

SOLVENT RECOVERY IN A MODERN
ROTOGRAVURE PRINTING PLANT

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Abstract

Toluol, the principal solvent in rotogravure inks, is the common name for the aromatic hydrocarbon methylbenzene (C₆H₅CH₃). Toluol is a photochemically reactive organic compound which reacts with oxidizing chemicals in the atmosphere under the influence of sunlight to form what is commonly called "smog." Progressive management stipulated that the new Meredith/Burda rotogravure printing plant to be built in Lynchburg, Virginia, should be as pollution-free as modern technology could provide. A fully automatic solvent recovery system captures toluol vapors at their sources on the printing presses and recovers liquid toluol, which is reused in making gravure ink at the nearby ink plant. This paper illustrates the basic components of the solvent recovery system and describes their operation. Design objectives and operating performance of the system are presented.

In late 1969, Meredith Corporation of Des Moines, Iowa, joined forces with Burda Druck GmbH, headquartered in Offenburg, West Germany, to form Meredith/Burda, Inc. The goal of this venture was the construction and operation of a modern and highly efficient rotogravure printing plant, which would utilize the best technology of both parent companies. A site was selected in Lynchburg, Virginia, and construction of the 120,000-square-foot first stage of the plant began in 1970. An additional 115,000 square feet were placed in operation in mid-1974.

Progressive management dictated that the new plant would not only produce the highest quality product, but would be as pollution free as could be designed. It was imperative that Meredith/Burda be a good neighbor in its beautiful setting on a hill in suburban Lynchburg. This policy meant in practical terms designing a plant with extremely low levels of air and water pollution and odor emission. This paper presents the system used to control the emissions of the vapor of the principal solvent in rotogravure ink, toluol.

Toluol is the common name for the aromatic hydrocarbon methylbenzene (C₆H₅CH₃). It is a highly flammable, moderately volatile, moderately toxic

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liquid. In vapor form toluol is considered an air pollutant. As a photochemically reactive organic compound, it reacts with oxidizing chemicals in the atmosphere under the influence of sunlight to produce what is commonly known as "smog."

The Regulations for the Control and Abatement of Air Pollution of the Commonwealth of Virginia (ref. 1) provide specific limitations on the amount of organic solvents that may be lawfully emitted to the atmosphere. Paragraph 4.05.03 (g) of these regulations, entitled "Organic Solvents," states: "A person shall not discharge more than 40 pounds of organic material into the atmosphere in any one day from any article, machine, equipment, or other contrivance used . . . for employing, applying, evaporating, or drying any photochemically reactive organic compound or material containing such solvent unless all organic materials discharged from such article, machine, equipment or other contrivance have been reduced by at least 85% overall Emissions of organic materials into the atmosphere . . . shall be reduced by:

(a) Incineration

(b) Adsorption, or

(c) Processing in a manner determined by the Board to be not less effective than (a) or (b) above The word person shall be synonymous with and have the same meaning as the word owner"

In order to comply with these regulations as a minimum requirement, a solvent recovery system having two basic objectives was designed for the plant:

1. Solvent removal from the exhaust-air from the printing press dryers, which would meet and exceed any existing air pollution, health, or safety ordinances regulating emissions of toluol vapor into the atmosphere;
2. Recovery of liquid toluol of sufficient quality and in sufficient quantity to be economically worthwhile to use in the manufacture of gravure inks in the nearby ink plant.

The solvent recovery system selected for use at the Meredith/Burda plant in Lynchburg was designed by Lurgi GmbH of Frankfurt, West Germany, and installed under the direction of American Lurgi, Inc. Installation was designed by the firm of Wiley & Wilson, Inc., Engineers-Architects-Planners, headquartered in Lynchburg, Virginia. This presentation will describe the specific Lurgi system installed in the Meredith/Burda plant, although certain principles are common to other solvent recovery systems.

The basic system consists of four principal elements: collection of vapors, transporting vapors to the solvent recovery plant, adsorbing the vapors, and finally condensing and separating the liquid toluol. Although oversimplified, figure 1 illustrates the concept of the complete system.

Toluol begins to evaporate from the web immediately after being in contact with the impression cylinder. Most of the vapor is captured and drawn into the dryer at point ① (figure 1). Other escaping toluol vapors from the web and ink fountain settle to the floor, since toluol has a vapor density relative to air of 3.1, and are collected by the floor sweep (point ②).

