two methods being investigated as alternatives to the conventional solvent-based paints. None of these methods have been tried on large scale, and the consensus seems to be that they cannot solve the current industry needs within the near future.

In this paper we have described a new drying process for solvent-based paints. This process can drastically reduce the auxiliary fuel requirements of the drying and incineration operation by recovering energy from the solvents. A specially designed incinerator, described in this paper, is the heart of the new process.

THE CONVENTIONAL PROCESS

Solvent-based paints contain 40 to 60% organic solvents, which are evaporated during the drying process. These vapors are highly flammable and are potential fire and explosion hazards. The insurance and fire prevention regulations require that for safe operating of the drying ovens the solvent vapors must be diluted to 25 percent of their lower explosion limit. In the conventional paint drying ovens the dilution is obtained by introducing 10,000 cu. ft. air per gallon of evaporated solvent. The conventional paint drying oven, shown in Figure 1, was designed for safety requirements only. The solvent-air mixture is discharged directly into the atmosphere. The heat required
FIG. 1 CONVENTIONAL PAINT DRYING SYSTEM WITHOUT POLLUTION CONTROL

FIG. 2 CONVENTIONAL PAINT DRYING SYSTEM WITH INCINERATOR
in such a system is used for heating the coated object and
the dilution air to the oven exhaust temperature.

The hydrocarbon concentration in the oven exhaust
from a process as shown in Fig. 1 is approximately 14,000
ppm of equivalent methane. Pollution control regulations
no longer permit emissions at these elevated levels. To
comply with the air pollution regulations the paint drying
ovens have been equipped with some type of pollution
abatement equipment especially thermal fume incinerators.
In a typical fume incinerator application, such as shown
in Fig. 2, the fumes are mixed with auxiliary fuel, and the
mixture temperature is raised to 1400° to 1450°F. In a
properly designed incinerator the treated gases are essen­
tially clean. The auxiliary fuel requirement depends on
the exhaust fume temperature and on the initial fume
loading. In most paint drying applications the fuel con­
sumption for the drying operation increases more than
twice compared to that used in the conventional system
shown in Fig. 1.

To reduce the fuel consumption, many new installa­
tions include a fume preheater in which the exhaust gases
from the incinerator are used to raise the fume tempera­
ture before entering the incinerator. Such a system is
shown in Fig. 3. Addition of the fume preheater increases
capital cost which is comparable or higher than the cost of
the incinerator. In many cases economic considerations do
not allow raising the preheater efficiency beyond 50 to
60 percent, and the additional fuel consumption in the
incinerator is still substantial. Recently a major oven man­
ufacturer offered a system which uses a liquid to gas heat
exchanger to recover additional heat from exhaust gases
from the fume preheater. Use of such a system, shown in
Fig. 4, reduces the fuel consumption still further. Obvious­
ly such a system is considerably more expensive and its
use is limited to very large installations. Even with such
an elaborate heat recovery system the fuel consumption is
higher than the simple conventional system without fume
incineration equipment.

Many small and medium scale installations cannot af­
ford to use a complete heat recovery system, and they
have to use considerably more fuel than in the past. The
present fuel supply shortages and the continuously rising
fuel costs are threatening the industry with higher pro­
duction costs, insufficient fuel allocations and production
cutbacks or interruptions. With the realization of such
potential threats the paint and coating industry has started
to look for alternatives for the solvent-based paints. The use of powder coatings and water-based paints is being considered to reduce or eliminate air polluting emissions and hence the additional fuel consumption in the incinerator. But the use of any one of these two methods still requires substantial fuel usage in the drying or heating oven. Also none of these methods have been tried on a large scale. Considering the history of development of both of these methods, it looks as though their use in large scale coating industry may take considerable time.

**ANALYSIS OF PAINT DRYING PROCESS**

In the beginning of 1972, research engineers at the Surface Combustion Division of Midland-Ross Corporation, together with the Consolidated Natural Gas Company realized this problem and initiated an in-depth analysis of the solvent-based paints, their application methods and conventional design requirements. This analysis revealed that, theoretically, the drying operations of solvent-based paints should not require any auxiliary fuel. Even more surprisingly, in a properly designed system, excess energy can be available which can be utilized for auxiliary heating requirements.

The solvent-based paints contain 40% to 60% solvents which have heating value of 120,000 to 140,000 Btu/gallon. These paints are applied as a thin coating of film on the painted object. In most applications the film thickness is of the order of few mils. During the drying process most of these solvents are evaporated and the pigments of the paint form a protective coating on the object. The heating value of the evaporated solvent vapors is usually many times more than the fuel requirements in a typical drying oven. If an oven can be designed to take advantage of this heat, while maintaining the basic requirements of safety, pollution free exhaust and unchanged product quality, the fuel demand of the paint drying industry can be reduced drastically.

