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# Environmental Aspects of Chemical Use in Printing Operations

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Environmental Protection Agency

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## RECOVERY AND REUSE OF ORGANIC INK SOLVENTS

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### Abstract

*Environmental and OSHA requirements are coupled with solvent supply and economic factors to make examination of solvent recovery and reuse important for the solvent-using industries. Solvent recovery process choices are discussed. For most solvent drying applications, with relatively low concentrations in the solvent-laden air, activated carbon adsorption is shown to be most suitable. Some theory and details of the adsorption process are presented. Applications of the carbon adsorption and solvent separation processes are discussed for several cases involving either single solvents or mixtures of solvents. A case history is presented of a gravure plant solvent recovery system that has been in operation since 1971. The recovery system treats all the plant exhaust and recovers 38,500 gal/wk, of which 12,900 gal/wk are exported for reuse in ink manufacture and the balance is reused for ink dilution. The overall efficiency of the solvent recovery and recycle system is about 90 percent. The consumption of solvent has been reduced from 2,215,000 gal/yr to about 215,000 gal/yr. The solvent cost savings and the independence from solvent supply problems are cited as valuable justifications for this system.*

### INTRODUCTION

This paper was prepared for a conference focusing on the environmental aspects of chemical use in printing operations. Thus, in the context of this conference, solvents are those used in inks as a medium to carry pigment to the surface of a web. However, in the broader sense, we are discussing any process wherein organic solvents are used in the application of a dissolved material to a moving web or film. The major

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examples of such processes and the ones to be referred to in this paper are: (a) gravure or similar printing, and (b) continuous coating on paper, metal, or plastic films. In addition, many other processes could be mentioned, all of which have the same essential elements: namely, a) application of a high-solvent-content material to the surface of a moving web or film; b) rapid evaporation of solvent to enable further processing or handling; c) evaporation accomplished by movement of heated air across wet surface; and d) solvent-laden air exhausted from system.

On examination of modern industry, one finds the concept of recovery and reuse of chemicals and solvents is not a uniformly accepted practice. Certain highly sophisticated industries have always recovered every BTU or pound of material and have indeed gained an edge in the competitive race by a fractional improvement in such schemes. Other industries have been quite content to use materials on a once-through basis and have concentrated their competitive efforts in other areas. The uniformity that is found is that, within a particular industry, all members treat the concept similarly. One must conclude that through experience and with mutual assurance, each industry has moved in the direction of maximum profits. In a perfectly free society, abundant in raw materials and energy, this is the conclusion that economic theoreticians would predict. However, we are no longer in a free society, abundant in raw materials and energy. Out of necessity, we are giving up the free society in favor of limitations that are intended to preserve our resources, restore the environment, and improve the quality of life. Industry now has the problem of reexamining its previous conclusions in light of these new restraints.

#### Emission Restraints

The most compelling of the new factors influencing consideration of solvent recovery are the emission control regulations that are now in effect in most States. Although there are differences in these regulations, it is safe to predict that the ultimate effect will be that users of solvents will gradually reduce emissions to the environment from 100 percent of the solvents used in their processes to the 2- to 10-percent range.

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### OSHA Restraints

Under the influence of the OSHA health and safety regulations, the management of solvent-using plants will have to give increased attention to lowering the concentration of solvent vapors within their plants. The preferred way is by improved plant design to prevent escape of the solvents from the process equipment. Solvent vapors that cannot be contained must be recaptured by exhausting the solvent-laden air from the area and this adds to the plant emission problem.

### Solvent Supply Restraints

The current shortage of supply of all types of solvents is an accepted fact and the long-term trend is certain to be of increased scarcity. Conditions exist which can cause a tenuous situation to develop into an absolute disappearance from the market of certain raw materials. The quantities of solvents used by many industries are such that it is impractical to inventory more than a few days or weeks supply. For example, it is not uncommon for a gravure printer to consume 20,000 to 40,000 gallons of solvent per week and to depend on deliveries every few days. With application of the solvent recovery and reuse principles available today, it is possible to eliminate such dependence and remove the specter of plant shutdown due to a solvent shortage.

### Economic Restraints

The cost of solvents has increased dramatically and the occurrence of spot shortages can cost additional premiums in order to maintain plant operations. Such economic pressures emphasize the importance of examining solvent recovery and reuse. However, due to the increased cost of facilities and their operation, solvent recovery projects do not always show an attractive return on investment. If it were so, then everyone would probably be doing it--for the reason cited earlier. When considered as a resolution to a problem involving the other factors mentioned above, solvent recovery and reuse may be easily justified.

## PROCESS CHOICES

Industry has available a number of alternate commercial processes for handling solvent emission control and occupational health and safety problems. First, consideration should be given to improvements to the design of the basic equipment for utilizing the solvent efficiently and keeping it physically contained within the system. Then through the use of incineration, adsorption, absorption, or condensation, the emissions to the atmosphere can be controlled. When the objectives also include solvent recovery and reuse, only adsorption with activated carbon has much application. Under certain conditions, condensation and/or absorption could be used in conjunction with one of the other processes to achieve both solvent recovery and the desired degree of emission control.

The outstanding advantage that the activated carbon adsorption process has over other solvent recovery processes is its ability to remove all the organics (solvents) from the air regardless of variations in concentration and humidity conditions. Concentrations of 3,000 ppm and below can be recovered at high efficiency leaving only a few ppm in the effluent airstream. With due allowance for explosive mixtures, concentrations above 3,000 ppm can be handled at even higher efficiency.

The condensation process, by comparison, can recover only those constituents above the saturation concentration at the condensing temperature. Even with refrigeration, condensation as a means to recover most commercial solvents would only be practical at vapor concentrations well above 10,000 to 20,000 ppm. Then after condensing, the residual solvent concentration would be several thousand ppm and probably well above emission requirements. The usual 25- to 50-percent LEL safety requirement for solvent-laden air systems therefore precludes the use of condensation for solvent recovery in the usual printing and coating operations. In the petroleum and petrochemical industries, where condensation has application, the residual gas stream would either be recycled to the process to pick up more solvent or would be treated by another control scheme before release to the atmosphere. Closed-loop systems may be operated safely using an inert carrier gas, such as nitrogen, or using air if the solvent is nonexplosive, such as methylene chloride.

