# DRYER SOLVENT LEVEL CONTROL IN WEB OFFSET PRINTING

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Abstract: With increasing costs of energy, the Heatset Web Offset Industry, like other industries, is interested in reducing operational energy consumption wherever possible. Each dryer is a major energy consumer in every heatset offset printing plant. In part this is due to the large volume of heated air exhausted from the dryer. This exhaust air is replaced with ambient temperature make-up air, for dilution purposes, to maintain a safe operating solvent level. This ambient temperature make-up air, once pulled into the dryer, must then be heated to bring it up to the dryer temperature. This article addresses increasing web offset dryer solvent levels to the maximum safe limit, thereby minimizing dryer energy consumption.

## Introduction

The National Fire Prevention Association (NFPA) has established guidelines for safe exhaust rates from continuous process dryers which evaporate combustible solvents. Normally, exhaust rates for these dryers must be fixed at a safe value. This value would result in a solvent vapor concentration equivalent to 25 percent LFL (Lower Flammable Limit) with the maximum potential solvent evaporation rate (Figure 1). For a typical web offset press dryer, this maximum potential solvent evaporation rate is never really achieved, since generally only about 80 percent of the ink solvent evaporates in the dryer, and only rarely is the press run with maximum ink coverage. Actual solvent vapor levels in offset dryers vary depending on the job and press speed, and are typically 5-15 percent LFL. This means that there is much wasted energy, since higher concentrations (up to 50 percent LFL), can be safely permitted, if properly controlled, with a corresponding exhaust rate reduction.

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Exhaust Rate = (Max. Web Speed)x(Max. Web Width)x (Max. Ink Laydown)x(Solvent Content of Ink)x(Air:Solvent Ratio for 25% LFL)

SCFM = (Ft/Min)x(Ft)x(Lb Ink/$Ft^2$)x(Lb Solvent/Lb Ink)x (SCF Air/Lb Solvent)

-Max. Possible Solvent Concentration = 25% LFL

-Normal Concentrations 5 - 15% LFL

-No Solvent Concentration Monitor Required

Figure 1. Conventional Fixed Exhaust Rates (NFPA 86A, Sec. 4-2)

The NFPA guidelines allow for such reductions in exhaust rates, when a solvent concentration (LFL) monitor and controller is provided. The monitor measures and indicates the solvent vapor concentration and triggers alarms and safety overrides if dangerous solvent levels are approached. Under normal running conditions, the exhaust rate is set in proportion to the solvent evaporation rate so that energy is not wasted with excessive exhaust and the solvent level is maintained at a safe level (Figure 2). For most printing jobs, the exhaust rate can be reduced substantially below the previous fixed rate, affording energy savings and a cost reduction for dryer operation.

Exhaust Rate = (Solvent Evap. Rate)x(Dilution Air Requirement)

SCFM = (Lb Solvent/Min)x(SCFM/Lb Solvent)

Solvent Evap. Rate = (Press Speed)x(Web Width)x(Ink Laydown)x(Solvent Content of Ink)x(Fraction of Solvent Evaporated)

Lb Solvent/Min = (Ft/Min)x(Ft)x(Lb Ink/$Ft^2$)x(Lb Solvent/Lb Ink)x(Lb Solvent Evap./ Lb Solvent Applied)

-Exhaust Rate Varied to Maintain High Solvent Concentration (up to 50% LFL)

-Exhaust Rate Determined by Actual (Not Maximal) Operation of Press

-Requires Solvent Concentration Monitor/Controller

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Figure 2. Variable Exhaust Rates (NFPA 86A, Sec. 4-4)

## Terminology

Refer to Figure 3. The Lower Flammable Limit (LFL) is the leanest mixture of gas or vapor in air where, once ignition occurs, the gas or vapor will continue to burn after the source of ignition has been removed. By keeping the exhaust air-gas mixtures below the lower flammable limit, it is possible to isolate sources of ignition from sources of solvent vapor. Once above the LFL, a flame front can travel via the gas-air mixture to the source of vapor and create a fire or explosion. LEL (Lower Explosive Limit) is a less pleasant term used interchangeably with LFL.