In a conventional drying system which includes an incinerator to avoid pollution, the dilution air requires a major portion of the total heat requirement. If we can eliminate or reduce the dilution air without endangering the safety requirements we shall be able to use a large part of the solvent heat for heating the oven and the work. Considerations relating to safety and perfect combustion lead
us to the fundamentals of the flammability characteristics of gas mixtures. Whether a given mixture is flammable or non-flammable can be determined by referring to flammability curves similar to the one shown in Fig. 5. This figure illustrates flammability limits of hydrogen when it is mixed with air, and other inert gases such as nitrogen and carbon dioxide. The shaded triangle area in the figure shows composition of potentially explosive, or flammable mixtures. Any mixture outside the triangle is, theoretically, non-flammable and safe from explosion. Curves similar to the Fig. 5 are available for most common gases and solvent vapors in Ref. [1]. A detailed examination of these curves shows that a mixture of common flammable gases including hydrogen, carbon monoxide, hydrocarbons and vapors of common solvents, with inert gases such as nitrogen, carbon dioxide and water vapor is non-flammable if the oxygen concentration in the mixture is less than 5 percent.

BASIC INERT GAS PAINT DRYING SYSTEM

In the following we are suggesting an alternative to the use of large quantities of dilution air to control potential explosion hazards. If we maintain an atmosphere with a low oxygen or an inert atmosphere with essentially no oxygen in the oven during the solvent evaporation, the gas-solvent mixture will remain non-explosive. In this case, therefore, it is not necessary to use dilution air because the gas-solvent mixture is outside and considerably away from the flammability region. From the viewpoint of safety requirements, the volume ratio of inert gases to the solvent vapors can assume any value, although the vapor condensation and other considerations may require to stay below a definite ratio. In most cases the required volume of inert gas per gallon of the evaporated solvent is much less than the dilution air required in conventional systems.

A paint drying system using this principle is illustrated in Fig. 6. For demonstration purposes we propose an external source of inert gas to maintain the inert atmosphere in the oven. The oven can be heated directly or indirectly. The evaporated solvents are mixed with the inert gas and the solvent concentration in the oven can be maintained by exhausting the contaminated gas at the required rate. The exhaust gases are cleaned by using an incinerator or some other type of pollution abatement equipment. Since the solvent concentration in the exhaust gases or fumes is considerably higher than that in the conventional ovens, the heat released by the solvent combustion is high enough to bring the fume-air mixture to the incineration tempera-

![Image](image_url)
ture. The incinerator does not require any auxiliary fuel except a very small amount for a pilot flame. The fuel requirement of the oven is additionally lowered because the inert gas heat load is much less than what is required for the conventional dilution air system.

At first sight this system looks very attractive, but it has two major drawbacks. First, the system requires an external source or supply of inert gas. The initial and operating cost of inert gas supply equipment can be a substantial part of the total system cost. Also, most sources of inert gas use some type of energy, and this system may not offer any savings in energy consumption when we account for the overall energy usage. The second drawback is related to the incinerator. Most of the currently available fume incinerator designs are not suitable to dispose of fumes with less than 14 percent oxygen. Any attempt to add oxygen in inert exhaust gas will bring us back to the conventional fuel requirements. A special incinerator design is required to handle low oxygen fumes. Until recently such a design was not available.

SURFACE INERT GAS PAINT DRYING PROCESS

The basic system, described above, can be modified to eliminate its drawbacks. The new paint drying process developed at Surface Combustion does not require an external inert gas supply, and it uses a specially designed fume incinerator. As a matter of fact, the incinerator serves as an inert gas generator, heat generator or burner, and as a pollution abatement equipment. The incinerator, which normally accounts for the increased fuel consumption in a conventional paint drying system, is used as a means of energy recovery. The new system, shown in Fig. 7, is the same as the previous system in most parts, but it does not require an external source of inert gas. The contaminated fumes, which are a mixture of inert gases and solvent vapors, is taken to an incinerator. The admission of combustion air to the incinerator is controlled so that it is just sufficient for the stoichiometric combustion of the solvent vapors. This results in exhaust gases with very low oxygen content. The exhaust gases are cooled to the temperature required for the drying operation in a heat recovery system and then used in the oven to satisfy its heat requirements. The heat recovery system may be a water heater, air heater, metal preparation section of the drying line or a low pressure steam boiler. Since these gases contain almost zero percent oxygen, they can be classified as inert and can be used in the oven.

The incinerator design and performance is a key factor to the success of such a system. The exhaust gases from
the oven are non-flammable and have a very small heating value. The stoichiometric combustion, or incineration, of such fumes requires controlled fume-air mixing and rather unusual flame stabilization techniques. With proper selection of incineration temperature and residence time in this design, we have been able to obtain conversion efficiency in excess of 99.9 percent. In a typical test, incineration of fumes containing 4 percent equivalent methane, and a mixture of nitrogen, carbon dioxide and water vapor was incinerated at approximately 1600°F. The hydrocarbon and carbon monoxide content of exhaust gases was less than 15 ppm, while maintaining 0.5 or less percent of oxygen concentration. The incinerator used in this system is known as the Rich Fume Incinerator. It is shown, schematically, in Fig. 8. Details of the design requirements, and how they are satisfied in this unit are described in two recently available papers [2 and 3].

