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Project Summary

Environmental and Energy Benefits of Microprocessor Control of Oven Airflows from Metal Painting Operations

In most industrial operations the percentage of the lower explosive limit (LEL) of VOC emissions typically remain at below 5 to 10 percent LEL at most metal coating operations. Although monitors are available to determine solvent concentrations, they require manual corrective action to the process when potentially explosive oven atmospheres are generated. This project demonstrated the capability of microprocessors to control and allow ovens to operate close to 50 percent LEL while not exceeding that level. With instantaneous process control allowing operation closer to 50 percent of the LEL dilution air and energy requirements for the process and for incineration will be reduced. Successful demonstration of the use of microprocessors resulted in a control option that is both efficient and economical, and make the use of incineration with heat recovery much more efficient and attractive.

Included in the final report is a technical design manual on the use and implementation of microprocessor technology into paint baking ovens for energy conservation and VOC pollution reduction from metal coating processes.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Industrial coating curing ovens require ventilation air to maintain the solvent concentration below its lower explosive limit (LEL). However, higher-than-required ventilation airflow rates drastically increase the oven exhaust rate and result in higher energy and environmental compliance costs. The increased cost of environmental compliance results from larger incinerator capital and operating costs. The added energy costs are due to the heating requirements for the ventilation air and the added fuel for the incinerator.

Prior to this project, automatic control of ventilation airflow rates based on continuous solvent concentration measurements in curing ovens and microcomputer technology were not used in the American coating industry. There were several reasons for this:

- Only recently have fuel costs and environmental compliance requirements made improved control a major economic factor.
- There was considerable industrial skepticism about the accuracy of instruments for continuous measurement of solvent concentrations.
- The complexities of oven dynamics preclude simple analog control and only recently has the microprocessor brought digital control within an economic range for most oven systems.

Because of the large number of paint curing ovens in the United States, automatic control can have a major impact on the cost of environmental compliance and energy costs.

The U.S. Environmental Protection Agency, the Department of Energy, and the Chemical Coaters Association cooperatively sponsored a program to evaluate, design, and demonstrate automatic ventilation airflow rate control through direct measurement and control of the concentration of the solvent in the oven. The specific objective of this effort was to demonstrate that ventilation airflow rates could be safely reduced, thus reducing the energy costs for curing and incineration of solvents being vented from the curing oven.

Industrial Survey

Prior to developing a control system, an industrial survey was undertaken to determine the potential benefits of this concept. A survey of 29 sites indicated that the average solvent concentration in the exhaust from curing ovens was about 7 percent of the LEL. In comparison, the National Fire Protection Association (NFPA) requires only that the percentage of the LEL be kept below 25 percent unless solvent indicators, alarms and shutdown of oven heating systems are provided. If this equipment is installed, the maximum solvent concentration should not exceed 50 percent of the LEL.

The lower-than-required solvent concentration in actual operation is usually a result of compounding safety factors built into the oven design, starting with the user's specifications and continuing with the oven manufacturer. The end result is excessively high curing oven ventilation airflow rates in most plants.

Based on the evaluation of curing oven systems during Task 1, it was concluded that automatic control could significantly reduce operating costs in both ovens and incinerators as well as lower investment costs for VOC control systems.

The sponsoring agencies stipulated that this concept be proven in the miscellaneous metal products industry and that its conclusions and benefits be applicable for other coaters using coatings containing volatile organic compounds. This could include such industries as:

- Coil
- Fabric
- Can
- Automobiles and Light Duty Trucks
- Printing
- Appliance

Demonstration Site

Based on established criteria for selection of a host site, Mack Trucks, Inc., agreed to participate. The Building 10 Assembly Plant in Allentown, Pennsylvania, which had multiple curing ovens and one catalytic incinerator, was chosen as the demonstration site. The curing ovens are typical of the systems used throughout the miscellaneous metal products coating industry.

Figure 1 shows the basic design functions of a control system. After a detailed evaluation, an Intel 8086-based controller and an analyzer using the flame ionization detection (FID) principle of operation were selected as the key hardware components. Solvent concentration was monitored at four points inside the controlled oven.

The system started up on October 1, 1981 and immediately reduced airflows from 1.6 m^3/s to 0.23 m^3/s (3400 $stdft^3/min$ to 490 $stdft^3/min$), a reduction of 86 percent. This resulted in an energy usage reduction for air heating of 55 percent in the curing oven and 13 percent in the catalytic incinerator. VOC destruction efficiency showed an improvement of 84 percent to 94 percent. At this point, most oven control dampers were closed and inflow from oven openings became the only source of ventilation airflow.