The LFL of all solvents decreases as the temperature increases. Thus a mixture which is below the LFL at one temperature (A on Figure 3) may be above the LFL when heated (B on Figure 3). In order to maintain a safe condition, this given mixture would require more dilution air at higher temperatures. The NFPA guidelines which pertain to printing ink solvents stipulate that the values for the lower flammable limit determined at room temperature may be used up to 250 degrees Fahrenheit. Between 250 degrees Fahrenheit, and 500 degrees Fahrenheit, (which is the typical operating range of heatset offset dryers) a factor of 1.4 shall be used to increase the volume of air required.

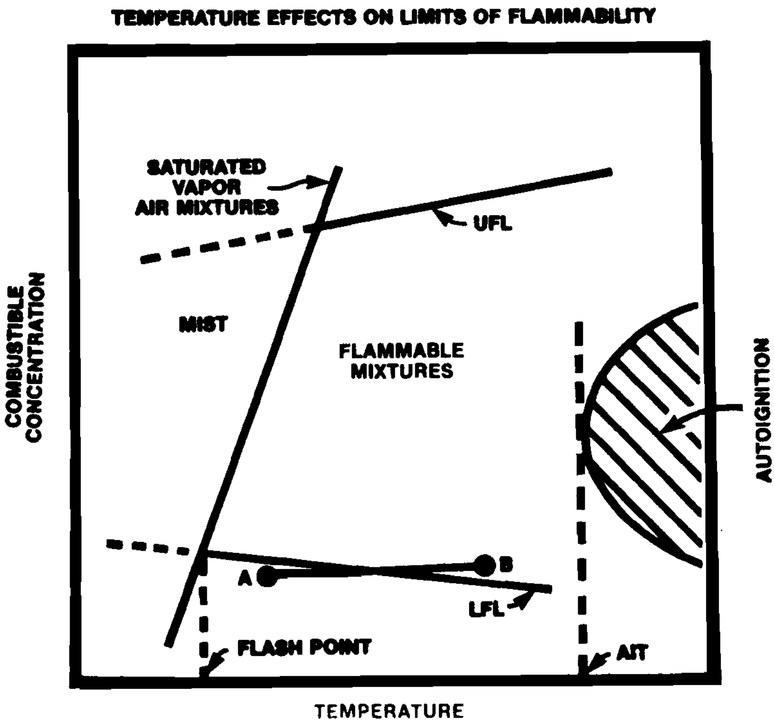



Figure 3. Explanation of Terms

The Upper Flammable Limit (UFL) is the richest mixture in which a flame will continue to burn after the source of ignition has been removed.

The Flammable Range is the range of flammable vapor or gas-air mixture between the upper and lower flammable limits. This is also sometimes referred to as the "explosive range".

The Flash Point of a flammable liquid is the lowest temperature at which it gives off enough vapors to form a flammable or ignitable (LFL) mixture with air, near the surface of the liquid. Many hazardous liquids have flash points at or below room temperatures and will ignite immediately if a source of ignition is brought near. There are also liquids which have flash points above room temperature whose vapors can only be in dangerous concentrations at elevated temperatures. The flash point, therefore, is an indicator of the hazard of handling liquid solvents related to the temperature.

The Autoignition Temperature (AIT) is the minimum temperature required to achieve spontaneous combustion of a flammable vapor in air.

The Stoichiometric Mixture is a flammable mixture which has the proper ratio of oxygen to solvent for both to be completely consumed by combustion. The lower flammable limit is typically about 50 percent of the stoichiometric concentration.

## Solvent Monitors

There are three types of relatively common solvent concentration monitors which have been devised to detect flammable vapors in air. These are catalytic combustion detectors, flame ionization detectors (FID), and thermal incineration detectors. The properties of all solvents and any other possible components present in the atmosphere to be monitored by a detector must be known in order to properly select a solvent vapor monitor which will be safe and reliable.

Various vapor and liquid components are normally found in the dryer atmosphere in the Heatset Web Offset Printing Industry. Obviously the printing ink solvent is a major component. These solvents are a petroleum fraction with a typical boiling range of 440 degrees Fahrenheit to 600 degrees Fahrenheit, a very low vapor pressure (typically below 0.2 millimeters Mercury at 70 degress Fahrenheit), and a typical flash point range of 210 degrees Farhenheit, to 285 degrees Fahrenheit. Due to the low vapor pressure and high flash point temperature, the solvent monitor must have a heated sample train and sensor. None of the solvent vapor being sampled can come into contact with any surface which is cooler than the solvent/air mixture dew point. Otherwise the solvent vapor condenses, causing plugging, gunking, and/or loss of monitor reading. Other often found components in the dryer atmosphere are alcohol from the fountain solution, traces of unburned natural gas, carbon dioxide, water vapor and sometimes silicone.

