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Project Summary

Evaluation of the Union Carbide PURASIV HR Vapor Recovery System

C. S. Parmele, H. S. Basdekis, and M. R. Clark

The objective of this study was to evaluate a new fluidized-bed adsorption technology developed in Japan, licensed by Union Carbide, and now being marketed in the United States as PURASIV® HR Vapor Recovery System. The engineering evaluation was developed by performing field tests on a full-scale PURASIV HR unit at Polaroid Corporation, Waltham, Massachusetts. The data from the tests supplemented operating information from a PURASIV HR system at General Motors Corporation, Fremont, California. Capital and operating costs were then developed for both PURASIV HR and fixed-bed adsorption systems, and these two types of adsorption systems were then compared.

The PURASIV HR technology can be viable for adsorption applications and can compete economically with fixed-bed systems, especially at flow rates above 5,000 scfm, where the higher capital costs for the PURASIV HR system can be offset by savings in steam and electricity costs. Selection of the better system should be based on an integrated evaluation of the benefits and drawbacks for each type of system. Neither type of system should be excluded apriori from a given application based on costs (in the range of flow rates of 5,000 to 100,000 scfm and inlet VOC concentrations of 0.1 to 1.0 lb VOC/1,000 SCF) without an evaluation of site-specific aspects of the existing tradeoffs.

Although the PURASIV HR system has been promoted for controlling emissions of water-soluble and reactive solvents, it is not uniquely qualified for these applications. Water will be present in the solvents desorbed from PURASIV HR systems as well as from fixed-bed systems, and similar precautions to minimize conditions that could lead to bed fires must be taken in designing and operating either type of adsorption system. Processing conditions which eliminate or minimize the possibility of bed fires are inherent in the process design for the PURASIV HR systems. The basic design of a fixed-bed system must be modified to provide these conditions.

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

Background

Steam-regenerated fixed-bed adsorption technology has often been applied for solvent recovery/emission control. One drawback to this technology is the inherent contact of water with solvents during the regeneration step. When suitable recovered solvents cannot be produced by decanting them from the condensed steam, additional costs are generated by additional recovery steps, such as distillation.

A new approach to vapor-phase adsorption using a fluidized-bed adsorber was developed in Japan. Since this approach allows the use of nitrogen to regenerate the carbon, it may reduce the need for additional steps to separate the water-miscible solvents from the water. This technology, licensed by Union Carbide, is currently being marketed in the United States as the PURASIV® HR Vapor Recovery System. The PURASIV HR process uses a new type of beaded activated carbon specifically developed to resist attrition, a major disadvantage of previously developed continuous-flow adsorption processes. The advantages of this fluidized-bed adsorption system are that it is reported able to desorb the organic from the carbon with reduced water contamination, to make use of inert gases during regeneration, and to consume relatively low energy.

The objective of this study was to perform an engineering evaluation of the PURASIV HR technology. First, the data available from commercial installations in the United States were reviewed and a site suitable for field sampling was identified. Field sampling tests were then conducted to assess the performance and economics of the PURASIV HR system. Inlet and effluent concentrations, mass emission rate, and quality of recovered solvent were determined during the tests. Reliability, cost effectiveness, and energy requirements were also assessed.

Summary and Conclusions

This engineering evaluation has shown that the PURASIV HR adsorption technology can be viable for solvent recovery/emission control applications and can compete with fixed-bed systems in some applications. However, it is difficult to categorically exclude one type of adsorption system (fixed-bed or PURASIV HR) from a given application without evaluating the specific aspects of the many existing tradeoffs. For example, PURASIV HR systems require less energy (for desorption) and less electrical power (to move the solvent-laden air through the adsorption system) than fixed-bed systems, but these cost savings are sometimes offset by higher capital costs and higher carbon replacement costs due to shorter carbon lifetime and higher carbon prices.

The PURASIV HR system has been promoted for controlling emissions of water soluble and reactive solvents (such as ketones, aldehydes, esters, and organic acids) because steam is not the regenerating fluid and conditions inside the equipment minimize the possibility of a bed fire. However, fixed-bed systems can also be considered for these applications because the solvent from the PURASIV HR unit may still contain enough water (5 to 10 percent when regeneration conditions have been properly adjusted) to require further treatment. Also, fixed-bed systems are designed and operated so that the possibility of a bed fire is greatly reduced.