The presses installed at Meredith/Burda utilize a steam-heated, recirculating forced air dryer on each unit to vaporize the solvent from the web. A portion of the recirculated air, approximately 2,000 cubic feet of air per minute per unit, is continuously drawn off for transport to the solvent recovery plant (point ③, figure 1).

The uptake duct from the dryer on each unit of the press (figure 2) includes a paper filter, motor-operated shutoff valve, which is connected to the dryer blower motor, and a flow indicator with an alarm.

A uniform flow of air and vapor from each press to the solvent recovery plant is kept uniform by a motor-operated valve, which maintains a constant 150 mm H₂O negative pressure in the press header duct (item ④, figure 1).

The solvent recovery plant serves four 10-unit rotogravure presses and one four-unit proof press. The common transport duct is run above the roof (item ⑤, figure 1). It is protected from fire internally by an automatic carbon dioxide deluge-type system. The duct is equipped with lightning rods to reduce the chance of damage from this source. The duct contains a solvent concentration meter, which will sound an alarm in the pressrooms if the toluol vapor in the duct reaches 25 percent of the lower explosion limit and will shut down the presses automatically if the concentration should reach 40 percent of the lower explosion limit.

The recovery plant itself consists of filter house, blowers, adsorbers, condenser-aftercooler, and separator.

The filter house (item ⑥, figure 1) contains a traveling curtain, self-cleaning air filter. Five direct-drive high pressure blowers (item ⑦) operating in parallel provide the total motive force to move the air-vapor mixture from printing-press dryer systems to the discharge side of the adsorbers. Six identical adsorber tanks (item ⑧) cleanse the air stream of solvents. The

