Solvent Loss Control Technical Guidance

With the resurgence of vapor degreasing as a viable method of cleaning in both the electronics and precision cleaning industries, a primary concern of customers is solvent loss control. ChemLogic prides itself on well over 30 years of combined vapor degreasing experience and has provided a set of user guidelines and diagrams that will allow the user to control solvent losses, minimize solvent use and achieve optimal cleaning consistency. The techniques discussed in this bulletin will improve safety, protect the environment and save money by reducing solvent consumption.

Vapor degreasing solvents are used in degreasing and defluxing equipment that may be configured in a variety of ways. Most equipment configurations are based on a fundamental concept: a simple two-sump, open-top unit. However, the same concepts that relate to small degreasers can be applied to larger, automated machines. Methods for reducing and minimizing solvent loss are based on this type of equipment as well as the following concepts:

- Equipment must be properly designed and maintained.
- Appropriate work practices must be applied.
- Solvent should be reclaimed and reused.

Equipment Design and Maintenance

Three major sources of solvent loss are emissions, dragout and leaks. Proper equipment design and maintenance may control emissive losses. Diffusional losses may be significantly decreased or eliminated by items such as freeboard height adjustment, properly fitted cover and the effective use of freeboard cooling or dehumidification coils. Dragout can be reduced by properly orienting parts to allow for complete drainage of the solvent from the parts. Using a sufficiently long dwell time in the vapor blanket so that parts reach equilibrium with the blanket temperature will also decrease solvent loss. A superheated vapor blanket is especially effective in eliminating dragout when properly used. Faulty equipment connections and poor maintenance allow solvents to leak or escape the system.

Emissions – Diffusion Losses

Heat Input:

In a vapor degreaser, solvent vapor must be generated to produce a vapor blanket. This is accomplished by heating the solvent with electricity, steam, hot water or hot refrigerant gas. In addition to the heat input required to produce the vapor blanket, additional heat is needed to warm the workload to the temperature of the vapor in order to dry, for solvent distillation and to replace radiation and convection heat loses (see Figure 1).

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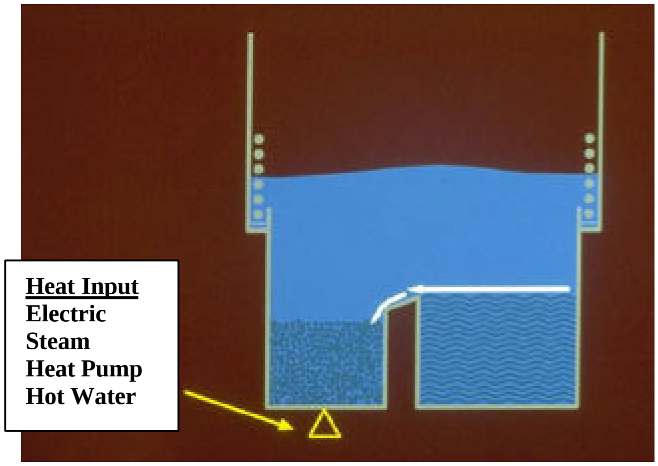

Figure 1

Work Shock:

If sufficient heat is not provided or if the workload is too massive, the vapor blanket will collapse when the workload is introduced, and air will enter the degreaser in a process called "work shock". As the vapor blanket is restored to its proper position, the vapor-laden air will be pushed out of the degreaser and high emission losses will occur. Work baskets should not be any heavier or massive than necessary to help minimize work shock. Do not waste "cleaning energy" on cleaning the basket versus the parts since the degreaser can not distinguish between the basket and the parts being cleaned. It is important to design a system with adequate heat input for the anticipated workload. Likewise, it is equally important not to introduce a workload more massive than the degreaser was designed to clean (see Figure 2).

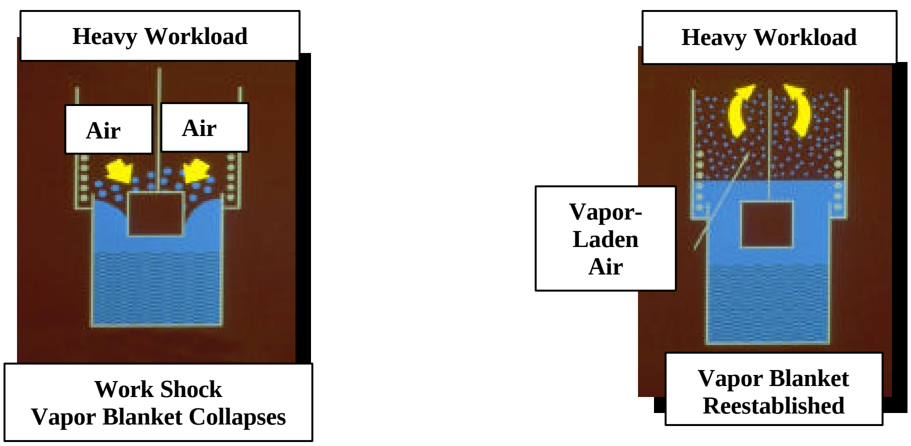

Figure 2

Condenser Temperature – Primary Condenser Coils:

Diffusional losses are directly related to condenser temperature. Heat input must *never* exceed cooling capacity. The primary condensers should be designed to operate at the lowest practical temperature, but above freezing. An attempt should be made to balance the vapor blanket on the center coil of the condensers. If the vapor blanket is higher, this means that there is either insufficient cooling or too much heat. If the vapor blanket is lower than the center coil, it is possible the system has insufficient heat and this can cause an unstable vapor blanket. Too much cooling can cause excessive water to be introduced into the system due to the dehumidification of the air above the vapor blanket (see Figure 3).