Figure 1 presents installed capital costs (all in 1980 dollars) for "basic" vapor-phase adsorption systems as a function of flow rate. These cost data are for "basic" adsorption systems, because they include only the battery limits costs of the adsorption equipment. They do not include costs for any auxiliary equipment that might be required for pretreatment of the inlet gas, for wastewater treatment or for purification of the recovered solvent.

Installed capital costs for PURASIV HR systems are 40 percent higher than the capital costs for comparable fixed-bed systems, because the PURASIV HR system is different from a conventional fixed-bed system. However, the higher capital costs can be offset by lower operating costs. This is illustrated in Figure 2, which shows the annual cost per scfm as a function of flow rate and type of adsorption system. Curve 1 represents basic PURASIV HR systems, Curve 2 represents fixed-bed systems using 1.0 lb/steam/lb carbon for regeneration, and Curve 3 represents fixed-bed systems using 0.3 lb steam/lb carbon for regeneration. The inlet concentration shown in this figure as 0.1 lb VOC/1000 scf corresponds to a concentration of about 450 ppm for a compound with a molecular weight of 80 lb/lb mole.

Figure 2 shows that annual costs for generic systems (including capital-related charges) are almost the same for these two types of adsorption systems. The differences between the annual costs for the two types of adsorption systems are within the error bounds of the calculations. Significant differences between the annual costs existed only for the cases at the lowest flow rate (where costs for PURASIV HR systems were higher) and at inlet VOC concentrations above 0.5 lb/VOC 1,000 scf (2250 ppm) when 1.0 lb steam/lb carbon was needed for regeneration of fixed-bed systems (where costs for fixed-bed systems were higher).

As is shown in Figure 3, both types of adsorption systems can be cost effective when the inlet concentration is greater than 0.1 lb VOC/1000 scf (~450 ppm)

