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Project Summary

Evaluation of Solvent Loss from Vapor Degreaser Systems

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The principal objectives of this project are to develop and implement a program for assessing solvent loss from degreasing systems of various designs, and to report the test conditions, procedures, results, and conclusions in a form usable by air pollution agencies and industry.

Tests were performed from October 1978 to July 1979 to evaluate the effects of different variables on the rate of solvent loss from degreasers. The variables tested include the following degreaser modifications and operating conditions:

- **Freeboard ratio**
- **Load cross-sectional area**
- **Refrigerated freeboard chiller (RFC)**
- **Hoist speed**
- **Lip exhaust**
- **Crosscurrent air velocity**
- **Degreaser size**
- **Solvent type**
- **Lid**

The cost of each modification was analyzed. These analyses were based on capital costs, annual expenses, and solvent saved because of the modification. The evaluations of solvent loss or savings were based only on the degreaser operating period; idle time (the solvent boiling and cooling period) was disregarded.

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).

Introduction and Methods

The U.S. Environmental Protection Agency has undertaken a study to evaluate the pollution reduction capabilities of vapor degreasers and new developments in vapor degreasing systems and operations.

The tests were conducted in a laboratory equipped with temperature, humidity, and ventilation controls. All the variables (except increases in crosscurrent air velocity) were tested under calm air conditions at an average velocity of 0.1 m/s (20 ft/min). All the tests but one were conducted in two typical degreasers (A and B). In one test a smaller degreaser (C) was used in place of Degreaser B.

Degreasers A and B had nearly the same specifications. Degreaser A was equipped with a refrigerated freeboard chiller (RFC I) that operated at temperatures above 0°C (32°F). Degreaser B was equipped with a chiller (RFC II) that operated at temperatures below -18°C (0°F). The degreasers had nearly equal top openings of 1.4 m^2 (15 ft^2). The other design difference was the location of the primary condenser coil. Degreaser A was equipped with a spiral condenser coil located horizontally along one end of the degreaser; Degreaser B was equipped with coil tubing wrapped

around the perimeter of the degreaser. Degreaser C had a top opening of 0.35 m^2 (3.78 ft^2), a 75 percent freeboard ratio, and a primary condenser similar to that of Degreaser B.

The two principal degreasers were used simultaneously in each test to verify the results and to eliminate the effect of physical conditions of the units. (Although Degreasers A and B had nearly equal top openings, their length and width dimensions were different.) The degreasers were virtually isolated from all extraneous variables that might affect solvent loss. Ambient air conditions were monitored continuously throughout the tests.

Each degreaser had a programmed hoist system with a 6.5-minute cycle and a simulated load cleaning capacity of about 454 kg/h (1000 lb/h). The load was a clean metal pipe placed in a basket.

The solvents used in the tests were 1,1,1-trichloroethane (TE) and methylene chloride (MC). The primary method of detecting solvent loss was to weigh each degreaser at intervals during the testing period. A relationship of time versus weight was developed and quantified by a least-squares regression analysis.

The degreaser modifications were evaluated by comparing the ranges of solvent loss under a given test condition. For each test, the overall range was established by using the two degreaser readings as the extremes of the range.

A typical degreaser with no controls was established as a base case and the standard against which the reduction capabilities of the various modifications were evaluated. The range of the solvent loss reduction capability of a modification was established by subtracting the specific solvent loss reading from the reading for the base case for each degreaser.

Effectiveness of Modifications

Tables I and II present a summary of the solvent reduction capabilities of different variables on operating degreasers using TE and MC.

Freeboard Ratio

Increases in freeboard ratio degreased solvent loss (i.e., increased solvent loss reduction) from operating degreasers under all conditions tested. The exception was tests of higher hoist speed (0.08 m/s or 16 ft/min) and normal load (50 percent load area); under these conditions, no effect was seen when the freeboard ratio exceeded 75 percent. No indication of decreasing effectiveness was found with TE, but tests with MC indicated a decreasing effectiveness as freeboard ratio increased. With the latter solvent, more solvent loss reduction was achieved when the larger load was used (70 percent load area).

Load Area

Solvent loss increased when an abnormally large load (70 percent ratio of basket cross-sectional area to degreaser top opening area) was used in place of a normal load (50 percent ratio, which is typically specified in the operating manual). The weight of the load was not increased in these tests. The increase in solvent loss was about 5 to 23 percent from degreasers using TE at 0.04 m/s (8 ft/min) hoist speed; however, it was about 50 percent from degreasers using TE at 0.08 m/s (16 ft/min) and from degreasers using MC at 0.04 m/s (8 ft/min).

