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Arbejdsrapport fra Miljøstyrelsen

Waterbased cleaning of mixing vessels

Cleaner Technology in the Lacquer and Paint Industry

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Miljø- og Energiministeriet

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Preface

This report describes possibilities for using water-based cleaning in the lacquer and paint industry. The water-based cleaning is an alternative to the traditional cleaning with solvents causing problems in the working environment as well as VOC emissions to the surrounding environment.

VOC regulation according to the Danish legislation and EC directives will be summarized by way of introduction. This regulation will update the interest for using water-based cleaning where it is technically and financially possible.

The possibilities are being illustrated by means of laboratory tests and full-scale tests. Moreover, experiences from suppliers of cleaning plants concerning establishment and operation of the plant as well as experiences with possible alternative cleaning agents are described. Examples of financial comparison of alternatives are included in the report.

Previous studies made by Teknos Technology A/S in 1997 will form the basis of the project.

The description of the cleaning agents and test methods in this report will inspire companies within the lacquer and paint industry to establish their own basis for decisions.

The project has been carried out by financial support from the Council concerning recycling and less polluting technology, with the Danish Paintmakers' Association as project manager.

Fichtner · Carl Bro a|s has been the consultant of the Danish Paintmakers' Association regarding the implementation of the project. Employees from Fichtner GmbH & Co. KS in Germany and Carl Bro a|s in Denmark have participated as consultants on the project.

The project has been followed by a group of experts with participation of:

Ole E. Jensen	Teknos Technology A/S
Rikke Østergaard	Teknos Technology A/S

Further employees from Teknos Technology A/S have supplemented on relevant sub-fields.

Two suppliers of cleaning technology, Renzmann in Germany and Riobeer in Switzerland have kindly participated in laboratory tests. Further, the company Renzmann has placed equipment at our disposal for a number of test in full-scale. Akzo Nobel Coatings GmbH in Berlin has placed an established plant with water-based cleaning (sodium hydroxide) at our disposal for inspection and has kindly informed about operation experiences.

Besides, a responsible steering committee has been appointed consisting of:

Erik Thomsen	The Danish EPA
Lilian Petersen	The Danish Directorate for National Labour Inspection
Steen Mejlby	SiD (The General Workers Union in Denmark)
Finn Toft Jensen	The County of Vejle (Association of County Councils in Denmark)
Vibeke Plambeck	The Danish Paintmakers' Association
Jørgen Vineke	Fichtner · Carl Bro a|s

Sammenfatning og konklusioner

Som resumé gengives tekstdele fra projektets artikel i publikationen "Ny Viden", der udgives af Miljøstyrelsen.

Vandbaseret rengøring – et reelt alternativ

Lak- og farveindustrien kan anvende vandbaseret rengøring for en række lak- og malingstyper. Herved vil nuværende brug af opløsningsmidler kunne reduceres eller eventuelt helt undgås med klare fordele for arbejdsmiljøet og det ydre miljø. For mange lak- og malingstyper vil en vandbaseret alkalisk rengøring være konkurrencedygtig med den opløsningsmiddel baserede. Specielle lak- og malingstyper kan naturligt udløse højere udgifter.

Muligheder og begrænsninger er beskrevet i en rapport, der redegør for en række forsøg i laboratorieskala og i fuldskala. Rapporten kan give inspiration til virksomheder, som ønsker at opstille eget beslutningsgrundlag.

Brancheprojekt i lak- og farveindustrien

Baggrund og formål
Lak- og farveindustrien i Danmark består af i alt ca. 20 malevareproducenter samt ca. 10 lim- og fugemasseproducenter.

Branchen har de senere år arbejdet med muligheder for begrænsning af VOC emissioner. Dette er foregået dels gennem produktudvikling for at reducere VOC indholdet i produktet og dels ved begrænsende tiltag i produktionsleddet på branchens virksomheder.

