Solvent vapor recovery and VOC emission control

PAUL N. CHEREMISINOFF

A wide range of industries use various systems for recovery and reuse of solvents that might otherwise be exhausted to the atmosphere. Use of such systems recovers and recycles many million gallons of solvents each year. Users usually find such methods economical as well as environmentally sound. The March 1985 issue of Pollution Engineering magazine carried the Special Report: Volatile Organic Compounds which reviewed solvent recovery systems last year. This year’s special report continues the update.

As solvents have become expensive, discharging them into the atmosphere as spent gases is not economically sensible as well as unacceptable from an environmental and regulatory view point. Recovery of valuable products using proven adsorption and condensation technology as well as air pollution control can give full return on investment in relatively short time periods.

Solvent recovery can pay off by:
- Recovery of valuable solvents,
- Recovery of process heat, and
- Protecting the environment.

Market for Systems

Potential markets for solvent recovery and VOC emission control systems is very large. Industries who are large users and emitters of organic solvents include:

1. Semiconductors
2. Auto paint baking
3. Aluminum siding painting
4. Appliance paint baking
5. Printing and labeling
6. Plastics and vinyl flooring
7. Wire coating
8. Textile
9. Pressure sensitive tape
10. Magnetic tape
11. Paint manufacturing
12. Dry cleaning
13. Solvent reclaiming
14. Furniture finishing
15. Plastic lined pipe
16. Solvent degreasing

The first eight industries are primary markets for emission control. It has been forecasted by professional market researchers that the value of equipment to be sold to these industries in 1986 will be $34-million.

Solvent Recovery from Gas Phase—Applications

Because of emphasis on air pollution control, solvent recovery need no longer be justified by economic considerations alone. Where solvents are evaporated and disbursed into surrounding atmosphere, this ecology factor is overriding for the recovery of volatile solvents no matter what the economics. Solvent Recovery is used whenever any of the following situations are encountered:
- Solvent Recovery—An economical recovery of valuable solvents or other compounds present in effluent streams being discharged from a process or operation.
- Air Purification—Here the emphasis is on air pollution control and the polluting contaminants may be a secondary consideration for economic recovery.
- Gas Purification—Applied when various contaminating compounds must be removed from a process gas stream for marketing or return to process.

Any application must be judged on its own merits and many factors need to be considered. Analysis of any application should include the following gas phase applications data:
- Solvent Recovery—solvents to be recovered.
- Air Purification—contaminants to be removed.
- Gas stream composition.
- Operating Conditions—air (gas) volume, cfm temperature, C (F) total pressure, psig relative humidity, % concentration of components to be adsorbed.
- Air (Gas) Stream Components Which May Polymerize and Their Concentrations.
- Particulate Matter Content.
- Operating Schedule (hours/day, week, year).

Evaluation of the following factors in any application is also essential:

1. Pretreatment of air (air filters, scrubbers, etc. required)
2. Adsorption capacity
3. Regeneration conditions
4. Materials of construction
5. Energy savings (heat recovery, etc.)
6. Instrumentation and automation
7. Pollutant recovery/reuse or sale
8. Pollutant disposition (fuel source?)
9. Separation of collected pollutant (distillation, etc.)
10. Treatment requirements for effluents
11. Adsorbent life

Decisions for recovery or other utilization of collected organic compounds or their separation and reuse have to be carefully analyzed. While superficially many organic emission control systems may look similar and basic design concepts are also the same, usually some customizing is required for the particular conditions at the source, or the application.

Carbon Adsorption Technology

Adsorption processes help purify liquids and gases by attracting and holding organic impurities on the vast surface area of an adsorbent. One of the most effective is granular activated carbon, having a surface area providing many potential adsorption sites. Activated carbon offers both theoretical and practical advantages that are especially valuable in high volume, continuous flow applications. Additionally, carbon reactivation or regeneration has been fully developed. Granular car-
bon is best used in multiple adsorption steps allowing each particle of carbon to be in contact with influent gas before reactivation or disposal.

Adsorption equipment can be of modular design, allowing easy system expansion to accommodate changes in gas volume to be treated as well as contaminant levels. Some units can be skid mounted (for smaller volume applications) with pipes and valves pre-assembled as part of each module. Skid mounting facilitates shipment and installation and helps reduce foundation costs. Connecting piping between modules can be pre-cut and flanged to fit a variety of equipment arrangements.