Refrigerated Freeboard Chiller

No significant solvent loss reduction occurred when either of the refrigerated freeboard chillers was used on an operating degreaser with TE and a 50 percent load area at 0.04 m/s (8 ft/min). When the freeboard ratio was changed from 50 to 75 percent, RFC II operating at -29° to -40°C (-20° to -40°F) achieved an additional 20 percent reduction in solvent loss under these same conditions. The chillers did, however, reduce solvent loss from operating degreasers with either solvent and with a 70 percent load area at 0.04 m/s (8 ft/min). The RFC I either increased solvent loss or made no difference on a degreaser operating with MC and a 50 percent load area; RFC II decreased solvent loss

Table I. *Effect on Solvent Loss Reduction of Various Modifications to an Operating Degreaser Using 1,1,1-Trichloroethane (percentage of reduction or increase over the base case[a])*

	Hoist speed, 0.04 m/s[c]							*Hoist speed, 0.08 m/s[d]* RFC: Off	
	Load area:[e] 50%				*Load area: 70%*				
Freeboard ratio,[b] %	*RFC Off*	*RFC I 1° to 2°C[g]*	*RFC II -23° to -32°C[h]*	*RFC II -29° to -40°C[i]*	*RFC: Off*	*RFC I 1° to 2°C*	*RFC II -23° to -32°C*	*Load area: 50%*	*Load area: 70%*
50	*0[a]*	*5*	*8*	*2*	*(5-23)[j]*		*14*	*(11)*	*(50)*
75	*7-25*	*8*	*18*	*46*				*16*	
100	*47-53*							*9*	
125		*34*	*47*	*51*	*(3)-4*	*27*	*34*	*20*	*(5)*

[a] *Base case: FR = 50, RFC: Off, hoist speed = 0.04 m/s, load cross-sectional area = 50%.*
[b] *Ratio of freeboard height to degreaser width.*
[c] *8 ft/min.*
[d] *16 ft/min.*
[e] *Ratio of load cross-sectional area to degreaser top opening.*
[f] *Refrigerated freeboard chiller.*
[g] *34° to 36°F.*
[h] *-10° to -25°F.*
[i] *-20° to -40°F.*
[j] *Percentages in parentheses represent increases in solvent loss over the base case.*

Table II. *Effect on Solvent Loss Reduction of Various Modifications to an Operating Degreaser Using Methylene Chloride at a Hoist Speed of 0.04 m/s*[a]

		(percentage of decrease or increase over the base case[b])				
		Load area:[d] 50%			Load area: 70%	
Freeboard ratio,[c] %	RFC:[e] Off	RFC I 1° to 2°C[f]	RFC II -29° to -40°C[g]	RFC: Off	RFC I 1° to 2°C	RFC II -29° to -40°C
50	0	(4)[h]	16	(53)	(39)	(5)
75	17-22	5	46			
125	25	25	61	9	22	44

[a]8 ft/min.
[b]Base case: FR = 50, RFC: Off, hoist speed = 0.04 m/s, load cross-sectional area = 50%.
[c]Ratio of freeboard height to degreaser width.
[d]Ratio of load cross-sectional area to degreaser top opening.
[e]Refrigerated freeboard chiller.
[f]34° to 36°F.
[g]-20° to -40°F.
[h]Percentages in parentheses represent increases in solvent loss over the base case.

under these conditions. Further requirements are recommended to explain these phenomena.

Hoist Speed

Tests on degreasers having 100 percent or more freeboard ratio and cleaning a normal load area of 50 percent (using TE solvent) showed greater solvent losses at 0.08 m/s (16 ft/min) than at 0.04 m/s (8 ft/min). At all freeboard ratios, tests using a load area of 70 percent showed greater solvent losses at the higher speed.

Lip Exhaust

Tests were conducted on an operating degreaser equipped with an exhaust system and using MC as the solvent and a hoist speed of 0.04 m/s (8 ft/min). Total solvent loss (through the exhaust system and the top opening) was increased by more than 100 percent at an exhaust rate of 0.25 m^3/s per m^2 (50 ft^3/min per ft^2) and by about 150 percent at 0.5 m^3/s per m^2 (100 ft^3/min per ft^2).

Crosscurrent Air Velocity

No significant differences in solvent loss were found when air velocity across the degreaser top was increased from 0.1 to 0.2 m/s (20 to 40 ft/min). At 0.26 m/s (52 ft/min), however, solvent loss increased by more than 100 percent.