Foreningen for Danmarks Lak- og Farveindustri (FDLF) har i 1994-1995 gennemført en kortlægning af mulighederne for anvendelse af renere teknologi i lak- og farveindustrien. Rapport om denne kortlægning er tidligere udsendt som *Brancheorientering for lak- og farveindustrien nr. 5, 1996 fra Miljøstyrelsen.*

I fortsættelse af kortlægningen i 1994-1995 har FDLF gennemført et projekt med det formål at verificere mulighederne for at anvende vandbaseret rengøring af blandekar og andet udstyr.

To leverandører af rengøringsudstyr Renzmann i Tyskland og Riobeer i Schweiz har velvilligt deltaget i laboratorieforsøg. Firmaet Renzmann har endvidere stillet udstyr til rådighed for en række forsøg i fuldskala. Akzo Nobel Coatings GmbH i Berlin har stillet et etableret anlæg med vandbaseret rengøring (natriumhydroxid) til rådighed for besigtigelse samt velvilligt fortalt om driftserfaringer.

Den danske virksomhed, Teknos Technology A/S, har deltaget i en teknikergruppe, som har fulgt projektet.

Miljøstyrelsen, Direktoratet for Arbejdstilsynet, SiD, Amtsrådsforeningen og FDLF har været repræsenteret i en styregruppe.

Medarbejdere fra Fichtner GmbH & Co. KG i Tyskland og Carl Bro as i Danmark har været konsulenter på projektet.

Projektets målgruppe er branchens virksomheder samt miljømyndighederne. Muligheden for at gennemføre projektet er skabt af økonomisk støtte fra Miljøstyrelsen.

Forløbet

Projektet
Der er indledningsvist gennemført laboratorieforsøg tilrettelagt udfra erfaringer med rengøringsprocesser hos leverandører af vaskeanlæg. I forsøgene indgår en række udvalgte lak- og malingstyper fra Teknos Technology A/S. Laboratorieforsøgene har efterfølgende været basis for tilrettelæggelse af forsøg i fuldskala med henblik verificere de reelle muligheder for at indføre den vandbaserede rengøring hos branchens virksomheder.

Omkring 10 virksomheder og leverandører er interviewet omkring deres erfaringer med vandbaseret rengøring ligesom erfaringer fra en afholdt workshop (hos Renzmann i Tyskland) indgår i projektet.

Vandbaseret rengøring er mulig – men med begrænsninger

Hovedkonklusioner
Erfaringsopsamling og gennemførte forsøg viser, at vandbaseret rengøring kan være et reelt alternativ til den traditionelle rengøring med opløsningsmidler. Der er således umiddelbart muligheder for forbedringer i arbejdsmiljøet og begrænsning af VOC emissioner til det ydre miljø.

Den enkelte virksomhed skal imidlertid ind og vurdere relevante rengøringsmetoder og -medier ud fra aktuelle lak- og malingstyper. Eventuelt kan det være nødvendigt at vælge flere metoder og medier, såfremt virksomhedens produktmix er meget forskelligartet og varieret.
Det vil også være relevant at lade eksisterende kartyper, -materialer og -størrelser indgå i en samlet vurdering. Aftapningshaner kan kræve supplerende rengøring. En generel udskiftning af kar vil være meget bekostelig.

Fra erfaringsopsamling ved interviews kan der resuméres følgende:

- Vandbaseret rengøring sker med en varm alkalisk opløsning (natriumhydroxid eller specialprodukt)
- Rengøring kan være vanskelig ved indtørring af produktet. Mekanisk påvirkning kan være nødvendig eventuelt suppleret med manuel slutrengøring
- Alle firmaer har gennemført forsøgsprogrammer inden implementering i fuldskala
- Leverandører af vaskeanlæg anbefaler normalt både laboratorieforsøg og fuldskalaforsøg med de konkrete produkter forud for en etablering af anlæg.