System Design

The control system at Mack Trucks wa[s] designed to control the dip oven at th[e] minimum ventilation airflow rate whic[h] would either control the solvent concer[n]tration at 35 percent of the LEL or mair[n]tain a slightly negative pressure inside th[e] oven. The control point became pressur[e;] the maximum solvent concentration reache[d] was 12 percent of the LEL. The minimur[m] ventilation airflow rate was 0.23 $m^3/$[s] (490 $stdft^3/min$) which was 1.37 $m^3/$[s] (2910 $stdft^3/min$) lower than the rat[e] before the control system was installed.

The expected control set point of 3[5] percent of the LEL was not reached for tw[o] reasons. First, due to the depressed truc[k] market, the production level through th[e] dip oven dropped to about one-third of th[e] normal level which, in turn, reduced th[e] solvent load. Secondly, although da[ta] received from Mack Trucks that repr[e]sented normal production levels indicate[d] that the solvent loading would give a[n] average exhaust concentration of appro[x]imately 6 percent of the LEL at 1.6 $m^3/$[s] (3400 $stdft^3/min$) ventilation airflow rate[s]

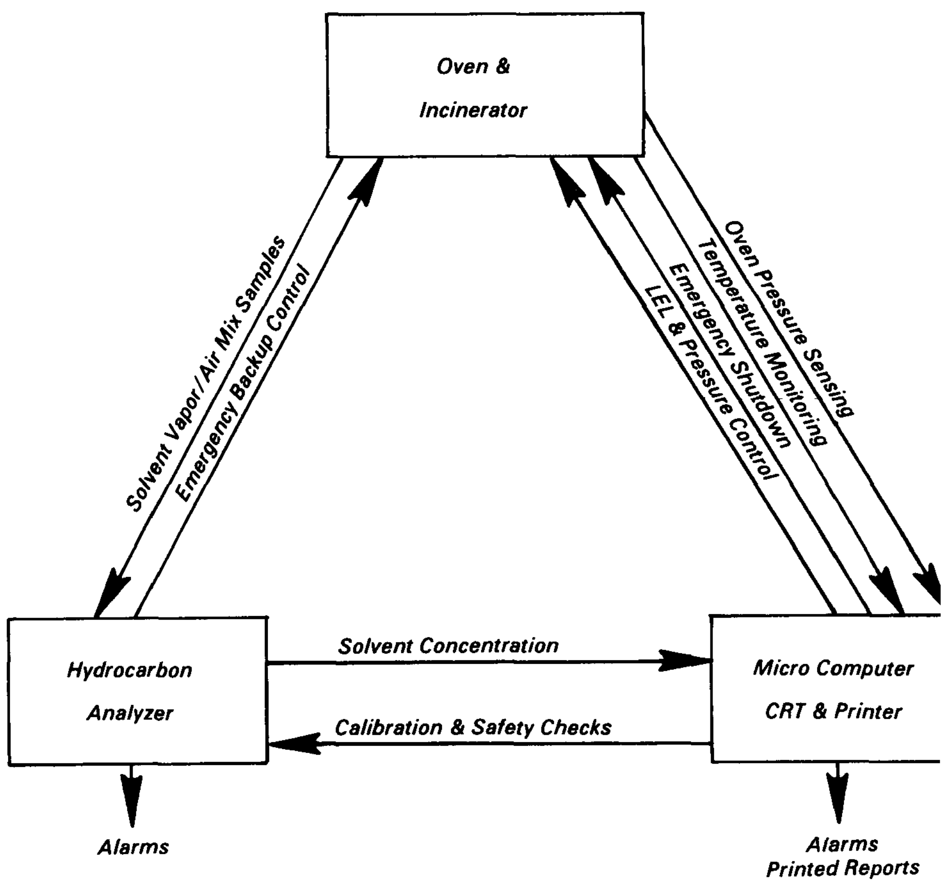

Figure 1. *Basic design features of control system.*

measurements taken at the plant just prior to installation of the control system showed that the solvent concentration was less than 1 percent of the LEL. With these very low solvent loadings and frequent line changeovers when no parts were cured, it was not possible to reach 35 percent of the LEL since the required airflow would be impractically low— well below normal in leakage. At an airflow rate of 0.23 m^3/s (490 $stdft^3/min$), the highest average solvent concentration approached 7 percent of the LEL. During brief runs at higher coating and production rates, the solvent concentration increased to 12 percent of the LEL.