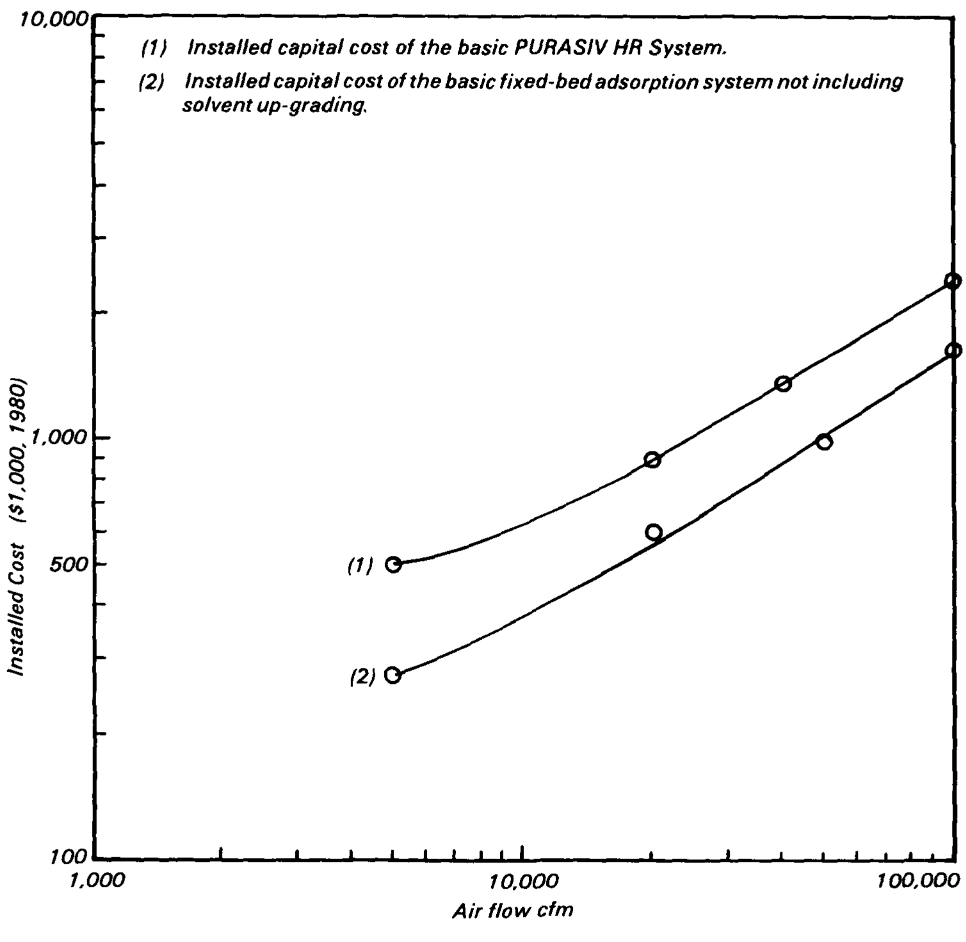

Figure 1. *Comparison of installed costs of PURASIV HR systems and fixed-bed adsorption systems.*