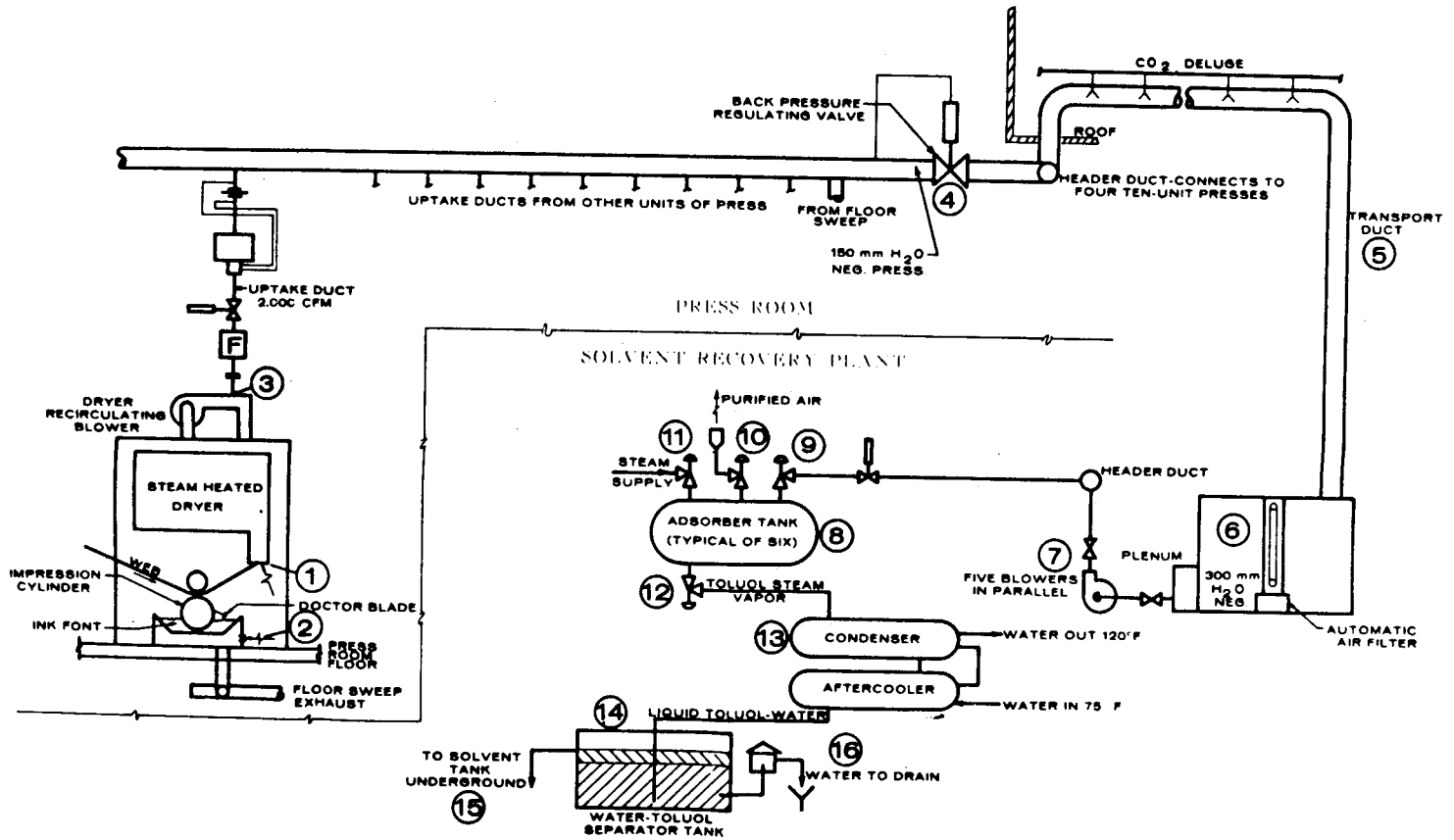


Figure 1. Schematic of the solvent recovery system.