Catalytic combustion detectors utilize a catalytic heat-sensitive resistance element, which responds to all flammable gases. When a hazardous gas contacts the active sensing element, the active catalyst oxidizes the gas which heats up the element, changing its electrical resistance. This unbalances a Wheatstone bridge creating an electrical signal which is amplified for indication and alarm activation. Catalytic poisons, such as silicones, halogens, lead, and plasticizers will coat a catalyst sensor element and render the detector ineffective.

The flame ionization detector (FID) is best known for its high sensitivity. The sample of solvent vapor is mixed with hydrogen gas and burned with air or oxygen. When groups of carbon bonded to hydrogen are introduced into the flame, positively charged carbon species and electrons are formed which enter a gap between two electrodes. Electrical circuitry ensures that a net current flows only when ionized material enters the gap. This current flow is sensed as a voltage drop, amplified, and displayed. The FID responds only to substances that produce charged ions when burned in a hydrogen/air flame, and this response is proportional to the number of oxidizable carbon atoms. It has no response to fully oxidized carbons such as carbon dioxide. The FID is a mass flow detector with its output accuracy depending directly on the flow rate of the sample gas, and the ratio of the hydrogen/air mixture. These critical flow rates and calibration-per-solvent requirements are a serious concern for safe and reliable daily industrial applications of offset printing dryers.

Thermal incineration detectors utilize a small pilot flame to detect the presence of any combustible gas. This sensing flame is encased in a cell with inlet and outlet flame arrestors through which a sample of the atmosphere being monitored is passed. The fuel delivery system to the flame is accurately metered. By strictly controlling the flame, a constant value can be determined for the heat of the flame. As the sample is passed through the small pilot flame, any solvent vapor is incinerated at flame temperature. The result is a heat increase which is measured by a temperature transducer which develops a signal proportional to the gas concentration. The signal is amplified for indication and alarm activation. Once calibrated, the accuracy is not significantly affected (unlike catalytic detectors and FID's) by the presence of other solvents in the sample. This is because, to a first approximation, the percent LFL is only a function of the heat released by combustion of the solvent or mixture of solvents. Also, because the sample is incinerated, the sensor is not subject to contamination.

## Impact of Increased LFL

Assuming most existing dryers in the heatset offset field were properly sized for operation at 25 percent LFL, there should be no significant problems in operating them at that level. However, that is not to say that there is no difference in performance between a dryer operating at 10 percent LFL and the same dryer, with LFL control, operating at 25 percent LFL. The most important factor to understand about dryer performance and solvent concentration is, simply stated, that increasing dryer solvent concentration has the same net effect as shortening the dryer length.

It must be realized that drying entails evaporating the solvent from the ink into a vapor which is swept away from the web and mixed with the dryer atmosphere. This mixing occurs throughout the dryer and recirculation duct creating a solvent vapor concentration in the dryer atmosphere. The net evaporation rate of the solvent is proportional to the difference between the vapor pressure of the solvent evaporating at the immediate web surface and the solvent vapor pressure in the dryer atmosphere surrounding the web. With higher dryer solvent concentration levels, this vapor pressure difference decreases, resulting in a decreased net evaporation rate. For example, a dryer operating at 25 percent LFL (and all other variables held constant) will not achieve the exact same level of dryness as the same dryer operating at 10 percent LFL. A slightly higher dryer supply air temperature setting will offset this difference by increasing the vapor pressure difference, and consequently increasing the net evaporation rate. In spite of the slightly higher temperature setting, using the same example, a net energy consumption reduction of about 30 percent is realized due to an exhaust rate reduction of about 52 percent. It is this 52 percent exhaust rate reduction which causes the dryer solvent level to increase from 10 percent LFL to 25 percent LFL.

Safe dryer operation may not always allow sufficient exhaust reduction to achieve solvent concentration levels of 25 percent LFL. A dryer must always exhaust a sufficient volume of air to maintain an internal negative pressure which does not allow it to spew fumes outward into the press room. If the printing coverage is very light and/or the printing speed is slow, the maximum available solvent being evaporated may not be sufficient to reach the 25 percent LFL level (due to the dilution effect of infiltration air) even with a minimum allowable exhaust rate. However, LFL control will permit exhaust rate reductions for this situation approaching 65 percent with a corresponding energy consumption reduction approaching 37 percent.