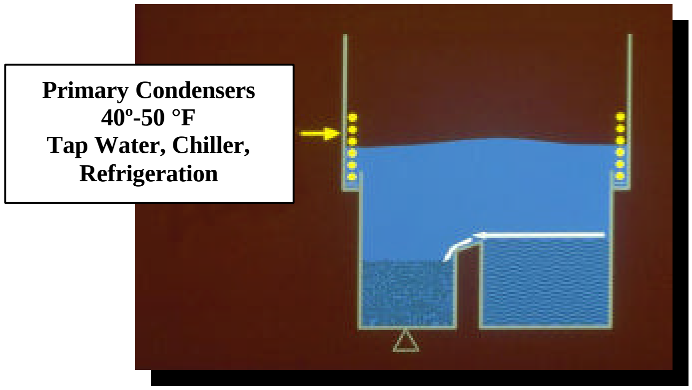

Figure 3

Condenser Temperature – Freeboard Chiller/Dehumidification Coils:

Freeboard condensers should *not* be necessary to control the position of the vapor blanket if the primary condensers are designed and operated properly. They *are* most effective, though, in combination with a condensate trough to dehumidify the air and help control the introduction of water into the degreaser. The freeboard condensers will also help reduce diffusional losses by lowering the solubility of the solvent in the air above the vapor blanket. The temperature of these coils can range between 35ºF to –20ºF and usually depends on the equipment manufacturer's design. The lower the temperature and humidity of the air above the vapor blanket, the lower the solubility of the organic solvent in that air. If freeboard condensers are used, it is important to remember that if the temperature of these coils approaches 32ºF (0ºC) or lower, they will ice up, and will need to be defrosted. When defrosting these coils, it is highly recommended that the resulting water be directed to a water separator that is dedicated to these coils. If the water is directed to the water separator or desiccant that is used with the primary condenser coils, the purpose of the dehumidification coils is defeated. The dehumidification coils are intended to dehumidify the air above the vapor blanket *before* that humidity or water is condensed on the primary condenser coils and mixed with the condensed solvent (see Figure 4).

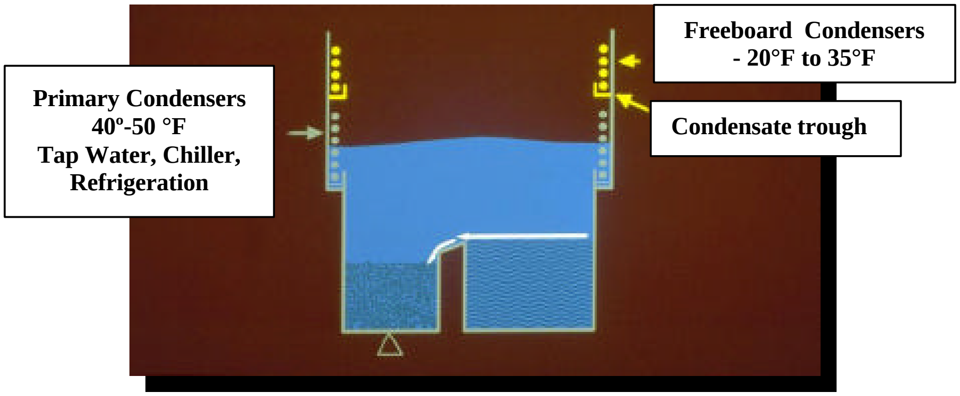

Figure 4

Vapor Depth:

It is important for the vapor blanket over the rinse or condensate sump to be deep enough to hold the largest workload that can be immersed in that sump. If *any* portion of the workload is removed from the vapor blanket prior to either equilibration in temperature or drying, dragout losses will be increased (see Figure 5). In an attempt to lower the height of their vapor degreasers, equipment manufacturers have been known to reduce the depth of either the vapor and/or the freeboard zones. Ultimately, this design violation will result in an increase in solvent emissions and consumption.

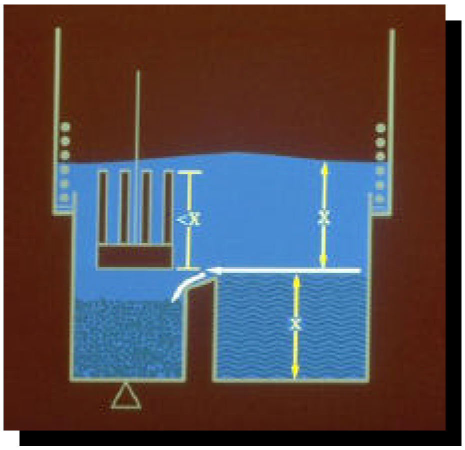

Figure 5

Freeboard Height:

Diffusional losses are inversely proportional to freeboard height. To minimize these losses, the freeboard should be at least 100%, but preferably 150%, of the smallest horizontal tank dimension, which is usually the width of the machine (see Figure 6).

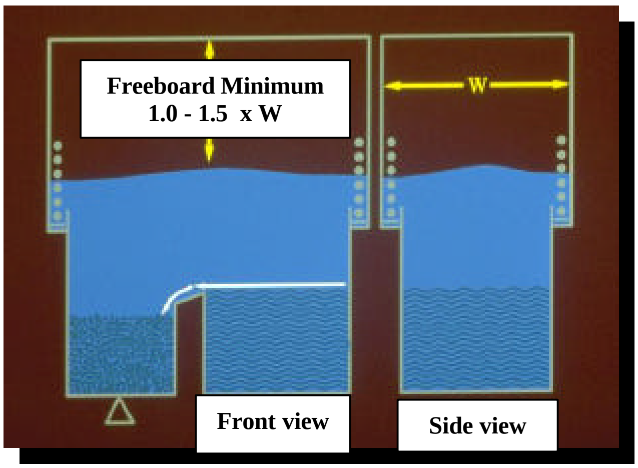

Figure 6

Vapor/Air Interface:

Diffusional losses are also directly proportional to vapor/air interface. If all sumps of the degreaser are not in use, or when possible, the vapor/air interface should be minimized. This practice is sometimes referred to as an "offset" boil sump or vapor generator (see Figure 7). Conveyorized and automated systems should be designed so that the vapor/air interface is minimized or only big enough to get the workload into and out of the unit's inlet and exit tunnels (see Figures 8, 9, and 10).