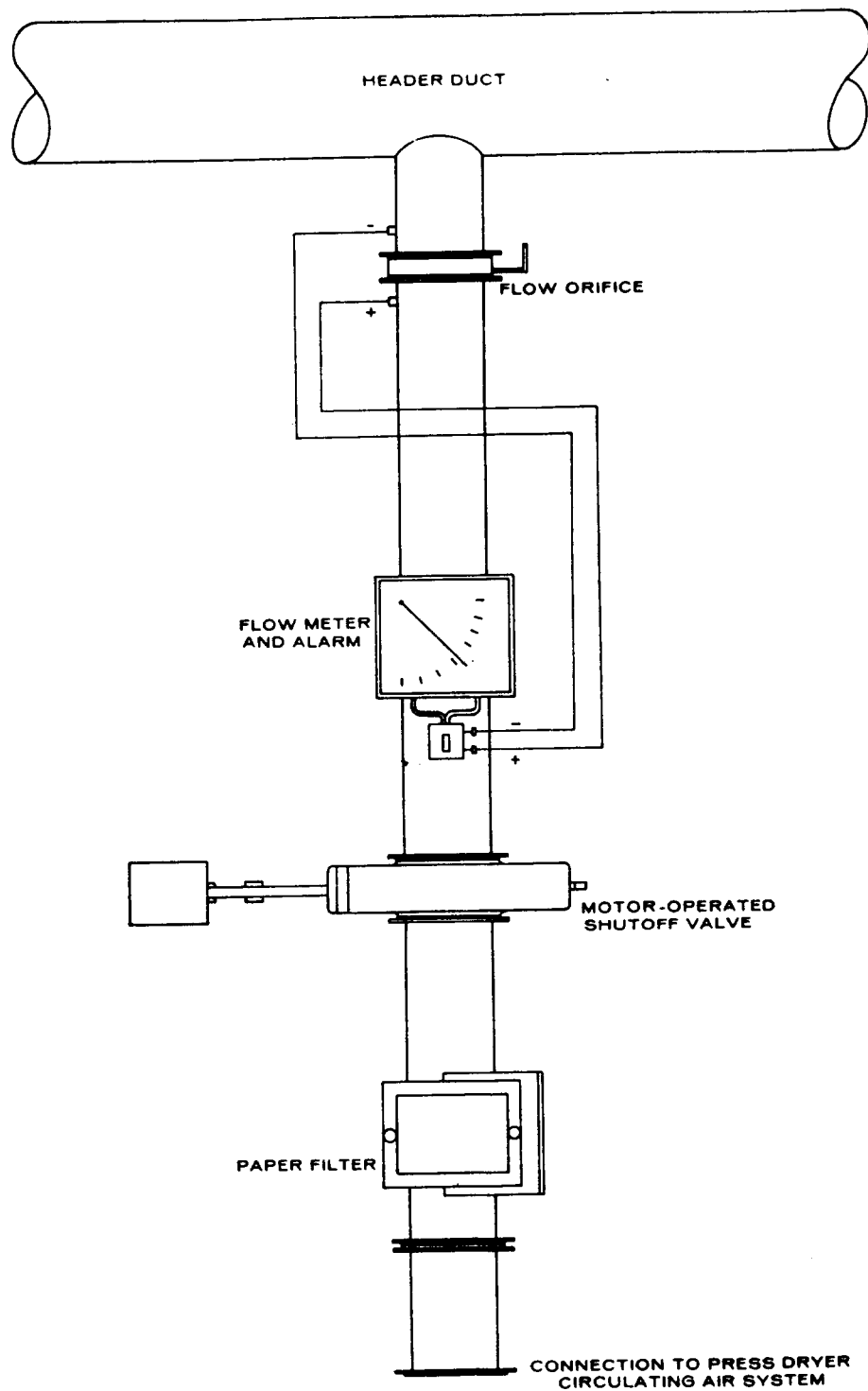


Figure 2. Solvent recovery uptake duct for each press unit dryer.

fully automatic control system maintains five adsorbers on the line at any one time with the sixth unit being regenerated. Each adsorber tank contains a bed of activated carbon held in place by ceramic grilles.

During normal operation of the adsorber tank, inlet valve ⑨ (figure 1) is open and the air-vapor mixture is circulated through carbon beds. Cleansed air is discharged to the atmosphere through valve ⑩. During regeneration, valves ⑨ and ⑩ close, and steam is admitted through valve ⑪, steaming the adsorbed vapor from the carbon. The toluol-steam mixture passes through valve ⑫ and is condensed and cooled in the condenser-aftercooler ⑬. Finally the water and solvent are separated by specific gravity in tank ⑭. The liquid toluol is piped to an underground storage tank ⑮ and water is discharged to drain ⑯.

The method utilized to provide cooling water for the condenser-aftercooler is worthy of special mention. The criteria for cooling water dictated by design of the condenser-aftercooler required that the water entering the aftercooler be a constant 75° F all year. A normal full-load water temperature leaving the aftercooler would be 120° F. The required entering water temperature was too low to utilize a cooling tower in summer, and city water would be expensive. To cool the water entirely by mechanical refrigeration would also be expensive. A further consideration was the desire of the engineers to use a closed-circuit water loop for the condenser-aftercooler to eliminate regular shutdowns for cleaning the tubes of these heat exchangers.

The equipment and piping system selected by the engineers to provide the cooling water is illustrated graphically in figure 3.

Primary and secondary pumping circuits are utilized, with most cooling of the water being done by a Fluid Cooler (item ①, figure 3). Water leaves the condenser-aftercooler (item ②) at 120° F and enters the coils of the fluid cooler. A fluid cooler is similar to a cooling tower except that the water to be cooled flows through closed coils while recirculated water is sprayed over the coils, cooling the water in the coils by evaporation.

At normal maximum summer-design conditions water will be cooled by the fluid cooler from 120° F to 85° F. A portion of this 85° F water is returned to the plant chilled-water-system return main (point ③, figure 3). The plant chilled-water supply ⑤, which is 42° F, is blended with the 85° F return water to produce 75° F water to the condenser-aftercooler unit (point ⑥). As outdoor temperature and humidity drop, the temperature of water leaving the fluid cooler drops. When the temperature drops to 75° F, no plant chilled water is required, and the water is cooled exclusively by the fluid cooler. Water temperature in