It is possible, with heavy ink coverage and/or high speed printing, to reach 25 percent in the dryer with only a slight reduction in the exhaust rate. Energy savings in this case would, of course, not be so large. Obviously, with an LFL monitoring control system, the exhaust rate could be reduced for larger savings by operating the dryer above 25 percent LFL. (With a proper monitoring system, codes will allow operation up to 50 percent LFL). However, if the dryer was sized for operation up to 25 percent LFL, operation above that level may create a lower quality product. Most TEC dryers have the heat transfer capability to successfully dry the product even with dryer solvent concentration levels of 40 percent LFL, but the supply air temperature required to achieve dryness in the available dryer length, with high LFL levels, could cause blistering on coated stock. This is caused by the web moisture being driven out of the web faster than it can escape through the coating on the paper.

## LFL Control System

This control system was developed to provide the web offset industry with a safe and reliable means to increase dryer solvent levels by reducing dryer exhaust rates. The solvent concentration monitor is of the thermal incineration type utilizing hydrogen for precise pilot flame control, and with all sampling and detector components heated to prevent condensation of printing ink solvents. The systems' safety features include: a warning alarm level, which automatically opens the exhaust damper, sounds an alarm, and illuminates a yellow lamp; a danger alarm level, which stops the process, and illuminates a red lamp; and a malfunction alarm circuit, which automatically opens the exhaust damper, sounds an alarm, and illuminates blue lamps to indicate whether the malfunction is due to low sample flow or flame-out/sensor failure condition. In the case of flame-out/sensor failure, the hydrogen fuel supply is also automatically cut off. Other safety features include automatic damper opening in the case of electrical power loss or loss of compressed air.

The exhaust damper control physical components consist primarily of: a 3-mode controller, which receives an LFL input signal from the LFL monitor; a photohelic pressure switch/gauge, which monitors the dryer internal negative pressure; and a pneumatic cylinder/positioner for exhaust damper control. With automatic systems, the press operator has the option of over-riding the automatic controls and manually selecting an exhaust damper position from the press console, however, all safety features will still function automatically. Manual control systems do not utilize the 3-mode controller.

With automatic LFL control systems, the primary control variable is dryer LFL, with dryer internal pressure acting as a secondary control variable. (Refer to Figure 4.) This means that the automatic controller input signal comes from the LFL monitor, and the controller sends an output signal to the damper positioner to adjust the damper to attempt to reach the LFL setpoint. In some cases, this causes the automatic controller to close the damper as far as possible in an attempt to increase the dryer LFL to the setpoint. This would often cause a dryer to spew fumes ("belch") from the web slot opening. This control system utilizes an adjustable double setpoint pressure switch/gauge, (which monitors the dryer internal pressure) to over-ride the primary dryer LFL control whenever the dryer internal pressure approaches the level at which "belching" occurs. The first setpoint is adjusted such that the damper closing motion will be stopped, and the damper will be held stationary at that position which results in a dryer internal pressure slightly more negative than an impending "belch" condition. If any drying variables should change, such as more heat load, which would cause the introduction of an increased amount of burner combustion air and might cause the dryer internal pressure to approach a "belch" condition, in spite of no damper movement, the second setpoint of the pressure switch/gauge would be tripped. This results in the damper being opened slowly until the dryer internal pressure is once again negative enough for the damper position to be stopped and held at that point. If any variables should change which would cause the dryer LFL to reach the LFL setpoint, the primary LFL control circuit regains direct control of the damper position to maintain the LFL set-point.

