

## Recent Development in Absorption Technology (Scrubbing vs. Contacting)

### Summary

A high surface area vigorous scrubbing device has been test proven for hot gas cleaning. The technology offers major advantages over existing methods in the application of absorption from gases and for similar applications.

### Background

Gas “scrubbing” technology has been in use for well over a century. Early examples include the purification of coal gas and the wet washing of iron foundry cupola exhausts.

The essence of “scrubbing” is the transfer of a material from a gas stream to a liquid stream, so that the gas stream is “cleaned”. Usually, one of the streams is continuous. E.g. bubbles of gas pass upward via a continuous layer of liquid OR droplets of liquid fall down via a continuous up flowing gas stream. The surface area of the interface between gas and liquid is important. The material to be transferred from gas to liquid must pass through this surface. Therefore, the larger the interface surface area (the bubble or the droplet) the better the rate of transfer.

Most current systems operate in a vertical mode. The gas flows up and the liquid flows down. This means that the length of contact time of any bubble, film or droplet is relatively short. The longer the contact time, the better is the transfer from gas to liquid.

Turbulence at the interface of bubbles, films or droplets promotes vigorous transfer. Unfortunately, most current mass transfer devices are not genuine “scrubbers” (i.e. there is no significant energy input at the interface to promote high Reynolds numbers). Rather most “scrubbers” are actually “contactors”, allowing a relatively gentle brief contact between gas and liquid.

These constraints mean that:

- For dumped packings, the apparatus is necessarily large in order to provide adequate surface and time for gas to liquid contact. Unfortunately, this very largeness leads to liquid maldistribution and loss of contact as liquid paths downward miss up coming gas paths in a phenomenon known as “channelling”.
- For plate columns, large liquid hold ups, with associated pumping and back pressure problems, are necessary in order to provide sufficient time for transfer from gas to liquid.
- For structured packings and falling films, high fanning rates may be necessary to promote sufficient turbulence at the liquid surfaces.

## **Film Trays**

In the late 1960's, a device to overcome these problems was developed. It was known as the film tray. Over two hundred columns were packed with film trays, worldwide. For various non-technical reasons, the technology has been overlooked for some years.

Film trays work by using some of the kinetic energy of an up flowing gas stream to evenly form and distribute a series of thin horizontal films of a step wise descending absorbent liquid. By effecting the transfer on a series of closely spaced horizontal plates, a large surface area is presented and the thin liquid film is vigorously scrubbed by the high velocity gas stream. The counter flowing horizontal gas stream, together with the near absence of gravity induced flow by the relatively low volume liquid on the horizontal plate, allow sufficient time for mass transfer to approach equilibrium limits.

Inherent within the technology, are particular benefits:

- The avoidance of by passing and channelling, because of the self-distributing aerodynamics.
- High tolerance of fouling, which does not change the simple shape of the structure.
- Very low pack heights (H.T.S.) because of the efficiency of mass transfer.
- Wide operating range (Turndown), because of the non-critical relationship between liquid and gas flow rates.

## **The Demonstration**

It was decided to revive, test and demonstrate the technology. A new experimental apparatus has been built. The apparatus consists of a fan capable of blowing 2,000 m<sup>3</sup>/hour of ambient air; a controllable series of electric heaters capable of heating the blown air to 120°C; a solvent vapour injection system based on a heated pressure cooker; a 600mm diameter absorption column containing 25 film trays at 30mm interplate spacing; a one cubic metre sump for absorbent; circulating pumps and sparge bars; etc.

Measurements included: electrical current consumption; fan speed; wet and dry air intake; heated, solvent laden and exit air temperatures; back pressures; sump volume and circulating flow rate of absorbent; concentration of solvent in absorbent; heat inputs; air flow rates; concentrations of solvent in air in and air out, and circulating absorbent temperatures.

## **The Results**

The apparatus has been used to trial the absorption of toluene into oil and the absorption of industrial alcohol into glycol and into water. 97% reduction in solvent in air concentrations have been measured and the trials have been independently witnessed. The achieved reductions equate to a H.T.S. (height of a theoretical absorption stage) of about 250mm, which is in accord with historic data.

The collected data from a series of more than fifty test runs has formed a bank of “know how” which may be applied to the design of absorption systems that are smaller, simpler and more economical than those based on current technology. The “know how” is backed up with the availability of the experimental apparatus, which may be used to replicate conditions and refine design.

Interestingly, the trials improved practical knowledge in several other aspects.

At a given temperature and pressure, the concentration of a compound in air will be in equilibrium with the concentration of that compound in a liquid in contact with the air. For example, the air in a big sealed container, which has a known dilute solution of a compound in a liquid at the bottom of the container, will reach an equilibrium concentration of the compound in the air above the liquid. Testing the air for the actual concentration gives a point on the “compound in air concentration versus the compound in liquid concentration” equilibrium line. The simple technique is known as “headspace testing” and establishes a point on the “Henry's Law” part of the curve, which at dilute levels is, effectively a straight line through zero/zero. The slope of the line is steep at higher temperatures and lower pressures, when compounds display greater volatility.

Because the experimental apparatus recirculates absorbent, which gradually increases in absorbate concentration, Henry's Law data has been confirmed in practical circumstances for a range of concentrations and for a range of operating temperatures. (All testing was at or near atmospheric pressure.)

### **Heat Transfer**

True scrubbing of a gas stream with a liquid offers the prospect of gas cooling, because of the much greater thermal capacity of the liquid streams than the gas streams. The trials demonstrated that alcohol vapour (vapour pressure 500mm Hg at 70°C) could be successfully absorbed from an air stream at 70°C by using the absorbent as a cooling medium, as well as an absorbent.

### **Scrubbing Energy**

The collected data was sufficient to allow the Reynolds number at the scrubbing surfaces to be calculated as about 10,000. Similarly, it was possible to estimate the energy absorbed by the scrubbing friction as about 30 watts per square metre.

### **Further Development**

The insights, gained into the mass transfer mechanisms, lead to the development of an improved design of horizontal transfer plate. The refined design has additional performance, cost and simplicity advantages. A patent application has been submitted for the refinements. Publication of detail will take place once protection is in place.

Author: Clive Hadfield  
22 Holly Drive  
Lutterworth  
Leicestershire LE17 4RQ  
01455 552999

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