The absorption process depends on a component's solubility in a relatively nonvolatile absorbent liquid. Solubility is directly related to vapor concentration, so absorption at low vapor concentration is highly inefficient. For solvent recovery applications with concentrations in the 0- to 3,000-ppm range, the absorption process requires excessively large equipment. Thus, the process is not suitable for solvent recovery for the printing and coating operations. There are special applications for a direct contact absorber or scrubber on a solvent-laden air stream as a pretreatment before going to another emission control scheme.

### ADSORPTION PROCESS

The adsorption process is dependent on the property of a solid surface to capture and accumulate molecules of a fluid with which it comes in contact. All molecules, whether gas, liquids, or solids, are subject to this phenomenon but the degree to which each material is affected is a characteristic of that material. By this process, constituents of an airstream may be selectively adsorbed or removed by materials known as adsorbents.

The exact mechanism by which adsorption takes place is still uncertain. Most theories attribute the phenomenon to the forces causing cohesion in solids and liquids. These forces can be divided into two groups: intermolecular or van der Waals forces causing physical adsorption, and chemical forces causing chemisorption. In the former, the adsorbed molecules are preserved intact while in the latter the adsorbed molecules break up into atoms or radicals which are bound separately to the surface as in chemical combination. In physical adsorption the surface of the adsorbent may be covered with multiple layers of molecules depending on the intermolecular forces. In chemisorption the mechanism is limited to a monolayer.

Most applications of the adsorption process to recovery of organic vapors involve only the physical adsorption mechanism. The process strongly resembles condensation and is accompanied by the liberation of heat of the same order of magnitude as the heat of liquifaction. The process can be reversed by supplying heat of this magnitude, whereby the adsorbent surface is regenerated.

It is apparent that the effectiveness of a solid to adsorb molecules is strongly related to the amount of interfacial surface. Therefore, to achieve a high degree of adsorption, it is expedient to create the maximum obtainable surface area within the solid phase. Commercial adsorbents, such as activated alumina, silica gel, and activated carbon, contain a large number of micropores having hundreds or thousands of square meters of surface within a gram of solid. Adsorption process equipment is designed to contain a quantity of adsorbent in small pellet or granular form, suitably arranged so that the adsorbate-containing air can flow through the entire quantity. The dimensions of the bed of adsorbent and the flow of air are selected so that adsorption can be substantially complete in the time of contact. After some period of flow, the adsorbent will become saturated with the adsorbate and will cease to function. When this occurs, the adsorbent must be replaced or regenerated.

Vapor phase adsorption is essentially an exothermic gas-solid equilibrium process, and conditions which shift the equilibrium toward saturation usually improve the process. Consequently, adsorption will take place more efficiently near the dew point and it is beneficial to operate at the lowest practical temperature. Regeneration of the adsorbent can be accomplished by raising the temperature of the system and supplying sufficient heat to break the adsorption bonds. However, some molecules are more difficult to remove from the microporic structure than others and tend to remain as a residual or "heel."

If the vapors to be adsorbed consist of several components, the adsorption of the various components will not be uniform. Generally, these components are adsorbed in an approximate inverse relationship to their volatilities. Hence, when air containing a mixture of organic vapors is passed through a bed of adsorbent, the vapors are equally adsorbed at the start; but as the amount of higher boiling constituent retained in the bed increases, the more volatile component reevaporizes and moves on through the bed to a more favorable adsorption site. Eventually some of the more volatile constituent will be forced out completely and can be detected in the effluent. The higher boiling component has thus displaced the lower boiling component, and this mechanism if continued would result in only the highest boiling component being retained on the adsorbent.

## SOLVENT RECOVERY DESIGN

The detailed procedures for the design of activated carbon adsorption processes are well documented in the literature. These lead to the selection of such items as carbon bed dimensions, number of adsorber vessels, cycle timing, regeneration conditions, precooling requirements, and condensing duty. This paper will not consider these design principles but will discuss questions of application to the overall solvent recovery problem.

### Basic Process Flow Diagram

In the typical solvent recovery application, illustrated in figure 1, activated carbon is used as the adsorbent, and multiple vessels (adsorbers) containing the carbon are provided so that one can be off-line for regeneration while the other(s) are actively treating the solvent-laden airstream. Adsorbers may vary considerably in design and in orientation of the carbon bed. However, with the usual design criteria, carbon beds are 16 to 24 inches thick and composed of pelleted or granular material in the 1/16- to 1/4-inch size range. Pretreatment of the solvent-laden airstream frequently consists of dust removal and cooling. For regeneration, steam is used in the reverse direction through the carbon bed to clean the outlet portion most thoroughly. The steam and solvent vapors are condensed and either decanted for reuse or further processed by distillation or other means.

The process, as illustrated, represents a sizeable number of actual installations. The plants are simple, they work well, and the carbon gives years of active service. However, conditions may exist which require special attention.

### Nonregenerable Constituents

Process generated particulates, airborne plant dust, and low-vapor-pressure components from the ink, coating, or web may be present in minute quantities but can accumulate on the carbon bed to substantial amounts after a period of operation, since they are not removed from the carbon during regeneration. Also, certain constituents from the ink or coating