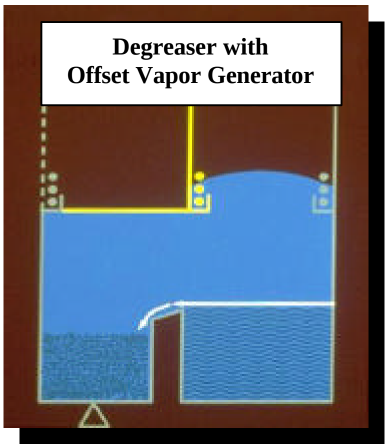

Figure 7

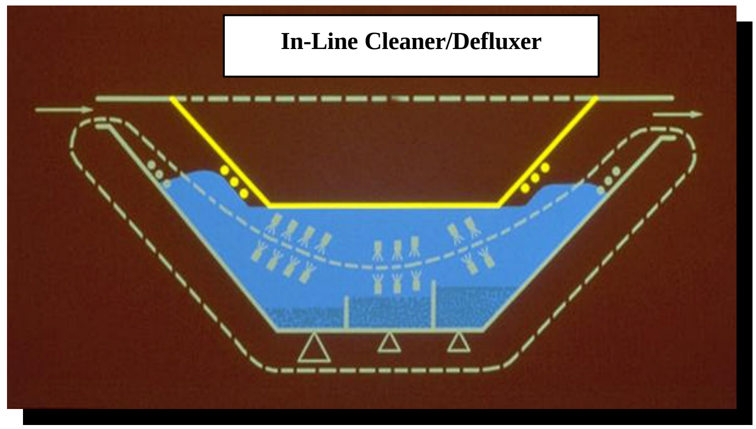

Figure 8

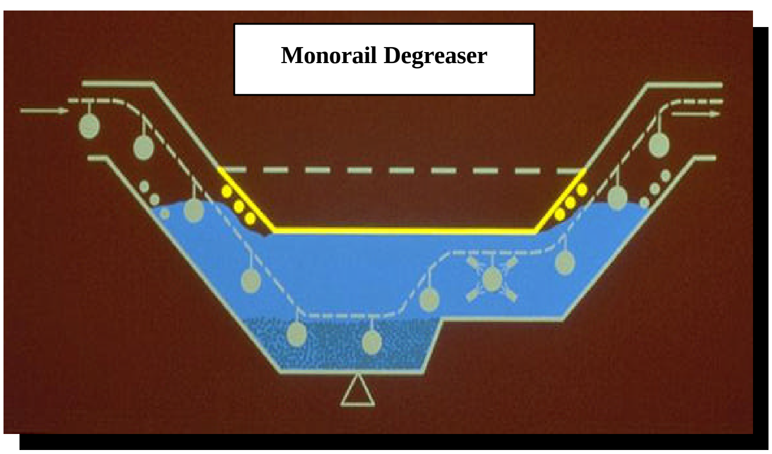

Figure 9

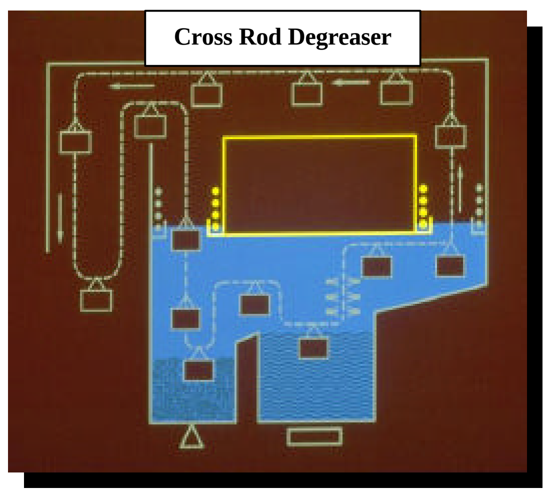

Figure 10

Covers:

Covers can also be used to minimize diffusional losses during idling periods, or when the equipment is shut down. The covers should be designed so they can be opened or closed with minimal disturbance to the vapor/air interface. One of the most important concepts in solvent conservation in a vapor degreaser is to protect the vapor blanket. The more the vapor blanket is disturbed or moves up and down, the more solvent is consumed. Covers should *never* be hinged; a sliding or rolling cover is preferable. (see Figure 11).

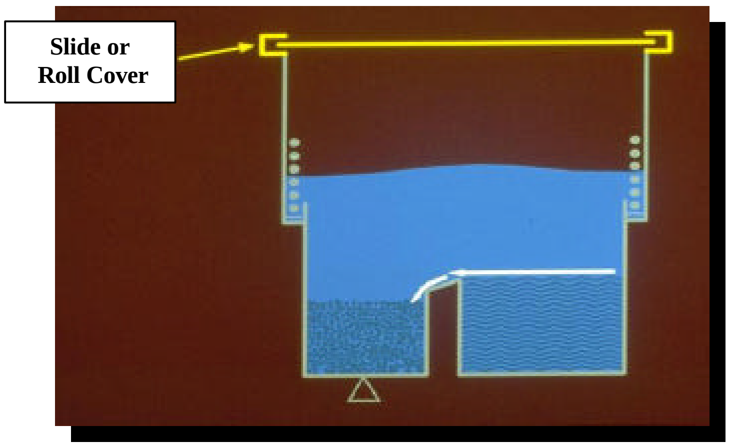

Figure 11

Cool Down Coils:

A liquid's evaporation rate is a function of vapor pressure, and in turn, a direct function of temperature. Cooling the solvent liquid as well as the air above the sumps during equipment downtime can minimize evaporation and diffusional losses. Cool-down coils are desirable, especially in large cleaning systems (see Figure 12). On small vapor degreasers where cool down coils are not practical, allowing the primary condensers and freeboard coils to operate while the boil sump heaters are off can accomplish a similar effect (check with the equipment manufacturer).

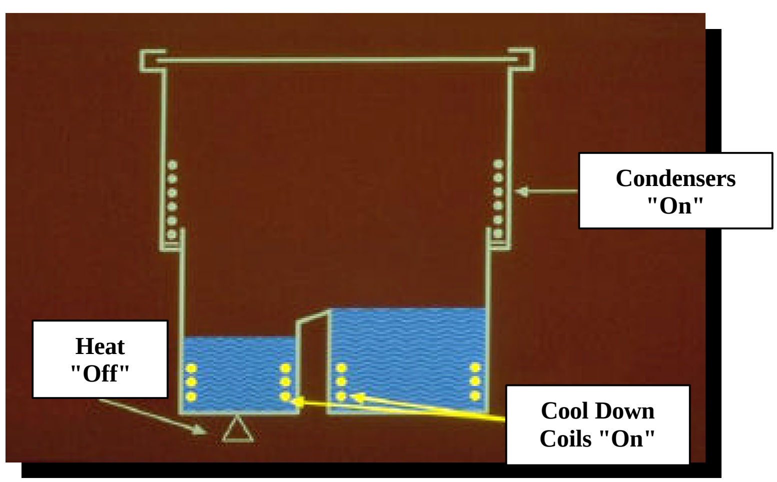

Figure 12

Automation and Work Enclosures:

The "human factor" is probably the greatest contributor to solvent loss versus any other factor in the vapor degreasing process. Automated or programmable work transports can help minimize solvent losses by eliminating the "human factor". Automation can provide consistent introduction and withdrawal of workload from the cleaning unit, while allowing the appropriate time for drying and at a rate (<10 feet/minute) that will minimize vapor/air turbulence (see Figure 13). Work transports with hood enclosures will further reduce solvent consumption and emissions by eliminating vapor/air disturbances caused by outside air currents (see Figure 14). Remember, any movement of the vapor blanket caused by operators or external influences will increase solvent consumption.