Data Development for Design and Application

Sizing and overall design of an adsorption system depends on the properties of both the gas feed to the system and the adsorbent (carbon). A principal is to maintain a compact, stable adsorption bed. Properties of the gas that need to be known for design purposes are:

- Composition.
- Fluid (gas) density and viscosity at operating temperature and pressure, which can be calculated from standard data.

Properties of the adsorbent required for design include:

- Volume and weight fractions (void volume and fraction)
- Particle size, usually reported as a mean particle diameter
- Pore data, which is important because it permits elimination from consideration adsorbents whose pore diameter will not admit desired adsorbate molecules
- Hardness, which indicates care that must be taken in handling adsorbents to prevent formation of undesirable fines
- Adsorbent life

A major design parameter for the adsorption section is the residence time of the gas in the bed. Once residence time has been determined other design factors must be considered. If gas flow is, for example, not relatively constant, adsorbers must be sized so that suitable effluent will be produced during peak flows. The length and cross-sectional areas of adsorbers and their number should be such as to allow sufficient residence time.

Figure 1 shows a typical adsorber for solvent vapors. Figure 2 is a process flow sheet for a conventional vapor phase adsorption system. Two flow arrangements for fixed-bed adsorption sections are shown in Figure 3 and a typical idealized breakthrough curve for an adsorption cycle is illustrated in Figure 4.

Carbon Adsorption System's Potential Problems

Typically some operating difficulties and disadvantages may include the following. This may necessitate
Figure 4. Idealized carbon breakthrough curve.

Figure 6. Full scale 1500-7500 cfm prototype VOC emission control system. The absorber (scrubber) is located at the far upper left of the figure, VOC's are collected at high efficiency and best suited to higher concentration because of absorption driving force and stripper efficiency. (Courtesy Celitco Corp.)

Figure 5. Carbon adsorption solvent recovery system featuring an evaporator/condenser to capture heat from the regeneration steam/solvent vapors leaving an adsorber. (Courtesy AMCEC Corp.)
the consideration of other recovery systems such as scrubbing systems or condensation as alternatives.

1. Carbon adsorption systems are usually regenerated on a batch basis, typically using steam requiring subsequent separation and/or wastewater treatment. Carbon adsorption systems have finite adsorption capacity and once breakthrough takes place removal efficiency deteriorates.

2. Continuous emission control and solvent recovery requires two carbon adsorption systems. One system is on stream while the second system is being regenerated.

3. When chlorinated solvents are stripped from carbon with steam, HCl is formed. Such applications require high alloy construction materials, increasing system costs.

4. Carbon adsorption systems are sensitive to bed plugging from particulates in the gas stream as well as formation of polymeric solids from certain VOC's (styrene is a good example). Bed plugging for any reason drastically shortens carbon life.

5. Hysteresis effects where certain VOC's (MEK is one example) cannot be efficiently stripped from carbon cause residual buildup and lowered efficiency with successive use. This requires ultimate high temperature regeneration (1800°F or higher in a special furnace). This adds expense and requires the system be unpacked and repacked.

6. The buildup of nonstripped VOC's in carbon beds represents a serious fire hazard when the system is placed back into operation.

7. Carbon systems generally work best with solvents which are immiscible with water and preferred to those which are water soluble. In the case of miscible solvents, distillation must be applied to separate solvent components from the water. Single solvents are also preferable to mixtures, especially if one or more are water miscible. Formation of complex azeotropes pose difficult distillation/recovery problems. Alternate recovery systems such as scrubbing and/or condensation may not be sensitive to these problems.

System and Service Suppliers

The following are suppliers of solvent vapor recovery and VOC emission control systems. Included are organizations that supply a wide range of systems as well as regenerant and solvent purification services. These companies do not represent all of the available sources for solvents recovery systems and services, but are those which provided information in answer to PE's request for editorial information for this special report.

AMCEC CORP (Oak Brook, IL)—A professional chemical engineering design and construction firm, for over 60-years specializing in solvent recovery systems based on carbon bed adsorption technology. Custom design of field constructed large scale systems including the largest single site plant in the world, the initial phase of which is operating at 375,000 scfm. Packaged solvent recovery systems are also available in standard designs from 500 scfm to over 40,000 scfm. Their ECOVAP-50 is a new process which represents a major improvement in operating economics of carbon adsorption type solvent recovery systems. The system reduces desorption steam requirements from the conventional 3-4 lb/lb of solvent to 2 lb/lb or less. (See Figure 5). Circle 401 for more information.