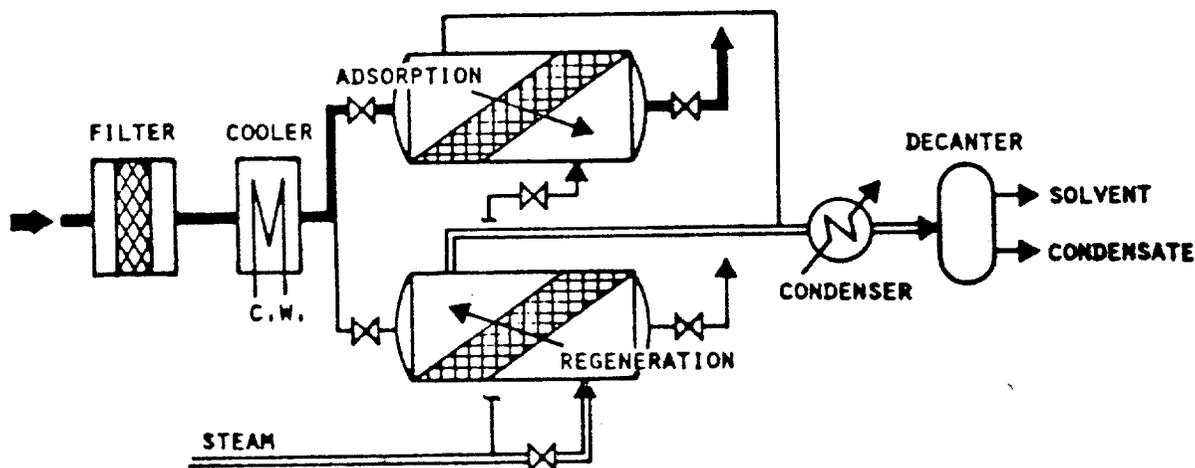


Figure 1. Adsorption process flow diagram.

may have a tendency to polymerize after adsorption or during regeneration under the influence of the heat and possible catalytic effect of the carbon or impurities.

The dependence of the process on available surface and on freedom of molecular movement in the adsorbent pore structure make it evident that any physical blockage will destroy the ability of the adsorbent to perform. High-efficiency particulate filters should be provided unless the cleanliness of the airstream is assured by other means. Nonregenerable vapor components can usually be removed from the airstream by providing a carbon bed filter or sacrificial bed. Initially this bed will adsorb to saturation all components of the vapor. Gradually, the lower boiling material will displace all other components and the sacrificial bed will be replaced. Prevention of polymerization products on the carbon requires a knowledge of the chemistry involved in order to predict how to avoid such damage.

#### Variation of Solvent Composition

Prolonged use of the carbon on solvent-laden air of a particular solvent composition results in the formation of a heel composed of each

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molecular species in "equilibrium" with the vapor composition. If the inlet airstream composition is altered in any way, the carbon will shift toward a new heel composition and the recovered solvent composition will show the effects of this shift until a new heel composition has been established. If air containing a new species of solvent is passed through the adsorber, the new species will compete for adsorption sites with those forming the heel from previous use and the recovered solvent will be contaminated by each species of solvent on the carbon. Such contamination may persist through several cycles.

## SOLVENT REUSE FLOW DIAGRAMS

### Single Solvent

If a single solvent (1 species) is used, its recovery for reuse can be very simple, as illustrated in figure 2. The solvent vapor and regeneration steam will be condensed. If two phases are formed, separation is effected and frequently the solvent can be reused without further treatment. In case of partial or complete solubility in water, distillation may be required to produce a reusable solvent as well as a reusable or disposable condensate. Dehydration schemes for many solvents are described in the literature.

### Mixed Solvent

If a solvent composed of two or more species is used, then the air from the drier will contain a mixture of the solvents and these will be adsorbed and recovered together, as illustrated in figure 3. If, upon condensation, two phases are formed, separation by decantation may produce a mixture suitable for reuse. However, due to variations of volatilities in the drier, variations of recovery efficiency in the adsorption, and variation of solubility in water, the recovered solvent mixture will differ slightly from the original composition. Based on a laboratory analysis, the composition can be restored by "doctoring", using fresh solvents.

If the solvents are partially or completely soluble in water, then the condensed mixture must be distilled to dehydrate. In so doing, the organic material will be separated into several fractions which, upon

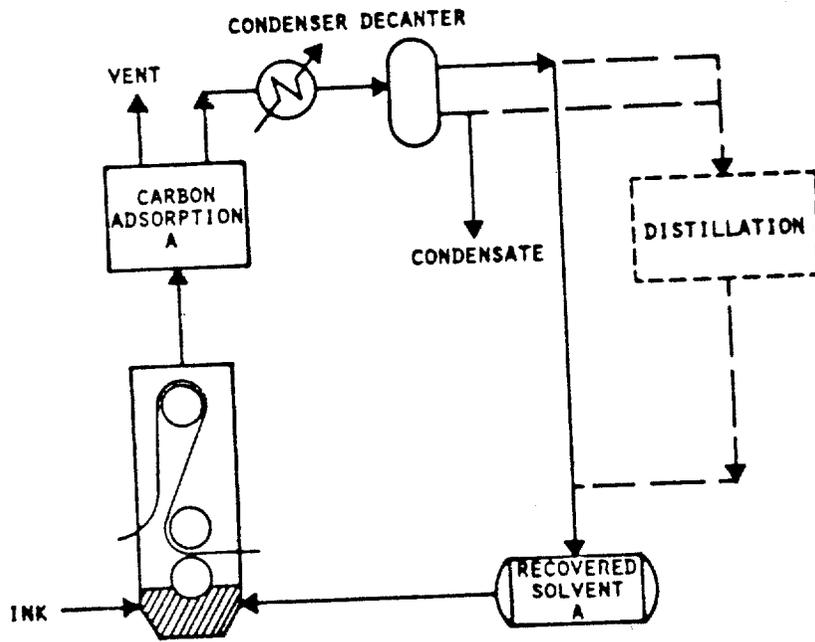


Figure 2. Solvent reuse diagram--single solvent.