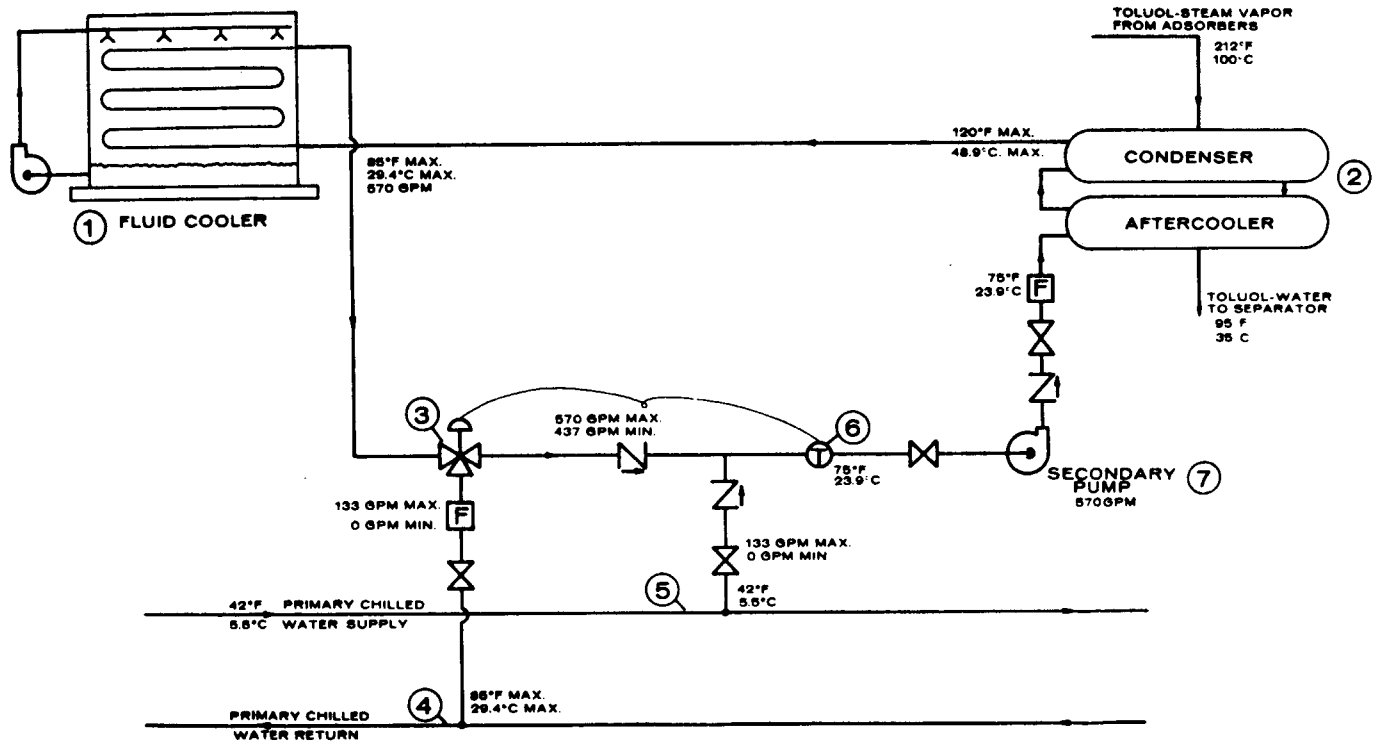


Figure 3. Schematic of pipe solvent condensing.

cold weather is maintained at 75° F by sequential control of fans and damper control on the fluid cooler. This system has demonstrated a significant saving in energy while maintaining the reliability of the system.

The process aspects and the economics of the solvent recovery plant are presented in the following paragraphs.

The Lurgi Supersorbon* process is employed universally for the recovery of various organic solvent vapors and contributes, therefore, to increasing the profitability of many industrial operations. At the same time, it prevents the discharge of noxious vapors into the environment, and its use brings about compliance with the air pollution acts brought into force in recent years. At present, there are over 3,000 Lurgi Supersorbon plants in operation worldwide.

The Supersorbon process, which is based on the affinity of certain activated carbons for organic vapors, can be applied in most industries employing solvent, e.g., surface coating, impregnating, extracting, rotogravure, viscose fibres, acetate silk, films, rubber goods, imitation leather, etc. In this paper, we describe its utilization in a modern rotogravure plant. However, the principles are quite general and are employed in most applications of the process.

The Supersorbon process comprises two key steps:

1. The purification of the solvent-laden exhaust-air (SLA) by exposure to Supersorbon activated carbon, which results in a selective and highly efficient adsorption of organic vapours, even at low concentrations. The removal efficiency generally exceeds 99 percent.
2. The regeneration of the carbon, with steam permitting the recovery of the adsorbed solvents and the further solvent recovery by the carbon.

Properties of the Adsorbent

Before describing the sequence of process steps, it is worth while to mention the characteristics of the activated carbon used to remove, by adsorption†, the printing ink solvents from the SLA (solvent-laden exhaust air).

Activated carbon is a product of organic matter (e.g., peat, wood, brown

*Supersorbon is a registered trademark of Lurgi.

†Consult any standard physical chemistry text for a discussion of the adsorption mechanism. For our purposes here, we may describe it as a purely physical process whereby the surface forces of the carbon are such that the solvent vapor molecules are bound to the carbon surface. As the temperature is increased, the bound vapor molecules are further energized and can overcome the binding forces and thereby escape (desorb).

coal, coconut shells), which is produced in numerous special grades. For exhaust air purification and solvent recovery, cylindrical shapes with a grain size of 3 to 4 mm and a bulk weight of approximately 380 kg/m^3 are used. Depending on the application, a grade is selected having suitable capillary structure, surface area, adsorptive capacity, and mechanical strength. The inner surface area of the various grades is in the range of 1,000 to 1,500 m^2/g of activated carbon.