Ceilcote (Berea, OH)—Removal of hydrocarbon vapors is carried out in a scrubber using SOL-VOL-X, a proprietary high boiling point organic liquid. Solvents recovery is achieved in a stripper column equipped with a fractionation section and condenser. After stripping, regenerated SOL-VOL-X is recycled for reuse in the scrubber. Unlike carbon adsorption equipment, the Ceilcote organic vapor recovery system is a continuous process not requiring an alternating unit for periodic shutdowns and regeneration. (See Figure 6). Circle 402 for more information.

Dedert Corp. (Olympia Fields, IL)—designs and supplies equipment and systems for the process industries. This organization claims to have built more solvent recovery plants for U.S. rotogravure printers than all other competitors combined. Equipment and systems feature new technology to reduce energy consumption by use of special engineering know-how and knowledge of vapor recompression evaporation. Energy consumption equivalent to less than 1 lb of steam per lb of solvent is not unusual in large scale commercial plants. Dedert Corp. can design and supply the whole solvent collection/recovery system, including installation, start-up and providing complete turnkey plants. (See figure 8). Circle 403 for more information.

Edwards Engineering Corp. (Pompton Plains, NJ)—markets hydrocarbon vapor recovery units based on direct condensation by refrigeration. The refrigeration process offers efficient vapor recovery and safety. The recovery condenser is essentially a flame arrestor refrigerated to −120°F. Vapors are simply passed over the cold condensing surfaces where solvent vapors condense on the surfaces and are collected as a liquid and returned to product storage. (See Figure 9). Circle 404 for more information.

Finish Engineering Co. (Erie, PA)—has manufactured solvent distillation equipment since the early 1970's and has over 1400 units installed in industry throughout the U.S. Reclamation systems are safe/efficient onsite reclaimers featuring all explosion-proof electricals: patented single-piece heating element and redundant factory-set thermostats. One button operation and no operator requirements make units even more enhancing. (See Figure 10). Circle 405 for more information.

Groundwater Technology (Div. of Oil Recovery Systems Inc., Norwood, MA)—has two systems that remove toxic air pollutants. One is used when toxic air pollutants accumulate in either a basement or sub-surface vault, and create a hazardous situation. It combines HVAC technology and vapor phase activated carbon to mitigate vapors quickly. The systems are portable, easily installed and work quickly to remove hazardous vapors. The other system that removes toxic air pollutants is an optional vapor carbon adsorption system unit that is used with an air stripper and VOC recovery unit. (See Figure 11). Circle 406 for more information.

Hoyt Manufacturing Corp. (Westport, MA)—their solvent recovery system can return 85-95 percent of the solvent that evaporates at emission points throughout a plant. With savings in solvent of this magnitude, the return in solvent cost savings can amortize the full cost of
the unit in less than a year. In the typical Hoyt system an activated carbon bed is mounted in one or more processing tanks which serve the function of adsorption and desorption which is coordinated with the equipment operating schedule, production shift or work week. Hoyt has also developed and is marketing the Solvo-Salvager, state-of-the-art distillation system to purify and recover 98 percent of used contaminated solvents. (See Figure 12). Circle 407 for more information.

Internal Corp. Environmental Control Systems (Englewood, CO)—packaged activated carbon systems up to 11,000 cfm are skid mounted, fully assembled, prewired systems, requiring minimum installation and start-up time. Special designs and design modifications are available depending on user requirements. Examples are single, intermittent operating vessels, electric steam generator for desorption, thermostatic cooling-water flow control, vessel insulation, purge air blower or compressed air purge, blower upstream or downstream of the adsorber, vapor breakthrough monitor, programmable controller and other variables. (See Figure 13). Circle 408 for more information.

Met-Pro Corp. (Systems Div./Harleysville, PA)—engineers and markets granular carbon/KF Solvent Recovery Systems: thermal/catalytic systems for incineration and concentration before recovery/incineration KPR systems. The KF system utilizes a carbon fiber mat with physical structure specifically developed to increase the rate of solvent adsorption and desorption, without an increase in system energy requirements. Compared to granular carbon systems, this unique material reduces potential of solvent dissociation, increases recovered product quality, resists carbon bed fire occurrence and reduces formation of potentially corrosive byproducts. KF systems are fully packaged modular units expandable in sizes ranging from 700 to over 100,000 scfm. Circle 409 for more information.