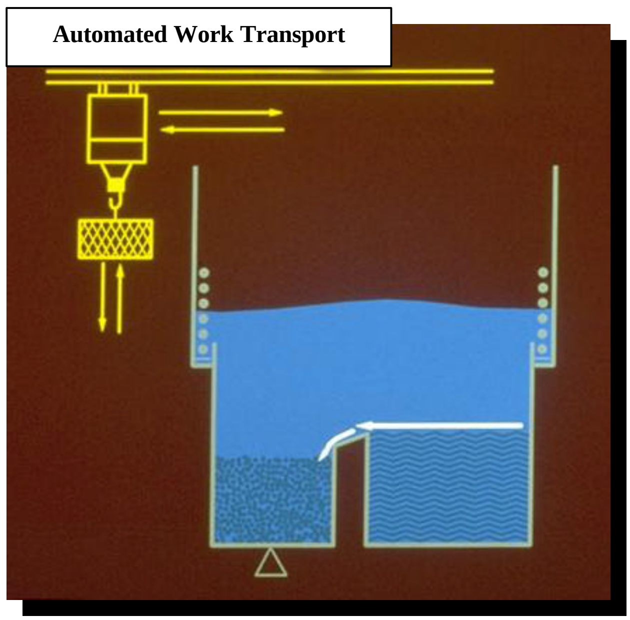

Figure 13

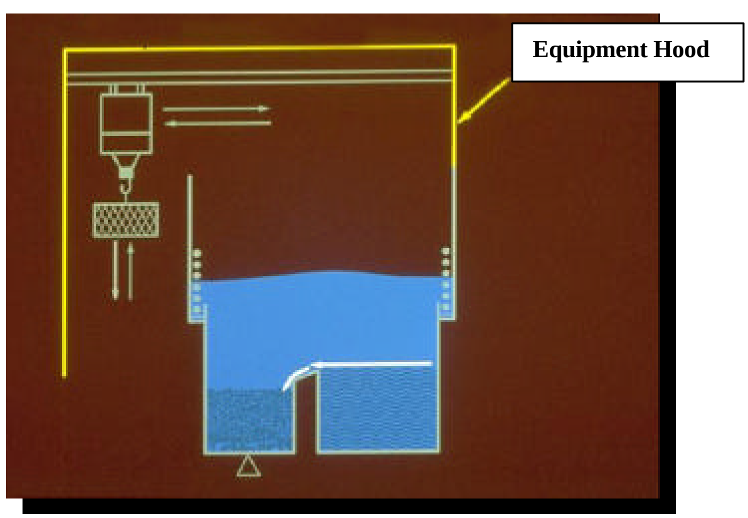

Figure 14

Ventilation /Carbon Adsorption:
Vapor degreasers designed according to prudent guidelines (and using the options presented here) will emit only minimal solvent when properly operated and maintained, thus eliminating the need for ventilation under normal conditions. Lip ventilation (see Figure 15) should be avoided when possible since it can dramatically increase solvent consumption by disrupting the air above the vapor blanket. Once the air above the vapor blanket becomes saturated with diffused solvent vapor, depending on temperature and humidity, it can hold no more solvent. If the "saturated" air above the vapor blanket is continually replaced with new air due to improper ventilation, solvent will continue to diffuse until it is saturated again. Ventilation, when necessary, should be designed in a manner to minimize vapor blanket/freeboard air disruption. All organic solvents are heavier than air and tend to "drift" or flow downward. Lip ventilation (see Figure 15) and vent "hoods" tend to increase solvent losses and consumption. Place vents *lower* than the top edge of the degreaser in order to allow the *heavy* vapors to flow down into the vent.

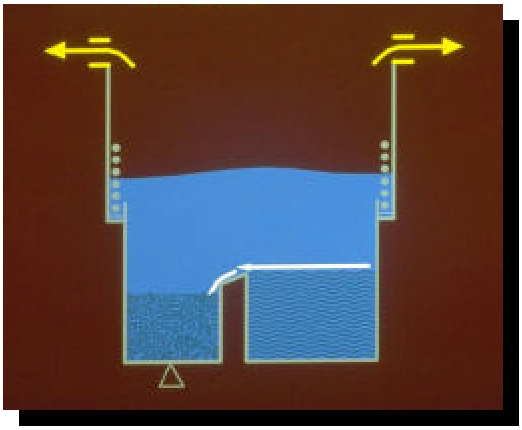

Figure 15

However, there *may* be some cases where a particular cleaning application may justify the use of lip vents when connected to an auxiliary carbon adsorption system. In these applications the lip vents will direct the organic solvent vapors to the carbon adsorption beds that will collect and recover emissions that *cannot be suitably minimized by other means*. Carbon adsorption should be the last resort since there are efficiency, solvent consumption, utility and maintenance limitations (see Figure 16).

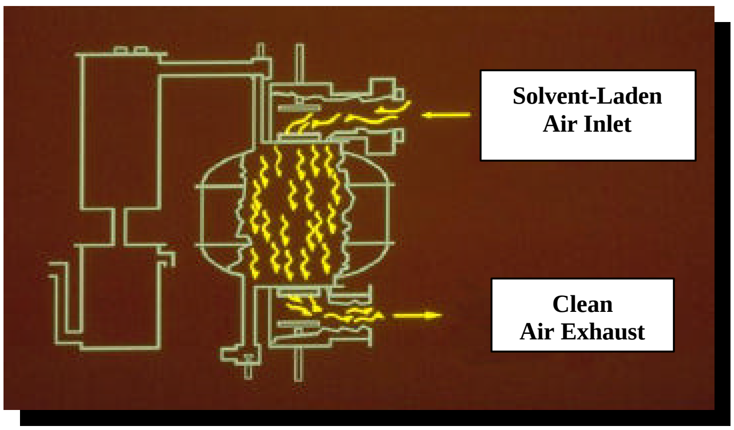

Figure 16

Safety Controls:

The appropriate safety controls should also be incorporated into the design of all vapor degreasers. A high-temperature sensor should be placed in the boil sump to shut the system down if the liquid level is too low, as a high temperature control for use in solvent reclamation, or if the heaters become too hot. Additional controls should be placed by the primary condensers and in the freeboard area to shut the system off if the vapor blanket is not in the proper position. Numerous other safety controls are available, depending on the system and regulations. Ultimately, all safety controls are meant to protect the employees by eliminating solvent emissions and preventing solvent decomposition if the system is not operating as designed. It is imperative that all safety controls be properly maintained, tested and checked to assure of appropriate operation (see Figure 17).