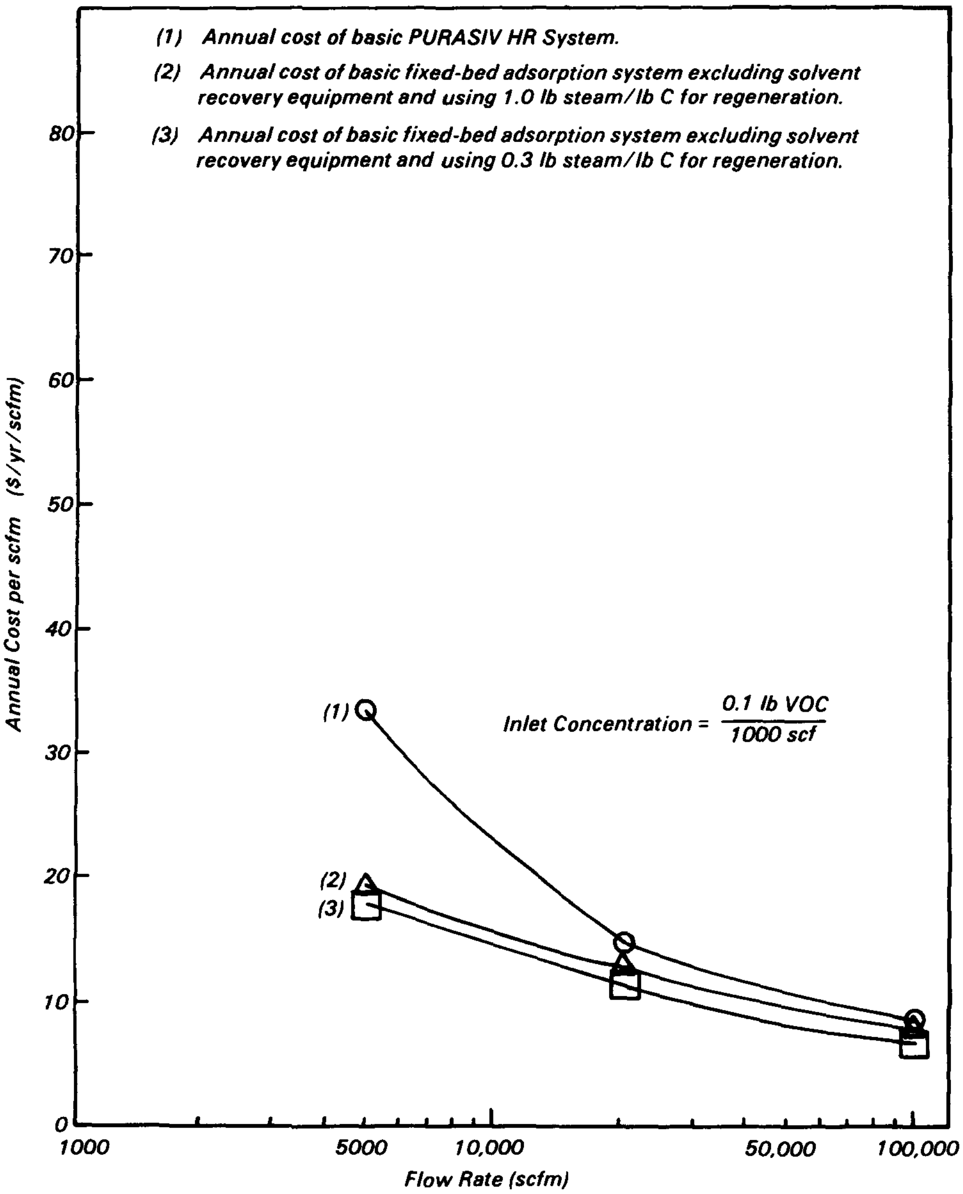

Figure 2. *Annual cost per scfm vs. flow rate.*

and the flow rate is above 5,000 scfm. For these cases, there are enough adsorbed volatile organic compounds (VOC) over which to spread the operating costs so that the cost/lb VOC is near or below the range of replacement costs for typical solvents ($0.20 to 0.40/lb VOC). The values for cost parameters used to obtain these results are shown in Table 1.

Mechanical problems such as erosion of the equipment and excessive carbon losses due to attrition have not been experienced with the PURASIV HR systems. Such problems have been overcome by replacing the granular activated carbon that was used in other continuous-flow adsorption systems with the spherical, beaded activated carbon developed in Japan.

The beaded activated carbon often has a shorter lifetime than granular activated carbon, possibly because there is usually less carbon in a PURASIV HR system and circulation of the carbon exposes all of it to the irreversibly adsorbed materials. These two factors suggest that the beaded carbon may become poisoned faster than granular carbon in fixed-bed systems. The impact of shorter lifetime on operating costs was reduced at Polaroid by thermally regenerating the carbon.

Pretreatment considerations are generally the same for fixed-bed and PURASIV HR systems because the same principles of adsorption influence the operation of both systems. However, the PURASIV HR system is more susceptible to conditions that cause the carbon to agglomerate (sticky solids or liquids) because the agglomerated carbon particles quickly interfere with the circulation of the carbon. The PURASIV HR system is also susceptible to "shot" upsets of high VOC concentrations because locally high VOC concentrations can lead to condensation in the desorption section.

The outlet concentration from a PURASIV HR system is influenced most by the condition of the carbon after regeneration. At Polaroid, the outlet concentration was 15 to 20 ppm using new carbon. By comparison, carbon which had been in service for nine months yielded an outlet concentration of 45 to 70 ppm. The regeneration process may be optimized to some extent if the carbon and nitrogen flow rate and/or the desorption temperature are independently adjusted. From this standpoint, more flexibility is available for designing and operating a PURASIV HR system than for a fixed-bed system.

Recommendations

PURASIV HR systems should be considered as an alternate to fixed-bed adsorption systems for solvent recovery/VOC emission control applications. Selection of the type of adsorption system should not be based on one or two features of either system, but rather on an integrated evaluation of *all* the benefits and drawbacks of each type of system.

Neither type of adsorption system should be categorically excluded from applications that include water-soluble or reactive solvents, because neither type of system is uniquely qualified for these applications. Water will be present in the desorbed solvent from either type of system, but there is likely to be more with fixed-bed systems. Also, precautions must be taken in designing and operating either type of adsorption system to minimize the conditions that can lead to bed fires. Processing conditions which eliminate or minimize the possibility of bed fires are inherent in the process design for the PURASIV HR system. The basic design of a fixed-bed system must be modified to provide these conditions.

Liquids should not contact the carbon in PURASIV HR systems, because the carbon distribution and circulation will be drastically affected.

When the carbon must be replaced frequently, methods to prevent the loss of adsorption capacity should be evaluated.