Degreaser Size

Tests were conducted with two degreasers of different sizes using TE and a 50 percent load area at 0.04 m/s (8 ft/min) hoist speed. The solvent loss from the smaller degreaser (0.35 m^2 or 3.78 ft^2 top open area) was about 80 percent less than the loss from a larger degreaser (1.4 m^2 or 15 ft^2 top open area). The solvent loss per unit of top open area was independent of degreaser size.

Solvent Type

No differences in solvent loss were found based on the use of TE or MC.

Lid

An idle degreaser has less solvent loss than an operating degreaser. Use of a lid further reduced solvent loss from 0 to 65 percent when TE was the solvent and 35 percent when MC was the solvent.

Idle Degreasers

Tests using MC showed that increased freeboard ratio was not effective in reducing solvent loss from idle degreaser holding nonboiling solvent. An increase in freeboard ratio from 50 to 75 percent was effective in reducing solvent loss from an idle degreaser holding boiler MC. An increase in freeboard ratio beyond 75 percent, however, did not achieve any further effectiveness.

The use of RFC I (>0°C or >32°F) did not affect solvent loss from an idle degreaser using nonboiling MC; the use of RFC II at -29° to -40°C (-20° to -40°F) increased solvent loss under the same conditions. RFC I was ineffective, whereas RFC II when operated at -29° to -40°C (-20° to -40°F) showed a solvent loss reduction capability of 25 to 30 percent on idle degreasers holding boiling MC.

Economic Analysis

Cost analyses for each modification were based on capital costs, annual expenses, and solvent saved because of the modification. The evaluations of solvent loss or savings were based only on the degreaser operating period; idle time (the solvent boiling and cooling period) and disregarded.

Tables III and IV present cost savings or additional expenses due to the modification of operating degreasers using TE and MC. The costs shown were based on the operation of the degreasers for one shift per day.

Increased freeboard ratio is the only modification to a normal degreaser that shows an economic benefit. Capital costs are low and annual operating costs are negligible. The payback of capital occurs in a time period shorter than the life of the equipment. As a result, the savings in solvent loss are substantially greater than the expenses incurred by the modification.

Table III. *Annual Savings Resulting from Modifications to a Degreaser Using 1,1,1-Trichloroethane and Operating Only One Shift Per Day[a,b] (1979 dollars)*

	Hoist speed, 0.04 m/s[c]						Hoist speed, 0.08 m/s[d] RFC: Off	
	Load area: 50%[e]			Load area: 70%				
Freeboard ratio, %	RFC:[f] Off	RFC I 1° to 2°C[g]	RFC II -23° to -32°C[h]	RFC II -29° to -40°C[i]	RCF. Off	RFC I 1° to 2°C	RFC II -23° to -32°C	Load area: 50%	Load area: 70%
50	0	(834)[j]	(997)	(1082)	(87-355)		(929)	(166)	(760)
75	51-291	(778)	(1031)	(523)				168	
100	629-686							56	
125		(590)	(521)	(260)	(34-133)	(586)	(735)	197	(171)

[a] *Profit due to solvent savings less the cost and operation of modification.*
[b] *Lost capacity resulting from increase in freeboard ratio not included in analysis.*
[c] *8 ft/min.*
[d] *16 ft/min.*
[e] *Ratio of load cross-sectional area to degreaser top opening.*
[f] *Refrigerated freeboard chiller.*
[g] *34° to 36°F.*
[h] *-10° to -25°F.*
[i] *-20° to -40°F.*
[j] *Values in parentheses represent losses.*

Table IV. *Annual Savings Resulting from Modifications to a Degreaser Using Methylene Chloride and Operating Only One Shift Per Day at a Hoist Speed of 0.04 m/s (8 ft/min)[a,b] (1979 dollars)*

	Load area: 50%[c]			Load area: 70%		
Freeboard ratio, %	RFC:[d] Off	RFC I 1° to 2°C[e]	RFC II -29° to -40°C[f]	RFC: Off	RFC I 1° to 2°C	RFC II -29° to -40°C
50	0	(1179)[g]	(902)	(535-743)	(1310)	(1191)
75	173-186	(887)	(522)			
125	172-289	(733)	(354)	0-13	(759)	(591)

[a] *Profit due to solvent savings less the cost and operation of modification.*
[b] *Lost capacity resulting from increasing freeboard ratio not included in analysis.*
[c] *Ratio of load cross-sectional area to degreaser top opening.*
[d] *Refrigerated freeboard chiller.*
[e] *34° to 36°F.*
[f] *-20° to -40°F.*
[g] *Values in parentheses represent losses.*

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The complete report, entitled "Evaluation of Solvent Loss from Vapor Degreaser Systems," (Order No. PB 81-176 398; Cost: $3.50 (microfiche only), subject to change) will be available only from
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