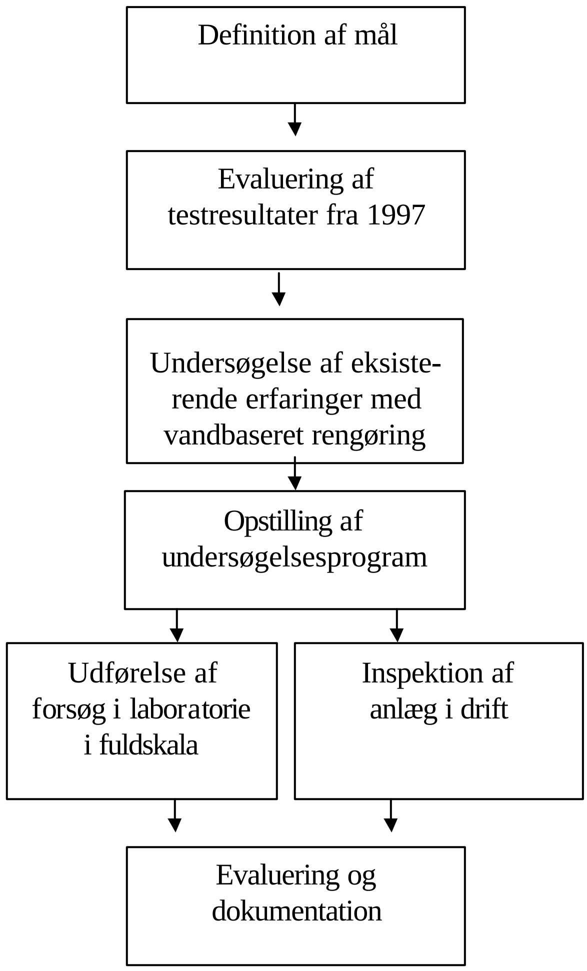
Procedure, metode og undersøgelsesprogram

Projektet

I forbindelse med projektet ”Renere teknologi i lak- og farveindustrien” undersøgte Teknos Technology A/S i 1997 muligheder for at anvende vandbaseret rengøring. Mulighederne så lovende ud i laboratoriet, men der opstod problemer med at verificere mulighederne i fuldskala.

Det tidligere grundlag danner basis for nye forsøg, hvor erfaringer fra bl.a. Tyskland indgår.

Metode og procedure fremgår af Figur 1.



Figur 1
Procedure og metode.

Da opstilling af anlæg til fuldskalaforsøg hos Teknos Technology A/S ville blive bekostelig og tidskrævende er forsøgene gennemført på firmaet Renzmanns eget testanlæg på udviklingscenter i Tyskland. Forsøgene er gennemført under realistiske forudsætninger og med en række lak- og malingstyper fra Teknos Technology’s produktsortiment. Forsøgene er fulgt af en medarbejder fra Teknos Technology A/S samt en repræsentant fra Fichtner · Carl Bro as.

Der er gennemført forsøg med 17 vådlakker (hurtigt lufttørrende) til industriel formål. Både vandbaserede og opløsningsmiddelbaserede lakker er repræsenteret.

Forsøgene er gennemført på kar af henholdsvis rustfrit stål og almindelig stål samt med såvel våd maling som maling efter 5 dages tørring.

Forsøgene er gennemført med 3 typer af udstyr:

Vaskeanlæg af typen "SKM"
Der er tale om et lukket system til rengøring af kar af varierende diameter. Der rengøres ved hjælp af roterende spraysystem på både inder- og yderside af karret. Mulige vaskemedier er vand, alkaliske midler (eks. Natriumhydroxid) og opløsningsmidler.

Anlægget har integreret tank for rengøringsmiddel (800 l) og udblæsning af rest-rengøringsmiddel, således at karret efterlades tørt. Rengøringen finder sted under tryk (8-80 bar) og ved forhøjet temperatur (ca. 60-80°C) for vand og kaustiske rengøringsmidler.

Ved rengøring af kar med aptapningshane kan supplerende manuel rengøring af denne være nødvendig.

Systemet vil kræve efterfølgende behandling af spild. Ved anvendelse af opløsningsmidler kræves der destillationsudstyr. Spildevandsrensning/fældning vil komme på tale ved anvendelse af vand og kaustiske rengøringsmidler.

"Robus" vaskeudstyr med børster
Systemet er til rengøring af inderside af kar og beholdere med aftapningshane. Rengøringen foregår med roterende børster, som kan varieres afhængig af kar og beholder type.