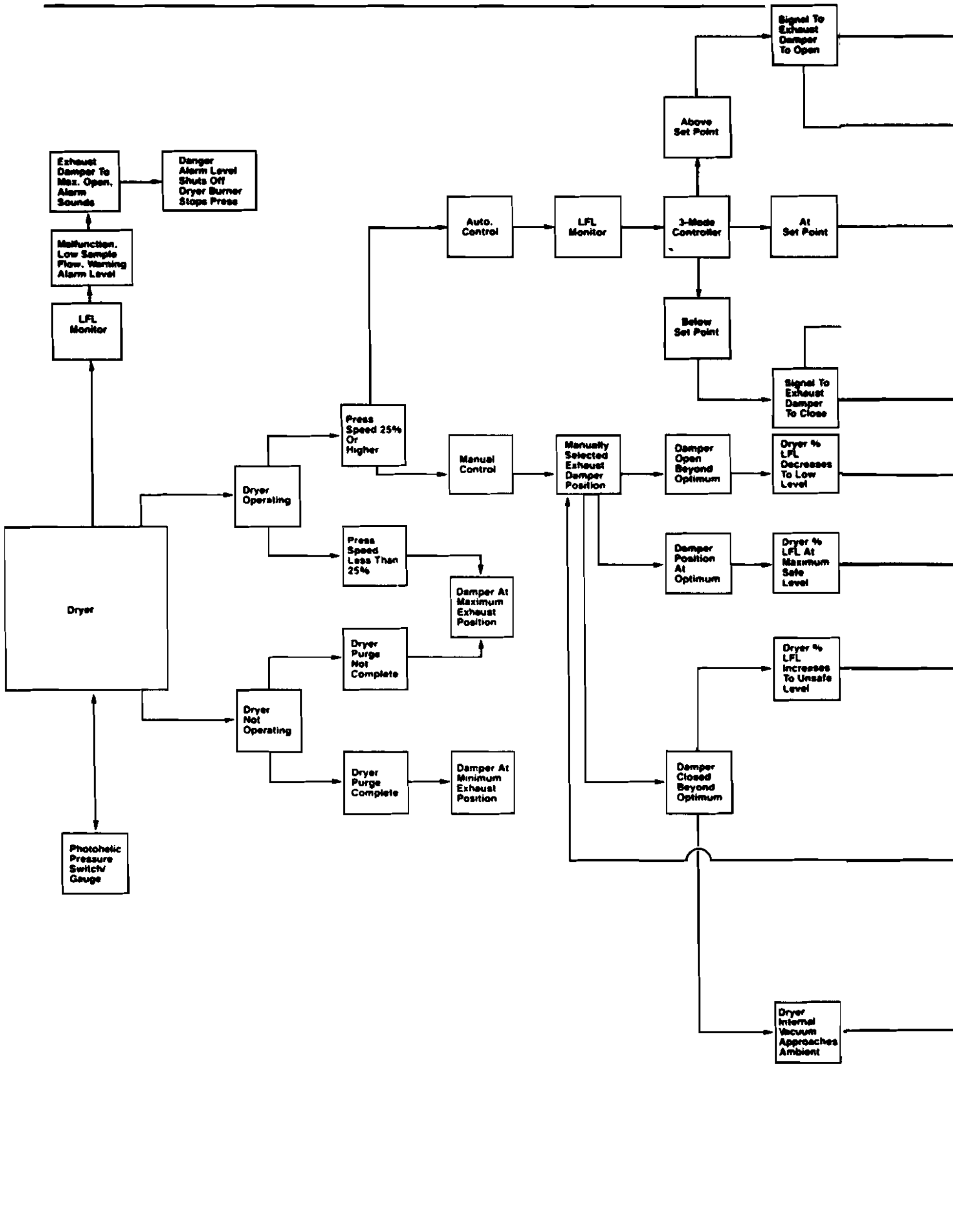
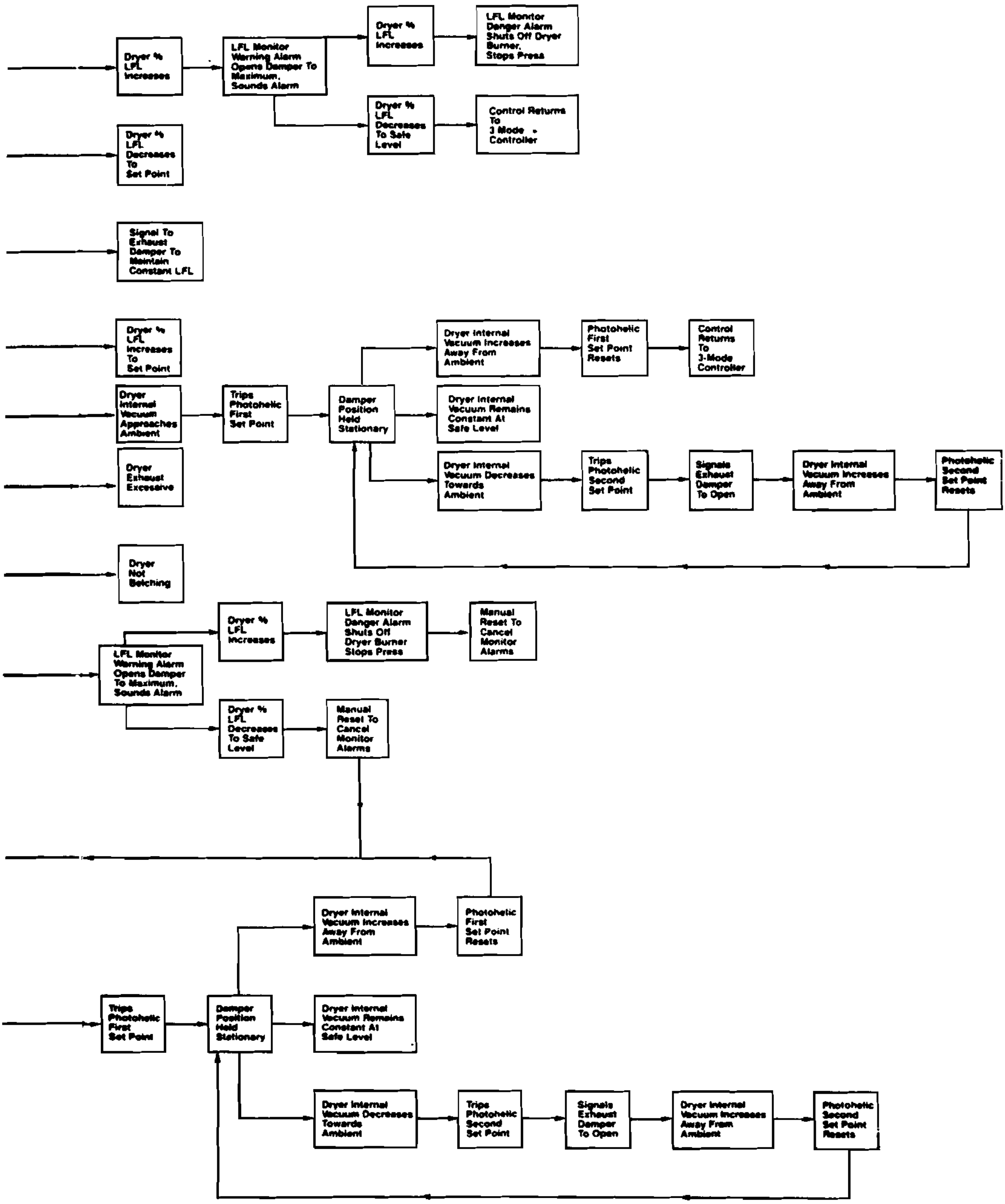