We have compared this new process with a conventional system. Table shows comparison of fuel, air and other utilities required for two systems. The conventional system includes a fume incinerator, pre-heat recuperator and a heat transfer liquid medium for total heat recovery.

It is similar to the one shown in Fig. 4. The gas consumption for such a system is 41 MM Btu/hr. The heat transfer rate to the work is 7 MM Btu/hr. For the same heat demand in the oven a properly designed new inert gas paint drying process the fuel consumption reduces to less than 5 MM Btu/hr. The fresh air requirements of the new system drops to 200,000 s.c.f.h. compared to 1,500,000 s.c.f.h. in the conventional system. Similarly the lower fume volume, 525,000 s.c.f.h. in new system compared to 1,300,000 in the conventional system, results in the smaller size exhaust fan, piping and the incinerator itself. In one application [4] comparison of the conventional and the new system showed that the cost of the new system is almost the same as that of the conventional system.

The inert gas paint drying process has some additional features and requirements which are described below.

WORK QUALITY AND SEALS

In the conventional ovens the paint drying is carried out in presence of gases containing a high percentage of oxygen. During the initial phase of this work it was un-

![Diagram of the New Proposed Inert Gas Drying System](image-url)
Table 1 Comparison of Two Paint Drying Systems

<table>
<thead>
<tr>
<th>Item</th>
<th>Inert Paint Drying System (Similar to Fig. 7)</th>
<th>Conventional System (Similar to Fig. 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Demand in Oven</td>
<td>7 MM Btu/hr.</td>
<td>7 MM Btu/hr.</td>
</tr>
<tr>
<td>Net Fuel Consumption</td>
<td>5 MM Btu/hr. or less</td>
<td>41 MM Btu/hr.</td>
</tr>
<tr>
<td>Air Blower Capacity</td>
<td>200,000 s.c.f.h.</td>
<td>1,500,000 s.c.f.h.</td>
</tr>
<tr>
<td>Exhaust Blower Capacity</td>
<td>525,000 s.c.f.h.</td>
<td>1,300,000 s.c.f.h.</td>
</tr>
<tr>
<td>Incineration Temp.</td>
<td>1600°F.</td>
<td>1450°F.</td>
</tr>
<tr>
<td>Atmospheric Seals</td>
<td>Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>Heat Transfer Liquid</td>
<td>Not Required</td>
<td>Required</td>
</tr>
</tbody>
</table>

FIG. 8 RICH FUME INCINERATOR
certain whether the use of low oxygen or inert gases in the oven would affect the work quality or not. The available literature and personal communication with people associated with the paint and coating industry gave conflicting opinions on this matter. To resolve this question we initiated a laboratory program in which thermosetting type paint samples were dried using the conventional oven gases and inert gases. The finished samples were evaluated by an independent laboratory and the results showed that for this type of paints the composition of oven gases does not have any effect on the finished paint properties or color characteristics. As a matter of fact, the inert atmosphere retains the paint qualities when the sample is exposed to such gases for a prolonged time. With the high oxygen gases, the paint pigments are oxidized and get dark. Thus, if anything, the drying with inert gases results in better paint finish and quality.

To maintain low oxygen concentration in the oven gases, it is necessary to prevent air leakage into the oven. The air or gas leakage from the oven walls and roof can be eliminated with proper design. However, special arrangements are required at the work inlet and outlet stations. During the development of this process we have developed aerodynamic seals to avoid air leakage.

In spite of all precautions there is always a chance for air leakage in the oven and a question always arises: what is the effect of such air leaks? Our calculations have shown that under normal operating conditions the air leakage into the oven cannot bring the gas mixture above about 40 percent of its lower explosion limit and the system will, therefore, remain safe.

The other possibility is that the solvent evaporation rate in the oven increases above the designed value. In conventional ovens, the air solvent mixture will approach the explosion limit and there is a possibility of explosion. In the new system the solvent evaporation can increase to any value and still the system remains perfectly safe, due to the low oxygen concentration in gases.

**CONCLUSION**

The impact of the pending fuel shortage on the solvent based paint drying industry can be reduced by using a new inert gas paint drying process. This process utilizes a specially designed incinerator to recover the energy of solvent vapors. The recovered energy is used for heat supply to the drying oven as well as other auxiliary operations of the process. Such a process is safe, pollution free and, compared to the conventional process, it uses considerably lower amount of fuel.

The process principles and the incinerator design can be used in many other processes in which high Btu vapors are released. Chemical coating, pyrolysis of carbonaceous material, carbon baking operations, resin coating, are only a few of the many examples. In each case incineration has been used as a means to recover energy and reduce pollution.

**REFERENCES**