En tætsluttende adapter fungerer som låg under rengøringsprocessen. Systemet er til trykløs rengøring med solvent (eller vand) og foregår normalt ved rumtemperatur. En efterfølgende tørring af karret er muligt. Rengøringsmediet recirkulerer og vil på et tidspunkt kræve destillationsudstyr for behandling af spild (opløsningsmidler) eller spildevandsrensning/fældning (vandbaseret).

Trykspulingsudstyr - type "SP50 / SP80"
Systemet er til rengøring af inderside af containere og transporttanke med aftapningshane.

Rengøringen foregår ved højtryksspuling ved 50 bars tryk ved brug af solvent og 80 bar ved brug af vand som rengøringsmedie. Der kræves en tætsluttende adapter som låg tilpasset hver enkel beholder container/ tanktype. Rengøringsmediet recirkulerer og vil på et tidspunkt kræve destillationsudstyr for behandling af spild (opløsningsmidler) eller spildevandsrensning/fældning (vandbaseret).

Til forsøg i fuldskala er anvendt er følgende 3 rensemedier:

- *Stripper 303 G/E (fra Foster Chemicals GmbH)*
  Alkalisk blanding af glycolethere og kaliumhydroxid i koncentration 5-6%
- *Natriumhydroxid-opløsning, 12%*
- *Teknosolv 601(fra Teknos Technology A/S)*
  Blandingsfortynder til rensning

Der er for de enkelte anlæg valgt faste parametre ud fra Renzmann's erfaringer. Derudover er forsøgene gennemført med kombinationer af kar i rustfrit/alm. sort stål, lakfilm tør/våd, vaskemedie og vasketid. Tør lakfilm er efter tørring/hærdning i 5 dage. De talrige kombinationer kan grupperes efter anlægstype i forsøgsrække a, b og c.

De enkelte kombinationer er afprøvet på en række lak- og malingstyper udvalgt af Teknos Technology A/S. De valgte typer er angivet sammen med forsøgsresultaterne i Tabel 2.

Vandbaseret rengøring (Stripper 303 G/E og NaOH-opløsning) er gennemført i vaskeanlæg SKM. Til brug for sammenligning er de samme lak- og malingstyper rengjort i udstyr med børster eller trykspuling ved brug af blandingsfortynder.

Udover anvendelse som sammenligningsgrundlag til vandbaseret rengøring kan forsøgene med blandingsfortynder sige noget om effekt af forskellige tryk og rengøringstider.

Forsøgskombinationerne er angivet i Tabel 1.

Tabel 1

Forsøgsparametre og varianter.

A – Vaskeanlæg af typen ”SKM”

Faste parametre:

- Rengøring af opløsningsmiddelholdige og vandfortyndbare lakker samtidigt
- Vaskemedie temperatur på 75-80 ^{o}C
- Forbrug af vaskemedie på 3-5 l
- Forbrug af skyllevand på ca. 40 l

For-søg	Ståltype på kar		Lakfilm		Vaskemedie		Tryk			Tid		
	Rustfrit	Alm. sort	Tør	Våd	Alk. stripper	NaOH-opl.	1 bar	10 bar	50 bar	5 min.	15 min.	30 min.
a1	X		X		X			X		X	X	
a2		X	X		X			X		X	X	
a3		X		X	X			X		X	X	
a4		X	X			X		X			X	X

B – ”Robus” vaskeudstyr med børster

Faste parametre:

- Rengøring af opløsningsmiddelholdige og vandfortyndbare lakker samtidigt
- Forsøg ved rumtemperatur

For-søg	Ståltype på kar		Lakfilm		Vaskemedie	Tryk			Tid		
	Rustfrit	Alm. sort	Tør	Våd	Teknosolv 601 (blandingsfort.)	1 bar	10 bar	50 bar	5 min.	15 min.	30 min.
b1		X	X		X	X				X	
b2		X	X		X	X					X
b3		X		X	X	X				X	

C - Trykspulingsudstyr - type ”SP50”

Faste parametre:

- Rengøring af opløsningsmiddelholdige og vandfortyndbare lakker samtidigt
- Forsøg ved rumtemperatur