Figure 4. Control System Sequence


Dryer % LFL Increases
LFL Monitor Warning Alarm Opens Damper To Maximum, Sounds Alarm
Dryer % LFL Increases
LFL Monitor Danger Alarm Shuts Off Dryer Burner, Stops Press
Dryer % LFL Decreases To Safe Level
Control Returns To 3 Mode Controller
Dryer % LFL Decreases To Set Point
Signal To Exhaust Damper To Maintain Constant LFL
Dryer % LFL Increases To Set Point
Dryer Internal Vacuum Approaches Ambient
Trips Photohelic First Set Point
Damper Position Held Stationary
Dryer Internal Vacuum Increases Away From Ambient
Photohelic First Set Point Resets
Control Returns To 3-Mode Controller
Dryer Internal Vacuum Remains Constant At Safe Level
Dryer Internal Vacuum Decreases Towards Ambient
Trips Photohelic Second Set Point
Signals Exhaust Damper To Open
Dryer Internal Vacuum Increases Away From Ambient
Photohelic Second Set Point Resets
Dryer Exhaust Excessive
Dryer Not Belching
LFL Monitor Warning Alarm Opens Damper To Maximum, Sounds Alarm
Dryer % LFL Increases
LFL Monitor Danger Alarm Shuts Off Dryer Burner Stops Press
Manual Reset To Cancel Monitor Alarms
Dryer % LFL Decreases To Safe Level
Manual Reset To Cancel Monitor Alarms
Dryer Internal Vacuum Increases Away From Ambient
Photohelic First Set Point Resets
Trips Photohelic First Set Point
Damper Position Held Stationary
Dryer Internal Vacuum Remains Constant At Safe Level
Dryer Internal Vacuum Decreases Towards Ambient
Trips Photohelic Second Set Point
Signals Exhaust Damper To Open
Dryer Internal Vacuum Increases Away From Ambient
Photohelic Second Set Point Resets

## LFL Control Test Results

Figure 5 is gas consumption data gathered on the same day with the press line printing the same form. This particular form had very light coverage (as shown by the dryer percent LFL), and consequently the minimum exhaust rate was determined by the dryers internal vacuum.