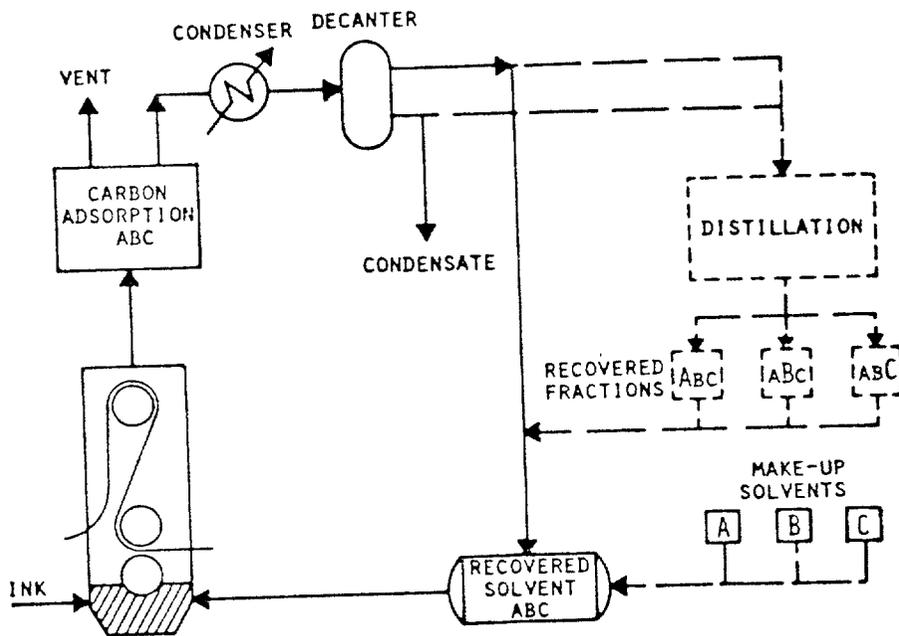


Figure 3. Solvent reuse diagram--mixed solvents.

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analysis, can be recombined to yield the desired solvent formulation.

The distillation need not be designed to produce solvent fractions of the same composition or degree of purity as the commercial solvents used to prepare the original formulation. Solvent mixtures, whose components coexist simply as the result of mixing dissolved pigments, resins, driers, and vehicles to prepare an ink or coating, are unique mixtures and may pose difficult problems of separation. The components are seldom members of a single family or homologous series of solvents and they range over the extremes of polarity. Such systems invariably contain potential constant-boiling mixtures or azeotropes. Liquid-liquid extraction and azeotropic and extractive distillation can be used to circumvent the formation of some constant-boiling mixtures. However, as an alternative to the expense of such a complex separation system, careful consideration should be given to reformulation of the ink or coating to allow the use of solvent fractions only partially separated or of azeotropic composition.

Success or failure of a recovery and reuse effort can hinge on a company's willingness to face this problem. The marketing organization insists that a product of a certain quality and uniformity be produced; the product development group insists that the formulation used in their product development program be adhered to; the production group wants to produce the desired product efficiently; the environmental group interprets the regulations and specifies the ambient and effluent requirements; and the facilities group, which has the responsibility for providing a solvent recovery plant to please everyone, must do so within a budget and schedule.

#### Multistage With Different Solvents

If the solvents used in successive stages of printing or coating differ, either in percentage composition or species, then the air from the driers will contain a blend of all solvents and these will be adsorbed and recovered together, as illustrated in figure 4. The condensed solvent mixture, whether soluble in water or not, will have to be separated into fractions by distillation in order to reuse in the separate stages. If the formulations for the stages differ only in percentage composition, then the components need not be highly segregated in the distilled fractions. On the other hand, if the formulations differ in the components,

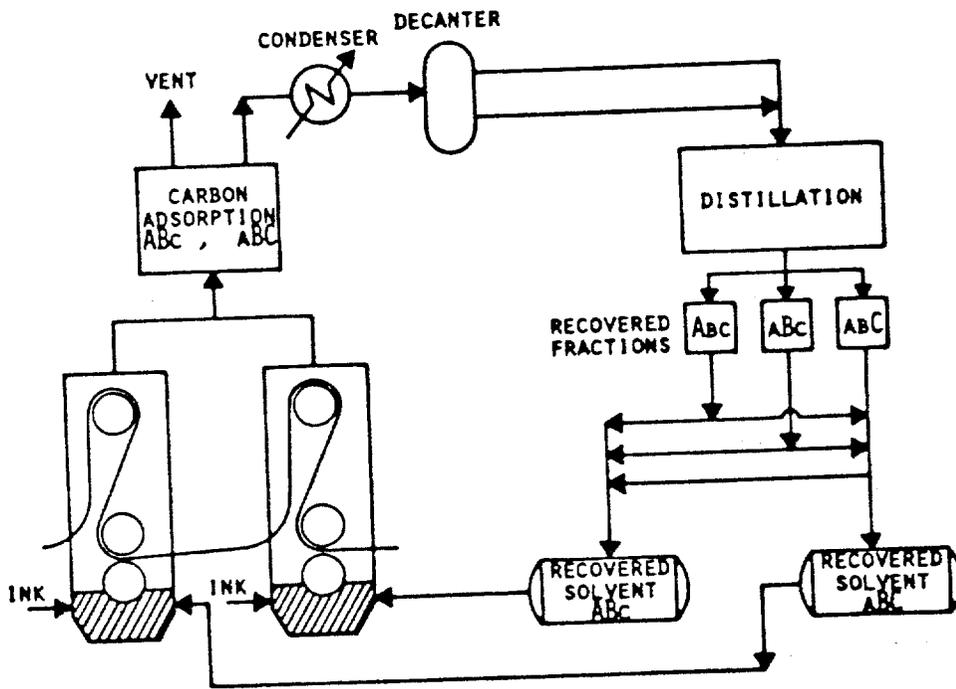


Figure 4. Solvent reuse diagram--multistage with different solvents.

a much higher degree of segregation may be necessary in the distilled fractions. This raises questions of compatibility of the ink or coating with solvents which are normally not used in the formulation. Here again, cooperation of the various interests within a company is needed to establish realistic design requirements.

In the extreme, if complete segregation of the solvents is necessary, it may be preferred to prevent the initial mixing in the drying airstream, by completely evaporating the solvent from one stage before going into the next stage. Separate adsorption and recovery systems would be needed for the different solvent-laden airstreams. This could result in an intermittent-continuous process which is practical in the case of certain processes but highly impractical in a high-speed multipress gravure-type operation.

#### Separate Products with Solvents of Different Percentage Composition

If solvent formulation, differing only in percentage of components, are used in separate products run either simultaneously on parallel

presses or intermittantly on a single press, the air from the driers may be handled by a single adsorption system if distillation is required for separation. This is illustrated in figure 5. In this scheme, the composition being recovered at any time is effected by the heel of solvent from previous operation and thus does not exactly correspond to the composition of solvent being used in the product. Alternately, if the solvents are insoluble in water, separate adsorption systems with decantation for each formulation may be practical.