For-søg	Ståltype på kar		Lakfilm		Vaskemedie	Tryk			Tid		
	Rustfrit	Alm. sort	Tør	Våd	Teknosolv 601 (blandingsfort.)	1 bar	10 bar	50 bar	5 min.	15. min.	30 min.
c1		X	X		X		X		X		
c2		X	X		X		X			X	
c3		X	X		X			X	X		

Tabel 2
Forsøgsresultater

		SKM-vaskemaskine				**”Robus” vaskeudstyr**			**”SP50” vaskeudstyr**		
Lak nr.		Forsøg a1	Forsøg a2	Forsøg a3	Forsøg a4	Forsøg b1	Forsøg b2	Forsøg b3	Forsøg c1	Forsøg c2	Forsøg c3
1	Isocyanate, solvent, Reaktion	+	+	++	+	+	+	+++	+	+	+
2	Vinyl/epoxy, solvent, lufttørrende	+++	+++	+++	+++	+++	+++	+++	++	++	++
3	Alkyd, solvent, lufttørrende	+++	+++	+++	+++	+++	+++	+++	++	+++	+++
4	Alkyd, solvent, ovntørrende	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
5	Polyester, solvent, ovntørrende	+++	+++	+++	+++	+++	+++	+++	++	++	++
6	Epoxy, solvent, reaction	+++	+++	+++	+++	+++	+++	+++	++	++	++
7	Vinyl, solvent, lufttørrende	+++	+++	+++	+	+	+	+	-	+	++
8	Acryl, solvent, reaction	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
9	Epoxideret fedtsyre, solvent, reaktion	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
10	Polyester, solvent, reaktion	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
11/ 12	Polyester/isocyanat e, solvent, reaktion	+++	+++	+++	+++	+++	+++	+++	++	+++	+++
13	Alkyd, vand, lufttørrende	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
14	Acryl, vand, reaktion	+++	+++	+++	+?	+++	+++	+++	++	++	+++
15	Acryl/alkyd, vand, lufttørrende	+++	+++	+++	+?	+	+	+	-	+	++
16	Acryl, vand, lufttørrende	+++	+++	+++	+++	+	+	+	+++	+++	+++
17	Acryl/epoxyester, vand, lufttørrende	+++	+++	+++	+	+	+	+	-	+	++

Signaturforklaring:
+++ fjernes helt svarende til egnet vaskemetode
++ fjernes næsten helt – spor af lak
+ fjernes næsten helt – rest på karrets bund og/eller øverste kant
(+) fjernes delvis
- fjernes i ringe grad
- - fjerner intet eller meget lidt – svarende til uegnet vaskemetode
? markering af resultat behæftet med usikkerhed

Vurdering

Projektets resultater
Vandbaseret rengøring med alkalisk specialprodukt (Stripper 303 G/E) er generelt egnet. For isocyanat er den ikke ubetinget egnet, men det skal dog bemærkes, at isocyanat generelt er vanskelig at rengøre, hvilket også gør sig gældende med blandingsfortynder jf. forsøgsresultaterne.

NaOH-opløsning er for et stort antal af de undersøgte laktyper egnet. Der er dog behov for længere vasketid end med Stripper 303 G/E. For de laktyper, hvor der er begrænset effektivitet kan der ses tilsvarende eller andre problemer også ved anvendelse af blandingsfortynder. For nogle af disse laktyper kræver opløsningsmiddelbaseret rengøring en mekanisk påvirkning for eksempel højt tryk (50 bar) for at være effektiv/delvis effektiv.

NaOH-opløsningen er en del billigere end Stripper 303 G/E både ved køb og ved efterfølgende behandling/bortskaffelse af spild.

Såfremt der helt eller delvist vælges rengøring med opløsningsmiddel viser forsøgene, at den bedste effektivitet opnås med en mekanisk påvirkning med børster frem for trykspuling. Et anlæg som ”Robus” vil ikke give væsentlig reduktion i emission af VOC i forhold til kendte mere manuelle rengøringsmetoder, men der vil afhængig af anläggets udformning kunne ske forbedring af arbejdsmiljøet.