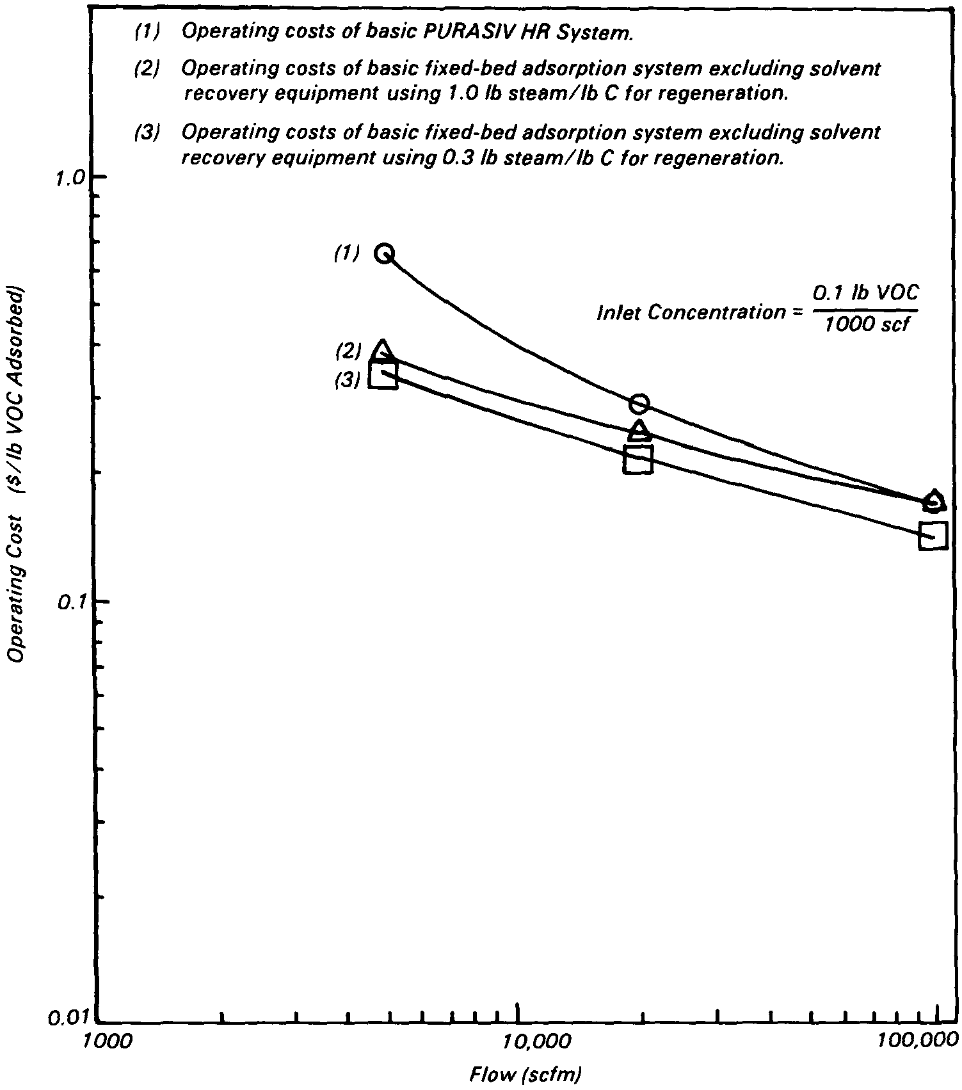

Figure 3. *Operating costs per lb VOC adsorbed vs. flow rate.*

Table 1. *Values of Cost Parameters*

Fixed costs	
Maintenance labor plus materials, 6%	
Capital recovery, 18%[a]	*29% installed capital*
Taxes, insurances, administration charges, 5%	
Utilities	
Electric power	*$0.04/kWh*
Steam	*$4.00/1000 lb*
Cooling water	*$0.10/1000 gal*
Chilled cooling water	*$0.90/1000 gal*
Nitrogen	*$0.40/1000 scf*
Beaded carbon replacement cost	*$4.00/lb*
Granular carbon replacement cost	*$1.00/lb*

[a]Based on 10-year life and 12% interest.

These methods include pretreatment to remove from the inlet stream the materials that cause loss of capacity or periodic treatment of the carbon via solvent regeneration or thermal reactivation.

On-line sampling equipment should be checked frequently. Carbon fines should be specifically excluded from the sampling equipment to ensure that the analyzer is receiving a representative sample from the process.

C. S. Parmele, H. S. Basdekis, and M. R. Clark are with IT Enviroscience, Inc., Knoxville, TN 37923.
***Ronald J. Turner** is the EPA Project Officer (see below).*
The complete report, entitled "Evaluation of the Union Carbide PURASIV HR Vapor Recovery System," (Order No. PB 83-193 599; Cost: $11.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
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The EPA Project Officer can be contacted at:
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