#### Separate Products with Solvents of Different Components

If solvents containing different species are used in separate products, run either simultaneously on parallel presses or intermittantly on a single press, the air from the driers should be handled by separate adsorption systems for each formulation, as shown in figure 6. The separate condensed phases would be either decanted or distilled as required. However, any distillation system needed would probably be less complex due to the complete isolation of the different chemical species.

#### A CASE HISTORY

The Standard Gravure Corporation of Louisville, Kentucky, installed solvent recovery facilities in 1971. At the time, public awareness of the environment was in full bloom. Some communities had established emission regulations while others, including Louisville, were just beginning to analyze the problem. Only "pessimists" were forecasting an energy shortage and the price of solvents had been relatively stable at 18 to 20 cents per gallon. Nevertheless, for reasons of good community relations, the Standard Gravure management made a decision that airborne solvent emissions were to be controlled and that recovery and reuse of the solvent were prime objectives.

Standard Gravure has its plant facilities in a complex of multistory buildings also housing the corporate offices and publishing facilities of the jointly owned Courier Journal and Louisville Times newspapers. The entire complex is air conditioned from a central utility area. The air exhausted from the ovens and other operating units in the printing areas

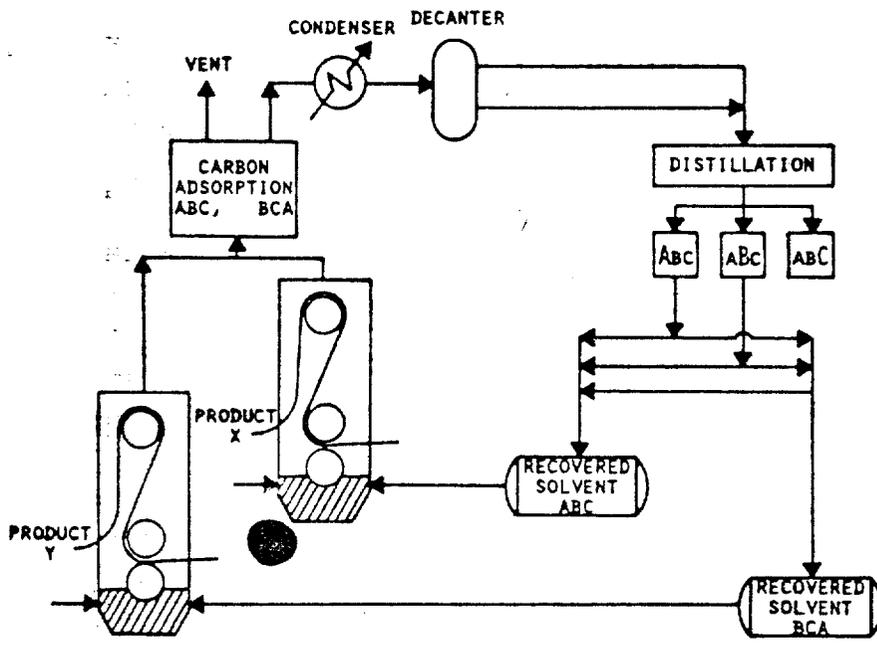


Figure 5. Solvent reuse diagram--multiple products with similar solvents.

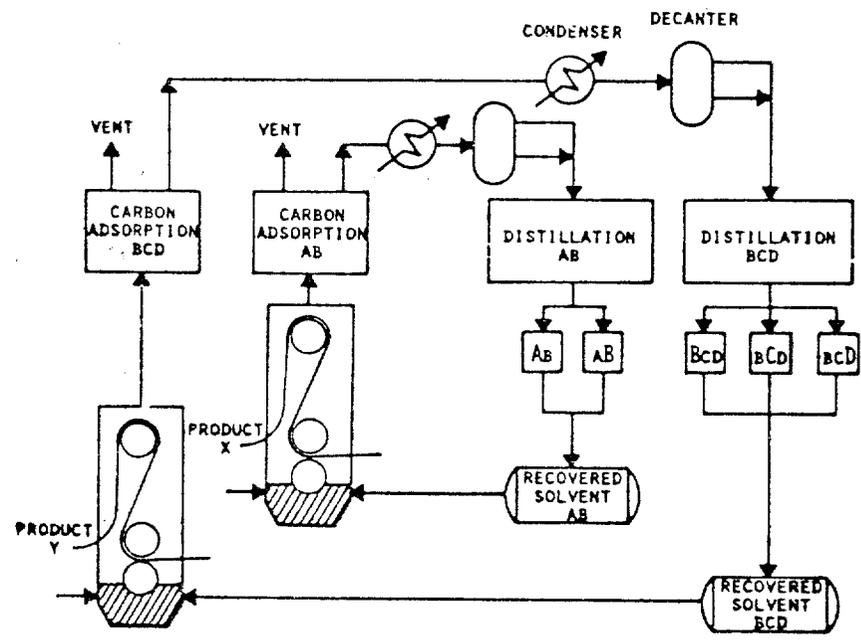


Figure 6. Solvent reuse diagram--multiple products with different solvents.

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is replaced by fresh, conditioned air distributed to various locations in the building complex. Solvents that escape from the presses or remain temporarily in the printed product are kept at a tolerable level by room exhausts in the printing areas. Thus, within the plant buildings, air flow is toward the printing areas and solvents are not distributed throughout.

Plant emission tests were set up to study oven and room exhaust solvent concentrations on a 24-hour basis. Inventory records of the quantity of solvent consumed indicated that the plant should be designed to recover approximately 2 MM gal/yr. On the basis of a straight average, this is a usage of 1,800 lb/hr at a concentration level of 400-500 ppm at projected exhaust volumes. However, the study of the actual concentration in the exhaust streams from individual oven discharge blowers showed variations ranging up to five times the average. The room exhausts were found to contain 100-300 lb/hr, thus indicating that they should be included in the solvent recovery system. Also, using the records of the preceding year, the actual operating times and exact quantities of solvents used were analyzed. A design basis then was selected which would handle the exhausts under all extremes of operation.