I Tabel 3 er der angivet hovedresultater af en omkostningssammenligning foretaget i rapporten. For nærmere oplysninger om forudsætninger m.v. må der henvises til projektrapporten.

Tabel 3
Sammenligning af omkostninger ved opløsningsmiddel - og vandbaseret rengøring. Vaskeanlæg af typen SKM (Renzmann, Tyskland) med 20 vaskeoperationer pr. dag er forudsat. For vandbaseret rengøring er forudsat system for recirkulering af skyllevand.

Anlægsudgift			
	Opløsningsmiddel (blandingsfortynder)	Natriumhydroxid 12%	Stripper 303 G/E
Anlægsudgift inkl. installationer mv. (SKM 15/16), kr. ekskl. moms	952.000 kr.	1.276.000 kr.	1.276.000 kr.
Årlige omkostninger			
Afskrivning (10 år)	95.200 kr.	127.600 kr.	127.600 kr.
Forrentning (6% p.a. af den halve investering)	28.560 kr.	38.280 kr.	38.280 kr.
Driftsudgifter	433.293 kr.	331.776 kr.	472.320 kr.
Totale årlige omkostninger	557.053 kr.	497.656 kr.	638.200 kr.

Omkostninger pr. vask	116 kr.	104 kr.	133 kr.

Summary and conclusions

As summary parts of the text from the project article in the publication "Ny Viden", issued by the Danish EPA are reproduced.

Water-based cleaning – a real alternative

The lacquer and paint industry is able to use water-based cleaning on a number of lacquers and paints. Hereby, the present use of solvents can be reduced or possibly completely avoided with clear advantages for the working environment and the external environment. As to many types of lacquer and paints a water-based alkaline cleaning will be competitive with the solvent based cleaning. Special types of lacquer and paint may naturally cause higher expenses.

Possibilities and limitations are described in this report explaining a number of tests in laboratory and in full scale. The report may inspire companies requesting to establish their own basis for decisions.

Trade project within the lacquer and paint industry

Background and purpose
The lacquer and paint industry in Denmark consists of approx. 20 manufacturers of paints as well as approx. 10 manufacturers of glue and sealing compounds.

During recent years the lacquer and paint industry has worked with possibilities for reducing VOC emissions. This has been done partly through product development with a view to reduce the VOC contents in the product and partly by limiting initiatives in the phase of production at various paint factories.

In 1994-1995 the Danish Paintmakers' Association carried out a review of the possibilities for using cleaner technology within the lacquer and paint industry. Report regarding this review has previously been published/issued as *Trade information for the lacquer and paint industry no. 5, 1996 from the Danish EPA, (Brancheorientering for lak- og farveindustrien nr. 5, 1996 fra Miljøstyrelsen).*

In continuation of the review in 1994-1995 the Danish Paintmakers' Association has completed a project with the intention to verify the possibilities for using water-based cleaning of mixing vessels and other equipment.

Two suppliers of cleaning technology, Renzmann in Germany and Riobeer in Switzerland have kindly participated in laboratory tests. Further, the company Renzmann has placed equipment at our disposal for a number of test in full-scale. Akzo Nobel Coatings GmbH in Berlin has placed an established plant with water-based cleaning (sodium hydroxide) at our disposal for inspection and has kindly informed about operation experiences.

The Danish company Teknos Technology A/S has participated in a group of experts having followed the project.

The Danish EPA, The Danish Directorate for National Labour Inspection, SiD (The General Workers Union in Denmark), The Association of County Councils in Denmark and The Danish Paintmakers' Association have been represented in a steering committee.

Employees from Fichtner GmbH & Co. KG in Germany and Carl Bro a|s in Denmark have been consultants on the project.

The target group of the project consists of companies within the lacquer and paint industry as well as the environmental authorities. The possibility of implementing the project is created by means of financial support from the Danish EPA.

The project course

The project
By way of introduction laboratory tests have been made being prepared by means of experiences with cleaning processes at suppliers of cleaning plants. In the tests various chosen lacquers and paints from Teknos Technology A/S are included. Subsequently the laboratory tests have formed the basis for arrangement of tests in full-scale with a view to verify the real possibilities of introducing the water-based cleaning at the companies within the lacquer and paint industry.