Although the maximum solvent level of 35 percent of the LEL was not achieved, the primary objective of airflow reduction combined with proof of concept for all safety, operating control loops, and report generation was accomplished. The resulting energy savings in both the oven and incinerator were nearly equal to the projected savings. The airflow rate reduction was equal to the original projection of 1.3 m^3/s (2900 $stdft^3/min$).

System Reliability

Table 1 is a summary of oven conditions immediately before and after the system was placed in automatic control.

The system reliability appeared good, but decreasing production with numerous shutdowns because of low sales at Mack Trucks prevented long-term evaluation of continuous mechanical reliability. As expected, the only major systems requiring significant maintenance attention were the hydrocarbon analyzers.

With the first prototype testing complete, the expected benefits to other curing ovens can be calculated from a knowledge of oven flow rates and the average percent LEL maintained before control. Table 2 summarizes the projected industrial fuel benefits as a function of oven parameters for the various applications.

This project has shown that reduction of airflow in curing ovens via microprocessor control of solvent concentration is a practical, workable technology. Although the prove-out of the Mack Trucks parts line does not allow the automatic extension of the technology to ovens with higher and more variable solvent loadings and temperatures, that prove-out on these other applications will most likely occur through normal commercial evolution.

Table 1. *Mack Trucks' Oven and Incinerator Conditions*

	Before Automatic Control	*After Automatic Control*
Oven		
• *Exhaust airflow, $stdft^3/min$*	*3400*	*490*
• *Solvent rate, lb/hr*	*5.7*	*5.7*
• *Exhaust solvent concentration, % LEL*	*1*	*7**
• *Exhaust air temperature, °F*	*252*	*282*
• *Energy consumption, million Btu/hr*	*1.74*	*0.77*
Incinerator†		
• *Total airflow, $stdft^3/min$*	*9240*	*6330*
• *Operating temperature, °F*	*975*	*1014*
• *VOC destruction efficiency, %*	*84*	*94*
• *Energy consumption, million Btu/hr*	*4.7*	*4.1*

**Maximum concentration in the oven was 12 percent of the LEL.*
† Includes three ovens plus fume tunnel exhausts. Temperature increased due to minimum catalyst reactivity temperature requirement and the higher solvent concentration.
NOTE: Data supplied by Mack Trucks, October, 1981; incinerator fuel demands were variable due to cycling of the temperature controller.

Table 2. *Projected Energy Benefits from Oven/Incinerator Control for Various Applications*

	Miscellaneous Metal Products Coating	*Fabric and Paper Coating*	*Coil Coating*
Initial exhaust airflow rate, $Stdft^3/min$	*2,000-10,000*	*10,000-17,000*	*17,000-40,000*
Controlled exhaust airflow rate, $Stdft^3/min$	*1,000-3,000*	*3,000-4,500*	*4,500-8,000*
Solvent removal rate, gph	*5-20*	*20-33*	*33-75*
Energy consumption of oven wo/control, MM Btu/hr	*1.0-4.0*	*4.0-6.5*	*6.5-15.0*
Energy consumption of oven w/control, MM Btu/hr	*0.5-1.5*	*1.5-2.0*	*2.0-3.2*
Energy consumption of oven & incinerator wo/control, MM Btu/hr	*3.0-15.0*	*15.0-25.0*	*25.0-60.0*
Energy consumption of oven & incinerator w/control, MM Btu/hr	*1.0-2.5*	*2.5-3.0*	*3.0-4.5*

Basis:

Solvent is Toluene.
Initial solvent concentration is 7% of LEL.
Oven exhaust temperature is 350°F.
Thermal incinerator is operated at 1400°F, no heat recovery.
Ranges below are approximations.
Air heating demand only.

This Project Summary was prepared by staff of Chemical Coaters Association, Wheaton, IL 60187.
***Charles Darvin** is the EPA Project Officer (see below).*
The complete report, entitled "Environmental and Energy Benefits of Microprocessor Control of Oven Airflows from Metal Painting Operations," (Order No. PB 83-225 250; Cost: $25.00, subject to change) will be available only from:
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