The gravure printing operations followed the time honored procedure of maintaining several bulk solvents with different drying speeds and solvency. Depending upon the job specifications, different amounts of solvents such as VM&P naphtha, toluol, xylol, etc., were used as diluents of the inks to obtain certain printing characteristics. These solvents are relatively insoluble in water so that an organic solvent phase could be separated from the regeneration steam condensate. Distillation would be required to separate the organic phase into fractions with properties similar to the solvents used. However, to avoid the expense and complexity of a separation plant, investigations proceeded into the possibility of using a single formulation of a "base solvent"<sup>1</sup> that would handle all but proof press operations and specialty jobs. This study had to take into account the solvent used by the ink manufacturer since it would also be recovered. With favorable indications that such could be done,

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<sup>1</sup> Patent pending on "base solvent" formulation by J. K. Anderson.

a solvent recovery plant was installed based on decantation and reuse of the solvent mixture.

### Process Description

A simplified process flow diagram is shown in figure 7. There are two gravure printing rooms, each designed for oven and room exhaust air volumes of 120,000 acfm. The exhaust plenum from each area has an automatic relief to the atmosphere in the event of an interruption in the solvent recovery plant. Solvent-laden air from each area flows through separate two-stage high-efficiency filters to remove paper and ink particles. The air to the gravure ovens is drawn from the pressroom, which is supplied with filtered air so that atmospheric dust does not represent additional load to these filters. The pressroom is held at approximately 75° F and 50 percent relative humidity and the combined oven and room exhausts range between 100° and 110° F. With these conditions, no further cooling or humidity control is required for efficient adsorption or plant safety.

From the filters the airstreams flow into two booster fans with automatic control to adjust to the capacity variations of the gravure presses.

Six activated carbon adsorbers are provided and each has inlet valves on the air ducts so that it can be switched in and out of service independently. Four adsorbers are active, each handling 25 percent of the total flow, and the two adsorbers not in service undergo a two-stage regeneration made up of back-flow steaming followed by forward-flow cooling with air. The four active adsorbers are always sequenced so that they are equally distributed on the loading cycle; that is, they are 25 percent of the loading cycle apart. When one adsorber becomes loaded to capacity with solvent and begins to break through, the others are 75, 50, and 25 percent loaded. In order to maintain this relationship, it is necessary to have balanced flow to the four adsorbers.

By automatic selection, samples of each of the purified air exhausts are withdrawn and a composite analysis of the total hydrocarbon content is continuously recorded. When a carbon bed becomes saturated with solvent, its breakthrough is detected by its effect on the composite sample.

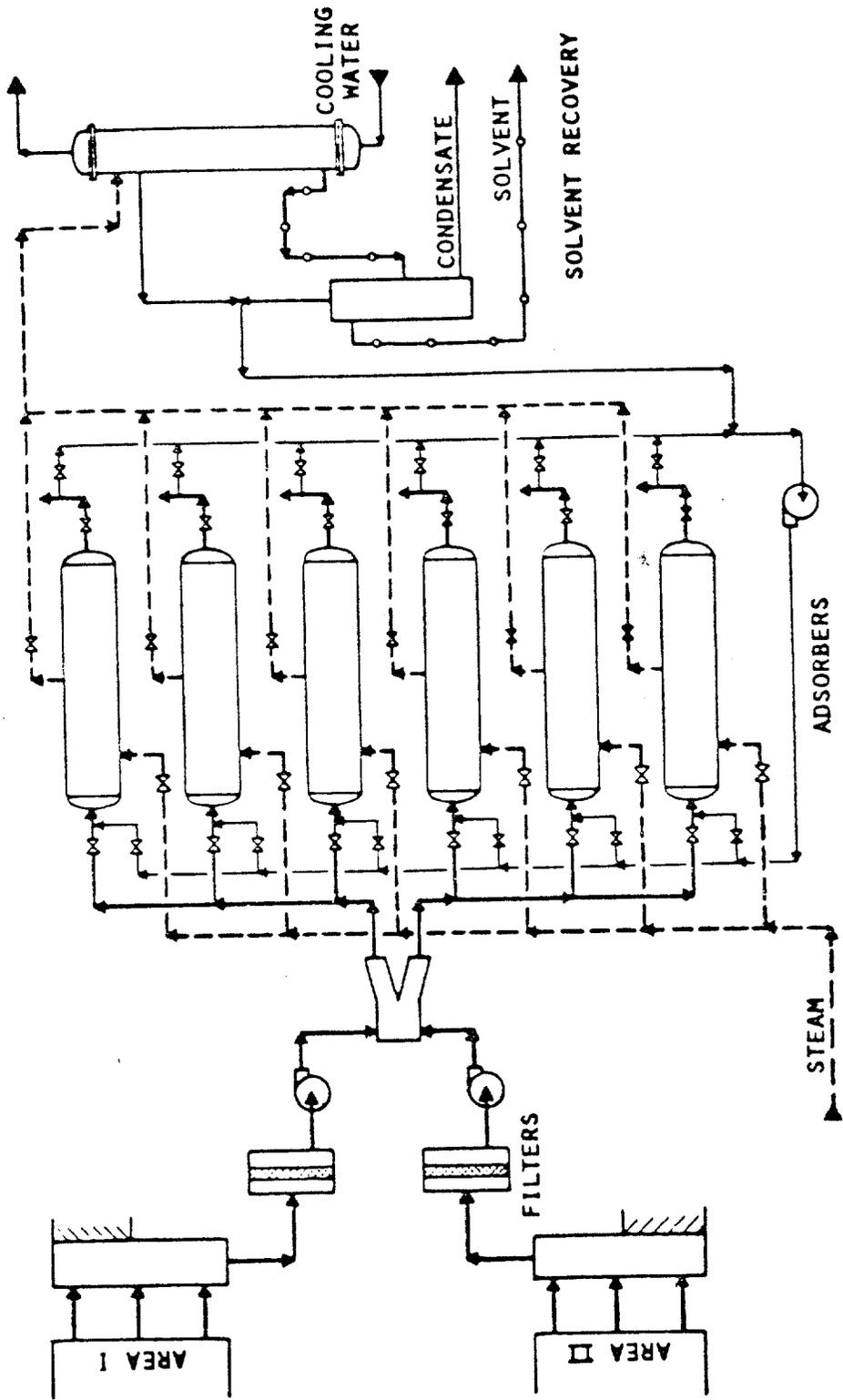


Figure 7. Simplified process flow diagram--Standard Gravure Corp.