The key point is that the carbon used should be tailored to the application. This will insure maximum recovery at a minimum cost.

We will now describe the two key process steps, i.e., adsorption and desorption (regeneration).

Adsorption (Charging Cycle)

The solvent-laden air (SLA) produced at the rotogravure machines is drawn off by means of the blowers and, after dust removal, flows upward through a portion of the adsorbers. The other adsorbers are simultaneously being regenerated, i.e., the solvent is being removed for them. The adsorbers are filled with the highly activated Supersorbon carbon, which is supported on perforated ceramic trays, which in turn are supported on grates. The activated carbon adsorbs the solvent, and the solvent-free air leaves through the top of the adsorbers to the atmosphere.

The adsorber-charging step is continued until the solvent is no longer completely adsorbed in the uppermost activated carbon layers. This so-called "breakthrough" (end of charging cycle) is monitored by a concentration-measuring instrument called a Solvomat* installed in the switch panel, which serves to initiate automatic control of the Supersorbon plant.

Desorption (Regeneration)

When breakthrough occurs, the gas inlet and outlet valves ⑨ and ⑩ (figure 1) to the adsorbers are automatically (by means of the Solvomat signal) closed and the steam inlet and distillate valves ⑪ and ⑫ are opened. The object of the steaming process is to raise the temperature of the carbon bed in order to free the bound solvent molecules from the surface of the Supersorbon activated carbon. The slightly superheated steam passes down through the bed,

*Solvomat is a registered trademark of Lurgi.

and the resulting steam-vapor mixture leaves the bottom of the adsorber and is condensed in a condenser-aftercooler unit (13).

Since toluene and water are immiscible, the toluene is easily recovered in the separator and then sent to tank storage.

After desorption, the hot and moist Supersorbon carbon in the adsorber is dried and cooled down to normal charging temperature as quickly as possible. This drying and cooling of the activated carbon is achieved by recharging with SLA. For this mode of operation, it is essential that the activated Supersorbon carbon has a sufficiently high adsorptive capacity even at elevated temperatures.

The Meredith/Burda plant is fully automatic, so that the timed sequencing of the charging and regeneration of each adsorber is controlled by instrumentation. The Solvomat concentration analyzer developed by Lurgi monitors the exhaust vapor solvent concentration. When the concentration rises, the Solvomat transmits a control signal whereby the inlet and outlet air valves (9) and (10) are closed, and immediately thereafter (2 to 3 seconds) the steam and distillate valves (11) and (12) open to initiate the regeneration step. In general, an adequate number of adsorbers must be available to handle the solvent removal while the other adsorbers are regenerated. At Meredith/Burda, five adsorbers are in various stages of charging while one adsorber is discharging (being regenerated).

Maintenance of the Supersorbon plant is routine and is carried out during the period set aside for press maintenance. Hence, the Supersorbon solvent recovery plant does not reduce or curtail production time in any way.

The original carbon charged in 1971 is still performing satisfactorily with no apparent need for recharging imminent.

The general economic operating parameters of a Supersorbon plant are stated below:

Operators per Shift	1
Utilities	
Steam (25 50 psi), lb steam/lb recovered solvent	2-3.5
Electricity, kWh/lb recovered solvent	0.1
Cooling Water, gal/lb recovered solvent	4 6
Carbon Loss, lb carbon/lb recovered solvent	0.0005 0.001

The basic operating data for the Lurgi Supersorbon facility at Meredith/Burda are as follows:

OPERATING DATA

Operating days per year	250
Shifts per day	3

Throughput of solvent-laden air	88,000 cfm
Toluol recovery per 24-hour day	6,720 gal
Electricity	13,000 kWh/day
Water (closed system cooling)	20,000 gal/day
Steam (60 psig)	168,000 lb/day
Labor, man/shift	0.2 man/shift

The annual operating costs for the plant are:

ANNUAL OPERATING COSTS

Labor (@ \$10/hr total)		\$ 12,000
Utilities		
Electricity (@ 2.2 cents/kWh)		\$ 71,500
Steam		
Gas Fuel, 80%	\$ 16,400	
Oil Fuel, 20%	\$ 12,200	
		\$ 28,600
Refrigeration of condenser water		\$ 2,000
Water		
Fluid cooler makeup	\$ 1,360	
Steam makeup	\$ 2,090	
		\$ 3,450
Taxes and insurance (@ 3% of capital investment)		\$ 36,000
Maintenance (@ 1% of capital investment)		\$ 12,000
Total annual operating costs		\$165,660

The capital investment costs for the plant are:

CAPITAL INVESTMENT COSTS

Solvent recovery equipment (including instruments and Lurgi engineering)	\$800,000
Erection of solvent recovery equipment	\$ 40,000
Water system piping (installed)	\$ 71,000
Steam piping (installed)	\$ 8,000
Process building	\$174,000
Foundations and pipe supports	\$ 12,000
Chilled water system (incremental cost charged to solvent recovery plant)	\$ 72,000
Nonprocess engineering fee	\$ 17,000
	\$ 1,194,000

The annual recovery of purchased toluol is 97,200 gallons per month x 12 months = 1,166,400 gallons. At a current price of \$0.59 per gallon, this represents a saving of \$688,176. In addition, there is a recovery of the toluol in the purchased printing ink. This toluol is sold to the ink manufacturer. The credit is 42,800 gallons per month x 12 months x \$0.20 = \$102,720. (Note that the total monthly recovery rate of toluol is 97,200 + 42,800 = 140,000 gallons.) The total annual credit for recovered toluol is \$790,896.

The overall plant economics can now be summarized as follows:

Capital Investment	\$ 1,194,000
Annual Toluol Credit	790,896
Annual Operating Costs	- 165,550
Annual Profit	\$ 625,346

Hence, the payout period (neglecting interest) is

$$\frac{\$1,194,000}{\$625,346/\text{Year}} = 1.91 \text{ Years}$$

In summary, the solvent collection and recovery system serves the important functions of safely removing solvent vapors from the printing presses and transporting them to a plant which through adsorption cleanses the solvent from the air stream. It recovers liquid toluol in sufficient quantity and purity to make the system an attractive investment for the modern rotogravure printing plant.

REFERENCE

1. "Regulations for the Control and Abatement of Air Pollution," State Air Pollution Control Board, Commonwealth of Virginia, February 3, 1974.

DISCUSSION

MR. W. N. FINGLAND (International Paper Company, Clinton, Iowa): I have some questions. In recovering toluene by adsorption, are you not also picking up other solvents? And then subsequently, how do you separate them? Finally, do you have a constant mixture of toluene that you are using?

DR. MARNELL: To answer the latter, we do have a constant mixture of toluene.

In the first instance, again, this particular plant was a simple plant in that it had a constant mixture. Toluene was the basic component. And most important, the toluene was immiscible with the water.

In the more general cases that we have handled, you have a mixture

of hydrocarbons and then you have added distillation steps. So you have a little more in the way of capital equipment. But there is no problem as far as effecting the separation.

MR. FINGLAND: In the event you have a mixture, then you can distill out?

DR. MARNELL: Yes, absolutely. We have done this also.

MR. FINGLAND: Thank you.

MR. WILLIAM S. BEGGS (New Jersey Department of Environmental Protection, Trenton, New Jersey): You say that toluene is insoluble, and yet it is soluble to a certain extent. What is the concentration of toluene in the effluent?

DR. MARNELL: As it stands now, I do not know what the concentration was. I know it has not been a problem in the State of Virginia. If it did become a problem, then we would introduce either a distillation step or steaming out step to take care of any residual.

You are absolutely correct; it is not 100% insoluble. If there were trace amounts that could become objectionable, we could handle it with a simple steaming process. I do not have the exact figure.

MR. BEGGS: Thank you.

MS. EMILY A WEBBER (Oxy-Catalyst, West Chester, Pennsylvania): Are those capital costs in 1970 dollars?

DR. MARNELL: No, 1975.

MS. JACQUELINE M. FETSKO: I think you ought to mention that your border plant in Germany for many years ran medical examinations on the staff and workers that were exposed to toluene. And they found no cumulative effects after 20 years.

DR. MARNELL: Thank you for mentioning it.

MR. WATKINS: Let me make one additional comment at this point. The design requirements on this plant were that at no time during normal operations could the toluol level in the pressroom exceed 200 ppm. It is checked regularly and is operating under 100 ppm.