Nuclear Consulting Services Inc. (NUCON) (Columbus, OH)—provides pollution control and solvent recovery services utilizing carbon adsorption technology. NUCON supplies testing, engineering and service for gas and liquid effluent control. Specific expertise includes testing on a contract basis in the adsorption field related to design and use of systems. Test programs establish design criteria or requirements for modification of design and/or existing equipment to result in optimized operation of the adsorption based system. The engineering department operates the largest adsorption related pilot plant in the U.S. (See Figure 14). Circle 410 for more information.

Ray Solv Inc. (Piscataway, NJ)—turnkey installations are available for complete solvent recovery and related facilities. Separation technology by proven activated carbon adsorption; regeneration is accomplished by purging the adsorber with an inert gas. Residual oxygen content is first reduced to a safe level and then heating, desorption and cooling follow on a recycle basis. Co-adsorbed water from the inlet solvent laden air stream is desorbed at the beginning of the heating step and the recirculating inert gas carries it to a dryer. Packaged, skid mounted Raysorb Systems are available in sizes up to 20,000 cfm. (See Figure 15). Circle 411 for more information.
Recyclene Products Inc., (So. San Francisco, CA)—small volume (5 gal) distillation/purification recovery of hazardous waste solvents into pure reusable material. The Recyclene machine purifies solvents using an explosion-proof, efficient, low cost distillation process. Circle 412 for more information.

Vara International Inc. (Vero Beach, FL)—provides complete solvent recovery systems as well as evaluation, consultation, engineering and management services. In addition to specially developed adsorption technologies services in heat exchange, mass transfer, extraction and distillation are provided with all systems automatically controlled utilizing state-of-the-art control concepts. (See Figure 16). Circle 413 for more information.

National AirOil Burner Co., (Philadelphia, PA)—manufactures a variety of air pollution control systems, including vapor control units. Their equipment efficiently thermally oxidizes vapor emissions of gasoline,

Figure 10. Standard Model BCF-600 reclaimer distills solvents contaminated with oil, grease, dirt, or other light contaminants at the rate of 75 gph. (Courtesy Finish Engineering Co.)

Figure 11. Carbon vapor system for removal of toxic air pollutants from subsurface leaks. (Courtesy Groundwater Technology)

Figure 12. Solvent recovery adsorber vessels. (Courtesy Hoyt Mfg. Co.)

Figure 13. Pre-assembled activated carbon system with three adsorber vessels for removal of toluene from 5350 cfm exhaust flow from a paper coating operation. (Courtesy Interel Corp.)
benzene, and other flammable or volatile materials. The systems are designed with a two stage flashback protection thus ensuring safe, reliable operation. Circle 414 for more information.

Pope Scientific, Inc., (Menomonee, W1)—produces wiped-film vacuum distillation equipment that can separate costly solvents from waste materials at rates up to 28 gph (depending on solvent and waste). This equipment is known for its efficient separation, low energy consumption and ease of operation. Circle 415 for more information.

Dual1 Industries, Inc., (Owosso, MI)—manufactures VOC removal and degasification stripping columns for groundwater decontamination and process water cleanup. The units combine carbon adsorbers where required. Turnkey installation is also available. Circle 416 for more information.

Emcotek, (Visalia, CA)—engineers and produces rotary atomizing scrubbers which have applicability in the cleanup of many gases. The company has recent experience in working on several VOC control projects and providing high efficiency removal of contaminants. Circle 417 for more information.

R.E. Wright, (Middletown, PA)—manufactures air stripping towers for removal of volatile organic compounds (VOC's) from groundwater. Their systems are available in single or discrete multiple pass units which can provide greater than 99.99% removal of VOC contaminants. The company provides a number of interesting options including trailer-mounted units, as well as pilot and rental units, and vapor treatment. Circle 418 for more information.

Tigg Corporation, (Pittsburgh, PA)—markets modular adsorbers using activated carbon and other sorbents. The company offers disposable/refillable filter systems...
up to 1500 cfm and can field assemble segmented modules to treat up to 20,000 cfm. Circle 419 for more information.

Safety-Kleen, (Elgin, IL)—is the largest solvent recycler in the U.S. By using this nationwide commercial supplier of solvents, the requirement for recycling and disposal of waste solvents is eliminated. The company takes complete responsibility for continually supplying their customers with clean solvent and removal and proper treatment of used solvents. Circle 420 for more information.