At this point, the air flow is diverted from the saturated adsorber to the one having been steamed and cooled.

Regeneration is accomplished by the use of low-pressure steam flowing equally through all portions of the carbon bed. The mixed steam and solvent vapors from the adsorber are condensed and the two liquid phases are separated by decantation. The solvent flows directly to the 20,000-gal-capacity underground storage system, ready for reuse. The separated solvent contains approximately 200 ppm of dissolved water and with proper decantation there should be no separation of water from the solvent as it is reused. However, the underground tankage allows additional time for minute water droplets to settle out.

### The Solvent Recycle System

In this plant, all solvent-laden exhausts are treated and the entire plant is operated under conditions to minimize loss of solvents. Since the gravure ink, which is purchased outside, contains an appreciable quantity of solvent, the recovery system always generates a net surplus which must be exported from the plant. The quantity exported is approximately equal to the solvent in the purchased ink, less any losses in the system. The exported solvent is used by the ink manufacturer in formulation of new ink supplies for the gravure plant. This recycle system for the "base solvent" is illustrated in figure 8. The plant also maintains a supply of xylo1 for operation of proof presses and Lactol for Spectacolor work. These solvents are the only ones still purchased and they are recovered with the base solvent.

During 1973 and 1974, the average quantity of solvent recovered was 38,500 gal/wk. Of this amount, an average of 12,900 gal/wk were exported to the ink manufacturer and 25,600 gal/wk were reused for dilution and minor purposes such as washup, cylinder cleaning, etc. The use of xylo1 and Lactol during this period was about 1,500-2,100 gal/wk. The quantity of base solvent in inventory throughout this period averaged 12,000 gal or about a 2-day supply. In the manufacture of ink, 1,800-2,000 gal/wk of additional solvents were used. If the base solvent composition required some adjustment, appropriate additions of the needed solvent could be made by the ink manufacture.

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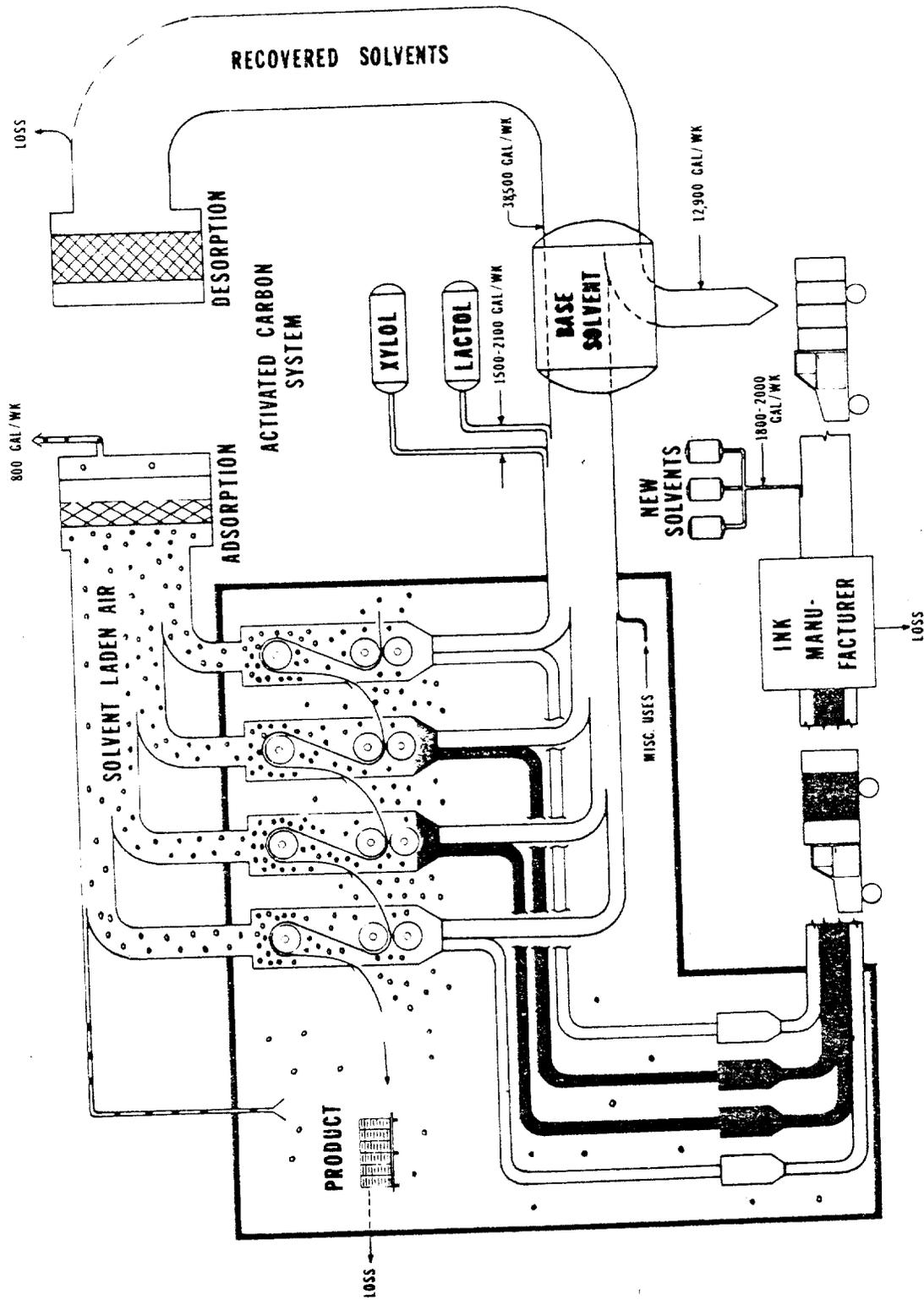


Figure 8. Solvent recycle system.