Press - Harris M-1000A  Dryer - TEC C-1500

| Test I | Exhaust Rates SCFM | Gas Consumption | Dryer Percent LFL | Press Speed |
|---|---|---|---|---|
| LFL Control Off | 1953 | 826 CFH | 6 | 803 FPM |
| LFL Control On | 733 | 526 CFH | 12 | 803 FPM |

This represents a 62.5% reduction in exhaust rate, and a 36.3% reduction in gas consumption.

| Test II | Exhaust Rates SCFM | Gas Consumption | Dryer Percent LFL | Press Speed |
|---|---|---|---|---|
| LFL Control Off | 1950 | 823 CFH | 6 | 800 FPM |
| LFL Control On | 729 | 523 CFH | 13 | 800 FPM |

This represents a 62.6% reduction in exhaust rate, and a 36.5% reduction in gas consumption.

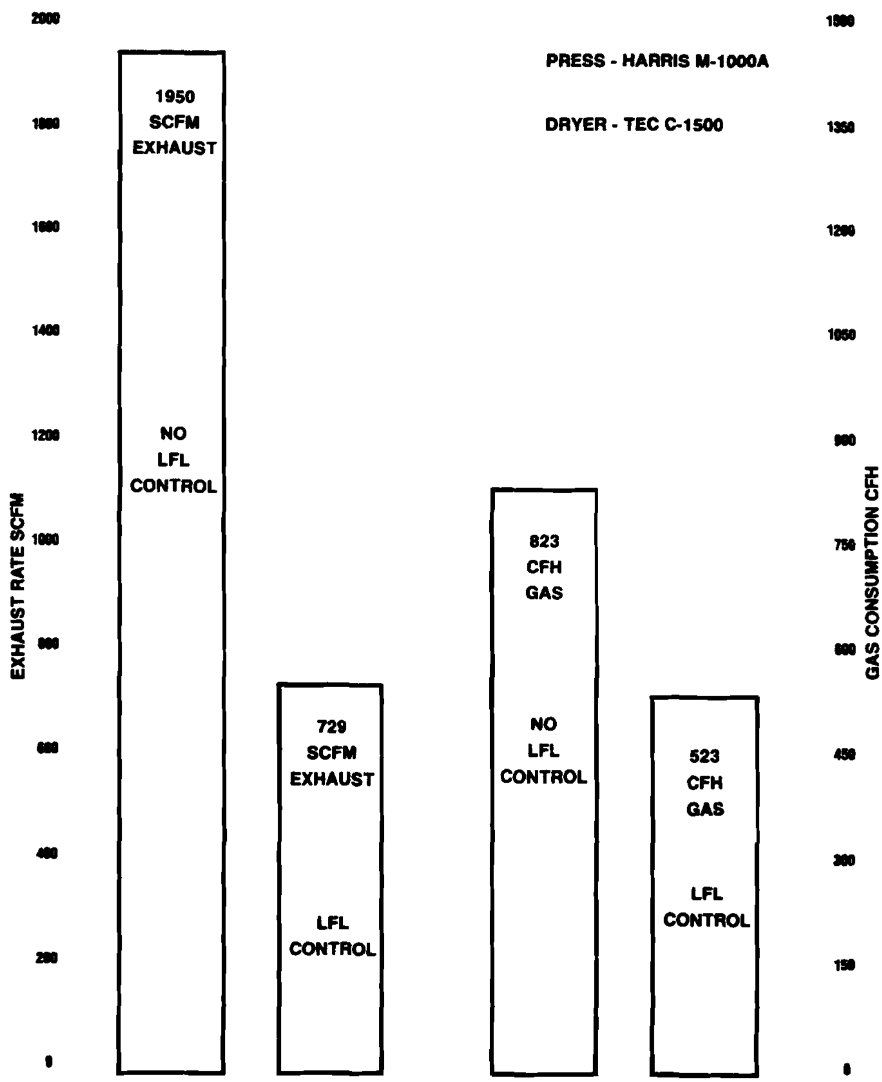



Figure 5. Comparison of Exhaust Rates and Fuel Consumption.