Dragout:

Dragout is the entrapment or retention of solvent by the workload being processed and is a major cause of solvent emissions. To keep dragout to a minimum, the workload *must* remain in the vapor zone, after the final cleaning step, long enough to drain any entrapped solvent and for the temperature of the workload to equilibrate with the temperature of the vapor blanket in order to dry. Work withdrawn before this equilibration will emerge wet with solvent condensate that will ultimately evaporate into the air (see Figure 18).

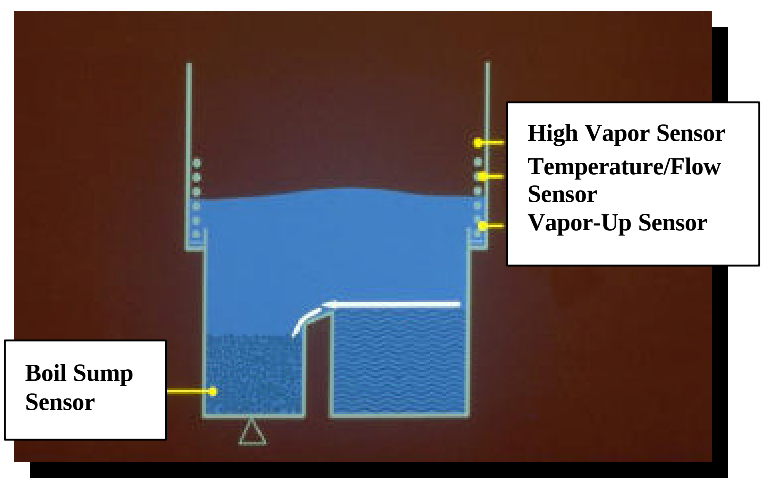

Figure 17

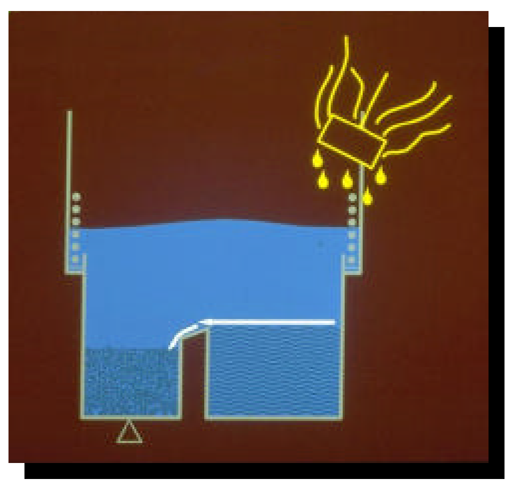

Figure 18

As discussed earlier, an automated work transport can minimize dragout losses by eliminating the "human factor" with a predetermined, programmed cleaning cycle. This will provide sufficient dwell time for the workload to equilibrate in temperature with the temperature of the vapor blanket (see Figure 13).

In actual use, under normal degreasing conditions, the temperature of the workload will *never* equilibrate exactly with the temperature of the vapor blanket. However, the closer the two are in temperature, the less dragout will occur. There are several things that can be done to speed the temperature increase of the workload:

1. Heat all liquid immersion sumps so that the workload is always heated and never cooled. Some people believe that the last immersion sump must be cool in order to lower the temperature of the workload and increase condensation or vapor rising before removing the workload from the vapor blanket. When a part is immersed in the liquid sump of a properly designed vapor degreaser, the clean solvent surrounds the part and enters all the cavities. If this process does not clean the part, it is doubtful that vapor rinsing will also be successful. Instead, heat or boil the last condensate sump to improve the scrubbing action and warm the immersed workload so it will dry faster in the vapor blanket and reduce dragout emissions.
2. Use either static or dynamic super-heated vapor drying. This concept involves heating the vapor blanket well above the boiling point of the solvent. The workload is exposed to this super-heated vapor upon removal from the final liquid immersion. The hot vapor rapidly increases the temperature of the workload to well above the boiling point of the solvent causing the it to boil and evaporate off the workload rapidly - totally eliminating any dragout (see Figure 19). Another concept incorporates the use of a “hot plate” or heated surface, under the vapor blanket. Once the cleaning cycle is complete, the basket or parts are placed on the “hot plate” in order to heat the parts above the boiling point of the solvent, eventually flashing off the solvent.

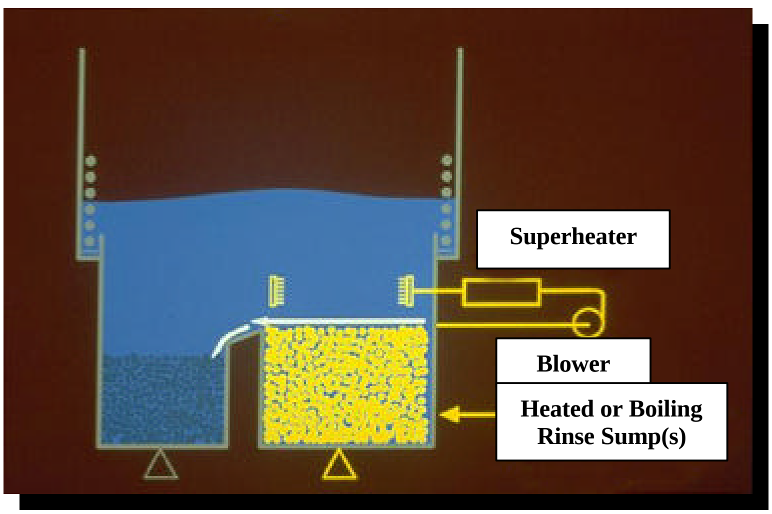

Figure 19

Leaks:

Leakage is a reflection of the workmanship put into building the cleaning system as well as how well it is maintained. Leaks can be a high source of emissions. A prudent maintenance program can eliminate leaks on a properly built unit. Leaks can be monitored simply by first visually inspecting the unit as well as the surrounding work area. Next, any equipment maintenance should be followed with an inspection using a halide meter, such as a TIF™ Halogen Leak Detector. Finally and as a *last resort*, hard-to-find leaks can be detected using a dye test. This test incorporates the use of a solvent soluble dye to make the leak more visible and should only be conducted by experienced personnel (see Figure 20).