The overall solvent cycle efficiency is about 90 percent based on total solvent imports of 42,600 gal/wk. This total is derived from plant records which take into account all solvents brought into the plant in the form of production ink, proof ink, and the xylol-Lactol solvents.

Of the 4,100 gal/wk apparent loss, approximately 800 gal/wk can be accounted for as leakage through the carbon adsorbers. The charts recording plant effluent concentration trace variations from a low of about 5 ppm immediately after a fresh adsorber is online, up to about 15 ppm at the end of a cycle. An approximate mean value of 8 or 9 ppm amounts to a 2-percent breakthrough loss, based on average inlet air concentrations of 400-500 ppm. Other solvent losses include; solubility in the decanter condensate, washup uses, solvent remaining in the product and handling losses.

Regular chromatographic analyses of the base solvent are run to make sure that the major components are within the established tolerable limits. Over several years of operation, compositions have stayed within these limits remarkably well. The use of xylol for proofing and Lactol for Spectacolor have offsetting effects and the additions made by the ink manufacturer have been sufficient to maintain the base solvent within specifications.

The Standard Gravure Corporation considers the solvent recovery system a great success story. Not only has the project met all of the technical objectives, but it has been given credit for keeping the plant running by making it independent of solvent supplies. Since the solvent recovery system is the major source of solvent for the ink manufacturer, the assurance of this supply is an additional benefit of equal importance. During the petroleum shortage of 1973 and the resulting energy crunch, crude oil was diverted from production of naphtha to other more profitable petrochemicals. Suddenly, naphtha was in short supply and its price soared to 56 cents per gallon, with some offered for as high as 80 cents per gallon. This was not a serious problem for Standard Gravure and its ink manufacturer, since it had reduced its solvent consumption from 2,215,000 gal/yr to 215,000 gal/yr.

The price of solvents has fluctuated considerably and is currently about 36 cents per gallon. It is obvious that the rate of return on

investment has improved considerably as compared with 1971.

#### ACKNOWLEDGMENTS

The author wishes to acknowledge the gracious consent on the part of Standard Gravure Corporation in allowing publication of information concerning its plant and operations. Also acknowledged is Mr. Jack Uhl, Production Engineer, whose helpful cooperation during the preparation of this paper was greatly appreciated.

#### DISCUSSION

MR. ALVIN R. SALTZMAN (New Jersey Bureau of Solid Waste Management, Trenton, New Jersey): It is a very interesting paper. And I think it really gets down to the nitty-gritty of some of our recycling problems.

You have shown a closed loop system having variable inputs, composition, and other factors. For this type of system, feeding back directly into the printing system, the matter of stability and control becomes a very important factor. Is that correct?

DR. HARVIN: That's correct.

MR. SALTZMAN: In that case, I wonder if you can provide us any information on how you go about the setting up of the stability and control system; particularly, how you decide whether you are going to use offset rate or proportional control?

DR. HARVIN: Are you referring to the control of the solvent composition limits?

MR. SALTZMAN: I am talking about all the subsystems, for instance on the distillation apparatus--

DR. HARVIN: I can go through the control theories on the solvent recovery system. However, I am not from the Standard Gravure Corporation, so I cannot speak of their control of the composition or concerning how they use their ink, except for the fact that we know they do reuse it. There is a representative here from Standard Gravure who may wish to comment.

Regarding the control of the solvent recovery system, I mentioned the fact that the inlet air system has variable capacity control on the blowers. Therefore, regardless of the number of presses operating or the amount of effluent air, the system can accommodate that particular air volume through automatic duct pressure control. Thus, the system can always handle all the air that is being sent out or being used by the plant. In the event of an emergency shutdown of the solvent recovery plant, the solvent-laden air will automatically vent to the atmosphere.

MR. I

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The inlet air composition is measured and recorded by total hydrocarbon analyzers on the incoming airstreams. The outgoing composition is also measured and recorded. A composite sample of the effluent from the four active adsorbers is used. Just after the plant switches to a new drum, there is about a 5-ppm breakthrough. Then the breakthrough gradually rises to a predetermined set point, which is currently set at 14 ppm. When 14 ppm is detected by the analyzer, the system cycles. It usually slips on by about 15 ppm before it finally completes switching. When it switches over, a new drum comes on and the breakthrough goes back to about 5 ppm. So the effluent composition follows a sawtooth pattern.

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As I mentioned, we avoided the use of distillation because Standard Gravure went to the use of a base solvent composition. Because of the way they operate with proofing operations, Spectacolor, and their regular gravure work, the solvent composition meanders but nevertheless stays within certain prescribed limits set up by Standard Gravure.

MR.

The laboratory people analyze the solvent on a regular basis. If they find that for some reason or other, due to the products they are producing, the xylo content is getting down a little bit, all they have to do is call up the ink manufacturer and tell him to go heavy on xylo in the small amount of solvent he must add. That will build up the xylo content of the inventory. Does that answer your question?

MR. SALTZMAN: Yes, I understand what you said. Thank you.

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MR. WILLIAM H. BROWN (FMC Corporation, Marcus Hook, Pennsylvania): What steam to solvent ratios do you find typical in the adsorption cycle?

DR. HARVIN: This particular adsorption cycle is not the most efficient in the world because of the fact that the Standard Gravure people elect to operate a very low ppm value--400 to 500 ppm. So the loading of solvent on the carbon is relatively low, and the steam-solvent ratio is not the most optimum. Its range is between five and seven.

MR. BROWN: Thank you.

DR. HARVIN: That, incidentally, is something that is less subject to the design of your plant and more subject to the way you operate your plant. There are some solvents that can be recovered with ratios down in range of three, and other solvents that require much higher steam ratios. The steam/solvent ratio is more a function of the particular solvent system and the way a plant is operated than of the design equipment being used.

MR. KING: Thank you.

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