This second example (Figure 6) is of longer term averages of savings rather than specific test points. Whereas the first example represented single job comparisons between LFL control not operating and operating, this example shows average fuel consumption per production hour before and after installation of the LFL Control System. The averages calculated after LFL Control installation do not take into account whether or not the LFL control system was being utilized. These figures assume the LFL Control was utilized 100 percent of the production hours after installation, when in fact it was not. Had it been utilized 100 percent these percent savings would be higher. This printing line generally prints heavy ink coverage. Dryer percent LFL generally determined the exhaust damper position with the automatic control setpoint at 25 percent LFL. This particular line operated with the automatic setpoint at 30 percent LFL for part of the period monitored.

Press - Harris M-850    Dryer - TEC MC-2400

| | Average Fuel Consumption | Basis |
|---|---|---|
| 1982 | 1082 cubic feet/ production hour | |
| 1982 pre-LFL | 1180 cubic feet/ production hour | [Based on 4 months prior to LFL installation] |
| 1983 post-LFL | 778 cubic feet/ production hour | [Based on first 4 months after LFL installation] |

This represents a 28 percent reduction in gas consumption in 1983 post-LFL as compared to 1982 consumption, and a 34 percent reduction in gas consumption as compared to 1983 pre-LFL consumption.

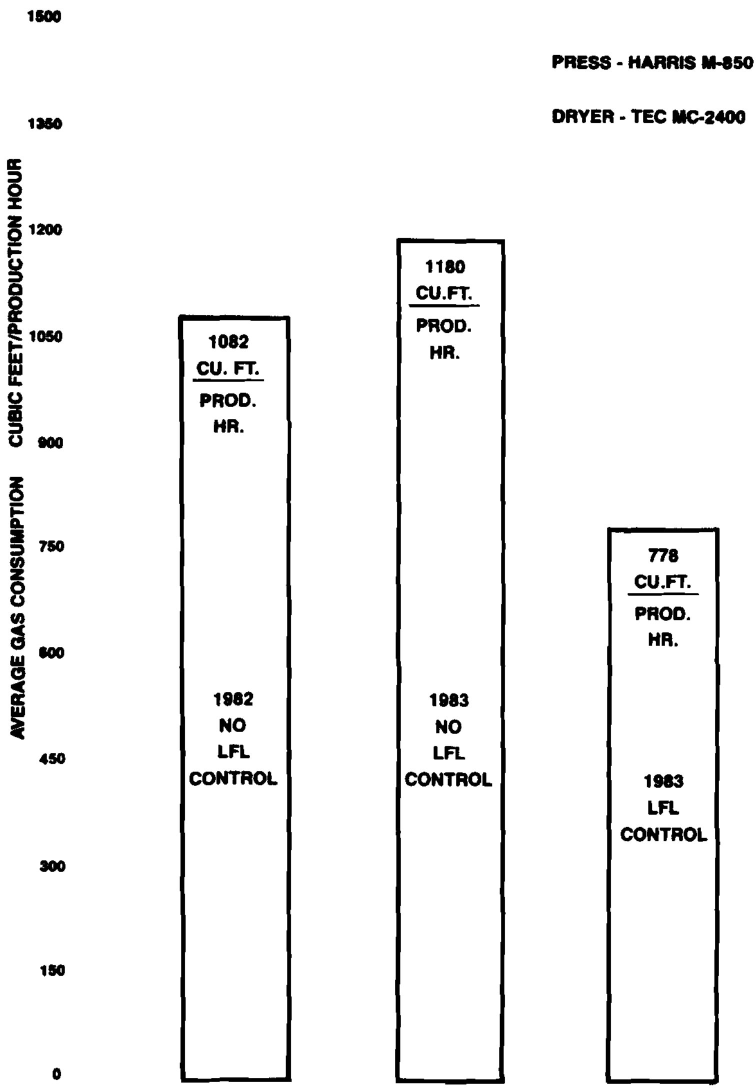



Figure 6. Comparison of Fuel Consumptions.

## Conclusions

The LFL Control System, as described, is capable of being successfully applied to nearly all Heatset Web Offset dryers, regardless of ink coverage levels and printing press speeds. The automatic systems are capable of operating in the automatic mode full-time, whether the press line is operating or not, with the absolute minimum of operator attention, which consists of periodic calibration checks. These automatic systems ensure maximum fuel efficiency and safety for each dryer, and as proven by units currently operating, these fuel savings can be significant.

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