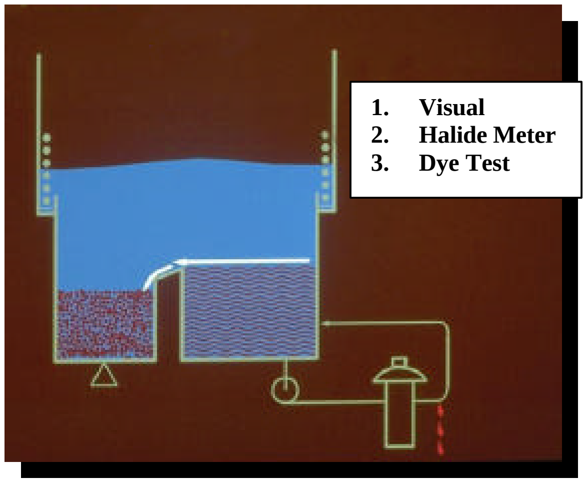

Figure 20

Work Practices

Appropriate work practices are imperative in the operation of vapor degreasers in order to minimize the amount of solvent consumed or lost during the cleaning process. A degreaser/defluxer should be located in a draft-free environment. Locating units near fans, vents, windows, doors or anything that will cause vapor/air turbulence will greatly increase the rate of solvent vapor emission (see Figure 21).

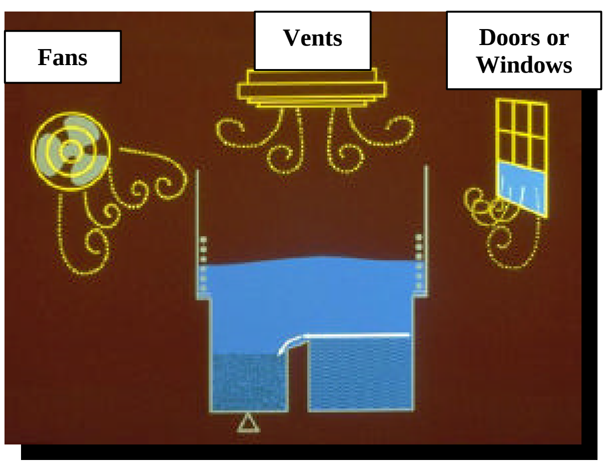

Figure 21

Spraying:

Spray cleaning should be avoided whenever possible. However, when required, spraying by spray lance or spray headers should be done deep within the vapor zone to avoid excessive disturbance of the solvent/air interface. Where applicable, high *volume* sprays should be considered over high *pressure* sprays. Spraying should also be avoided where the solvent can ricochet into the freeboard area. In addition, heated sprays will minimize the potential for thermal shock and vapor blanket collapse, along with its accompanying solvent loss (see Figure 22).

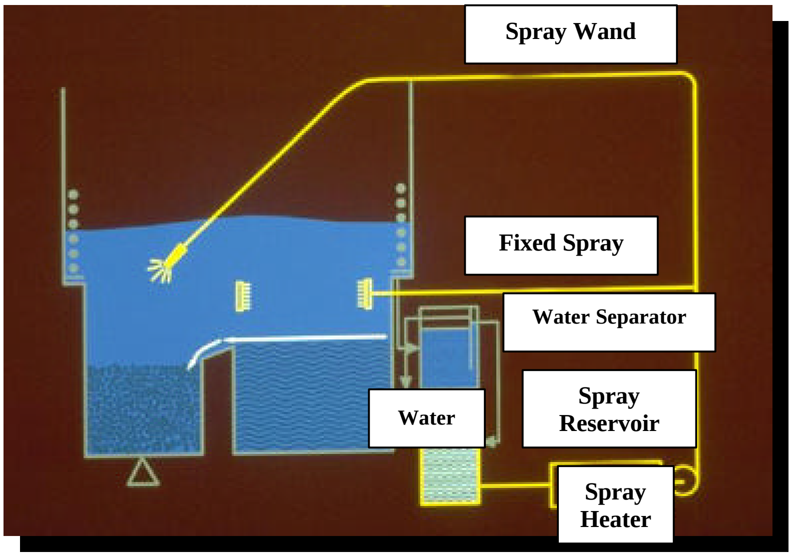

Figure 22

"Piston Effect":

Work areas above each sump, as measured in a horizontal plane, should be sufficient to avoid "piston effect" when the work is raised or lowered through the vapor zone (see Figure 23).

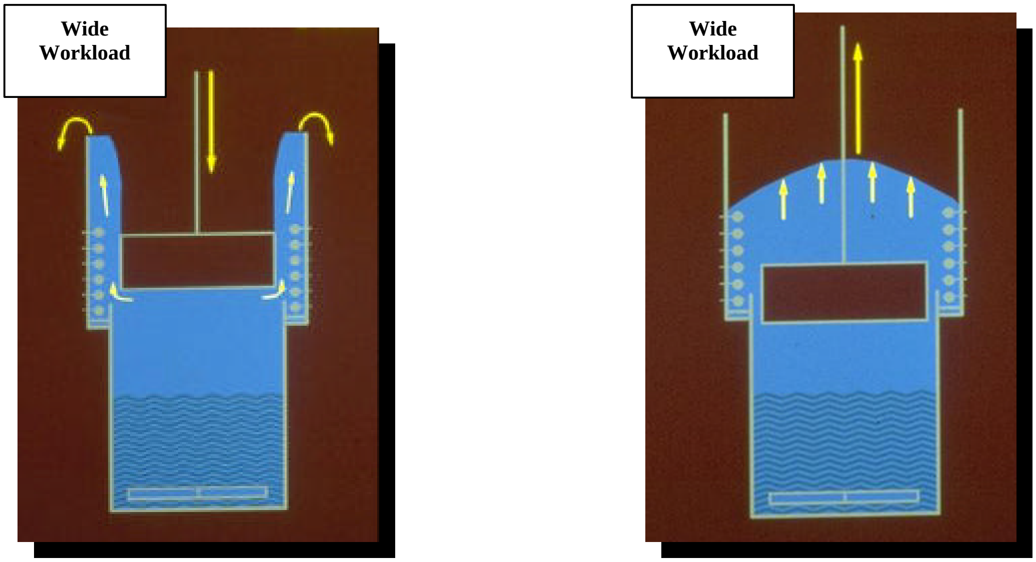

Figure 23

The horizontal cross section of the basket or work load should be no larger than 1/2 to 2/3 the horizontal cross section of the sump the basket or work load is being lowered into or over. The recommended maximum speed for work entry and removal as well as horizontal movement in a degreaser should not exceed ten feet per minute. Higher throughput rates can disturb the vapor and result in solvent loss (see Figure 24).