Detox Inc., (Dayton, OH)—designs and supplies portable, low cost, easy to install, easy to operate systems for groundwater treatment. Available systems include biological treatment, carbon adsorption, in-situ, metal removal and air stripping. Circle 421 for more information.

McKesson EnviroSystems Co., (Fort Wayne, IN)—is in the waste management and service business. The company owns and operates solvent recycling plants throughout the United States. They will either totally destroy and/or recycle hazardous chemicals including solvent. Circle 422 for more information.

Tri-Mer Corp., (Owosso, MI)—manufactures packaged wet scrubber systems. This is one of the several technologies that may be employed for solvent emissions control. These scrubbers can be combined with other devices to also provide for the recycling of collected solvents. Circle 423 for more information.

Calgon Carbon Corp., (Pittsburgh, PA)—offers granular activated carbon adsorption systems, proven in removing organic compounds from groundwater flows. They can provide packed tower or induced draft air stripping units as well as a specialty tailored system combining carbon adsorption with air stripping. Circle 424 for more information.

Detrex Chemical Industries, (Southfield, MI)—manufactures the Solvent Vapor Recovery Modules (SVRM’s) that form an expandable system that can grow as your requirements grow. The systems can be used with most chlorinated and fluorinated solvents. Their systems are ideal for operations using between 200 and 6000 gal of solvent per month. Many systems can pay for themselves in savings in less than one year. Circle 425 for more information.

Venus Products Inc., (Kent, WA)—provides systems that will recover 95% of your solvent. Their systems process approximately four barrels of contaminated solvent in an 8 hour shift. An output manifold automatically fills barrels sequentially. Circle 426 for more information.

Gold Shield Solvents, a division of Detrex Chemical Industries (Southfield, MI)—will pick and process your spent degreasing solvents. They specialize in reclaimation and recycling of solvents. Their plants are fully licensed TSD facilities. The company has 10 reclamation centers across the country and a large fleet of trucks to pick up your wastes. Circle 427 for more information.

Baron-Blakeslee, Inc., (Melrose Park, IL)—produce VOC stripping systems. Their experience and knowledge in the field of VOC removal and solvent recycling is well respected. The company produces packaged systems available in batch or continuous flow operation. Claimed removal efficiencies are in the range of up to 99.975%. Circle 428 for more information.

Hydro Group, (Linden, NJ)—markets air stripping systems, activated carbon systems, and biological treatment units to handle chlorinated solvents, gasoline and petroleum products, contaminated groundwater, and industrial effluents. Circle 429 for more information.

Union Carbide, (Danbury, CT)—provides the Purasiv Solvent Recovery System. Efficiencies up to 99% are achievable with the Purasiv HR System. These highly efficient large systems have been found to often be able to pay for themselves in about two years. Circle 430 for more information.

Groundwater Technology, (Norwood, MA)—designs systems for removal of organic contaminants from water. Their system is a combination of air stripping/activated carbon. Systems are available from 5 to 1000 gpm for air stripping. Circle 431 for more information.

NEPCCO Equipment Div., (Foxboro, MA)—produces their AirPurge system, an air stripping unit which removes trace VOC’s from water and dissolved organics to less than one part per billion. Circle 432 for more information.

Sauk Valley Equipment Co., (Rock Falls, IL)—can help solve hazardous waste control problems by use of their Chief Solvent Distillation Equipment. The Model LS-15 distills 15 gal per shift and processes alcohols, ketones, aromatics, chlorinated solvents and aliphatics at a minimal operating cost of 4-10 cents/gal. Circle 433 for more information.

Progressive Recovery Inc., (Columbia, IL)—markets the Model SC series of solvent recovery units with recovery rates from 3-30 gph. Operating and recovery costs ranges from 5-8 cents/gal. The units will distill all common solvents up to a boiling point of 500 F with vacuum assist. Circle 434 for more information.

Hoyt Corp., (Westport, MA)—has developed the Solvo-Salvager distillation system to purify and recover up to 98% of used contaminated solvent. The unit is completely automatic and runs on a continuous basis. Circle 435 for more information.

Paul N. Cheremisinoff is Professor of Civil & Environmental Engineering; Director of the Physical Treatment Div. of the NSF Industry/University Cooperative Center for Research in Hazardous & Toxic Substances, New Jersey Institute of Technology, Newark, NJ