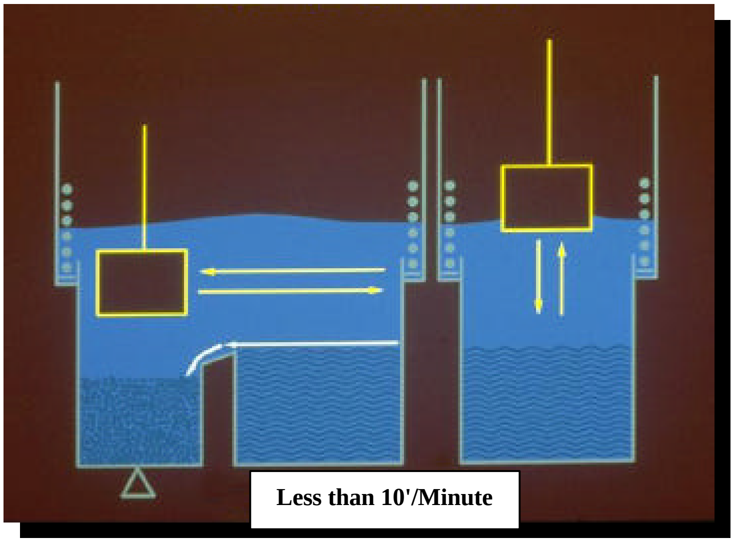

Figure 24

Careful attention should also be given to the design of work baskets and to the way the work is racked for cleaning so that liquid or vapor can drain freely. When racking parts that cup solvent, position them in a way that will allow for complete drainage. If this is impossible, consideration should also be given to rotating the baskets during the cleaning cycle. In addition, open mesh baskets that allow solvent vapors to pass through and around the parts, will help to minimize the piston effect (see Figure 25).

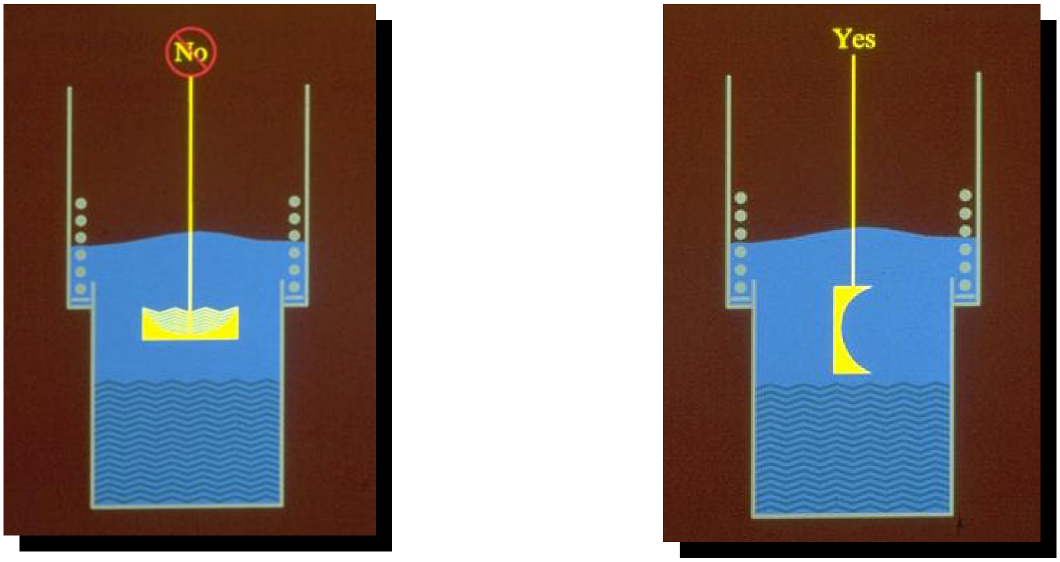

Figure 25

Solvent should be added to any degreaser with care, and in a manner that will create minimal disturbance to the vapor/air interface. Virgin solvent should be added to the rinse sump in order to flush any contamination to the boil sump. A hose or fill-line should be connected to the container of virgin solvent with the opposite end immersed below the liquid level of the rinse sump to minimize disruption of the vapor blanket (see Figure 26).

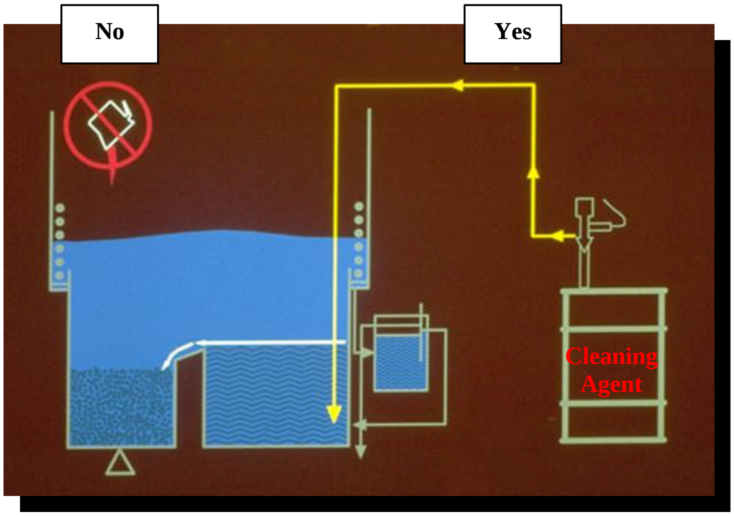

Figure 26

Solvent drums should be kept tightly sealed to prevent unnecessary evaporative losses or the introduction of unauthorized material that could prevent reclamation. Placing open funnels in empty drums for waste collection has been known to emit approximately one pound of solvent per day, eliminating possible reclamation of good solvent and unnecessarily emitting solvent. Drums should also be stored in an upright position with the bung end up to eliminate the possibility of a major spill or leak. Prior to opening a drum, the drum should be stored in the area of the vapor degreaser so that the temperature of the drum can equilibrate with the temperature of the work area. *Never* position any portion of your body *over* the drum when removing the drum caps or "bungs". Also, always allow pressure in the drum to be "vented" prior to completely removing the drum "bungs"

Reclamation and Recycling

Reclamation and recycling will significantly improve the lifetime of the solvent thus cutting solvent consumption. Many vapor degreasing solvents can be easily reclaimed for re-use.

Two-sump Vapor Degreaser:

Solvent reclamation and reuse may be achieved in a simple two-sump vapor degreaser. First, the safety controls must be checked, then, clean solvent must be removed from either the spray reservoir or condensate sump. The boil sump is then allowed to boil and vaporize solvent until either the level of the contaminated solvent approximately one inch from the top of the electric heaters, or until the boiling solvent starts to become viscous. Never run the distillation process to a point where the heating elements are exposed due to possible thermal decomposition of the solvent. Nor do you want to concentrate the contaminated solvent to a point where it is so viscous that it cannot be easily removed from the sump. The process must never be left unattended (see Figure 27). At the conclusion of the boil down operation, drain the dirty solvent out of the boil sump and place it in a suitable container for either disposal or additional recovery. Check the stabilizer/inhibitor levels (if applicable) of the distilled or recovered solvent as well as “secondary solvent” concentrations, in the case of azeotropes. Adjust these levels, per manufacturer’s recommendation, as necessary. Addition of stabilizer/inhibitor and/or "secondary solvent" to the distilled or recovered solvent should only be done by a knowledgeable and qualified employee who is familiar with the appropriate procedures and practices in order to avoid an unsafe situation. Refill the remainder of the degreaser to the appropriate levels and the degreaser is ready for continued operation.

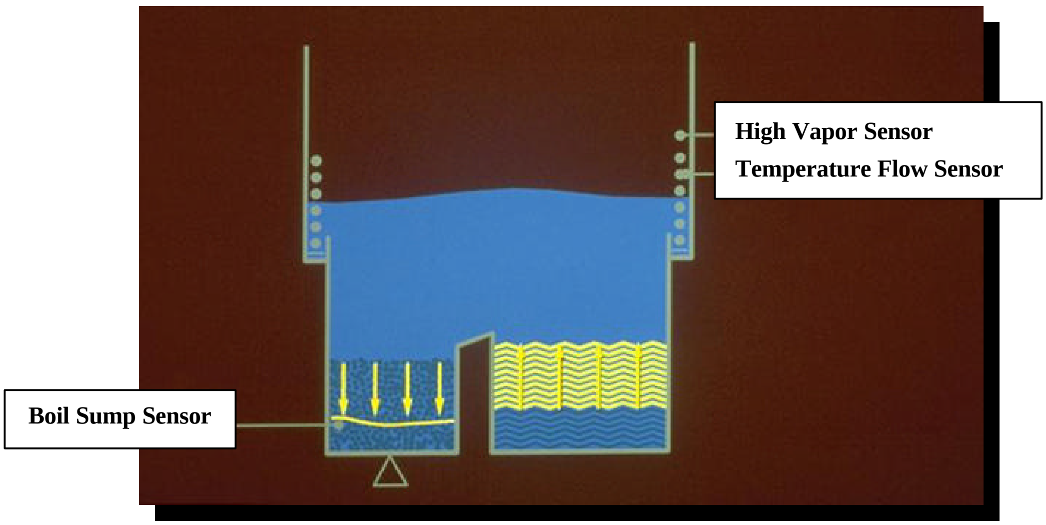

Figure 27

Auxiliary Still:

More sophisticated methods of in-house reclamation can be incorporated by using an auxiliary still attached directly to the degreaser and continuously operated. It is not possible to reclaim any solvent in a vapor degreaser or one plate auxiliary still back to virgin solvent specifications, but this is not necessary. The recovered solvent will be considerably cleaner than before reclamation and any low levels of contamination will be those introduced by the user's own cleaning process and should not be detrimental. Acid acceptance (where applicable) and “secondary solvent” levels, in the case of azeotropes, should be checked periodically and after reclamation. Doctoring the reclaimed solvent with stabilizer/inhibitor and/or "secondary solvent" should only be done by a knowledgeable and qualified employee who is familiar with the appropriate procedures and practices in order to avoid an unsafe situation. Simple systems like the one illustrated in Figure 28 are currently being used to recover and reconstitute solvents in industry today.

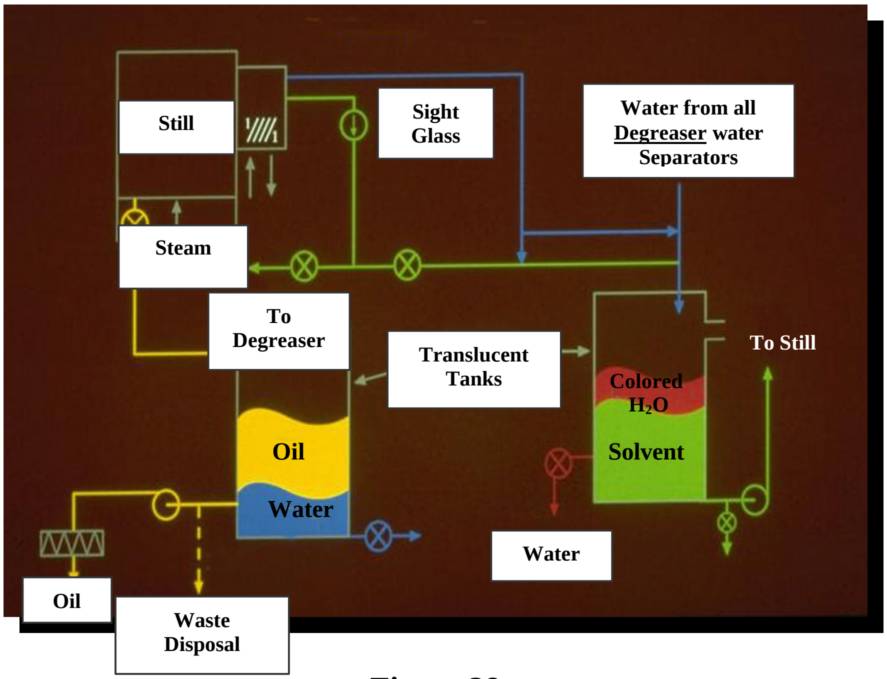

Figure 28

SUMMARY

The most important concept in vapor degreasing is protection of the vapor blanket. As a standard rule, solvent should always be kept inside the machine versus trying to collect it outside the machine.

Four simple steps may effectively control solvent loss:

1) Educate employees on design, use and maintenance of solvent and equipment.
2) Use all means available to protect disruption of the vapor blanket.
3) Eliminate or reduce solvent dragout.
4) Reclaim and recycle solvent whenever possible.

For more detailed information on all of the points proposed in this paper, contact your ChemLogic representative at 512-426-5728 or www.vapordegreasing.info

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