Approx. 10 companies and suppliers have been interviewed regarding their experiences with water-based cleaning as well as experiences from a workshop (held at Renzmann in Germany) form part of the project.

Water-based cleaning is possible – with limitations, however

Main conclusions
Collecting of experiences and completed tests show that water-based cleaning may be a real alternative to the traditional cleaning with solvents. Thus, there are immediately possibilities for improvements of the working environment and reduction of VOC emissions to the external environment.

However, it is necessary for each company to assess relevant cleaning methods and cleaning media based on actual types of lacquer and paint. Possibly it may be necessary to choose more methods and media in case the product mix of the company is very different and variable. It will also be relevant to let existing types of vessels, materials and sizes enter in an overall assessment. Valves may require additional cleaning. A general replacement of vessels will be very costly.

Based on experiences at interviews the following can be summarized:

- Water-based cleaning takes place with a hot alkaline solvent (sodium hydroxide or special product)
- Cleaning may be difficult when the product dries up. Mechanical influence may be necessary, possibly supplemented with manual final cleaning

- All companies have completed test programs before implementation in full-scale
- Suppliers of cleaning plants usually recommend both laboratory tests and full-scale tests with the products in question prior to establishing the plant

Procedure, method and investigation program

The project
In connection with the project “Cleaner Technology in the Lacquer and Paint Industry” Teknos Technology A/S investigated in 1997 the possibilities of using water-based cleaning. The possibilities showed promising in the laboratory, however problems arose with verifying the possibilities in full-scale.

The previous basis forms the basis for new tests, where experiences from among others Germany are included.

Method and procedure is indicated on figure 1.

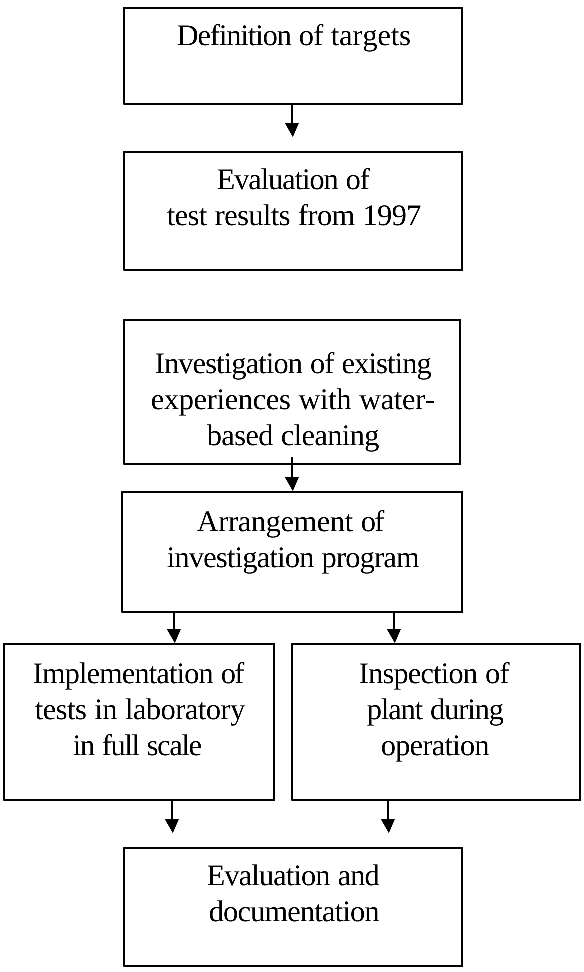


Figure 1
Procedure and method.

As erection of plant for full-scale test at Teknos Technology A/S would be costly and time-consuming, the tests have been carried out at the company

Renzmann's own test plant at the development center in Germany. The tests are carried out under realistic conditions together with a number of lacquers and paints from the product range at Teknos Technology A/S. The tests have been followed by an employee from Teknos Technololgy A/S as well as an representative from Fichtner – Carl Bro a|s.

Tests have been carried out with 17 wet-type lacquers (rapid air-drying) to industrial purpose. Both water-borne and solvent-borne lacquers are represented.

The tests are carried out on vessels of stainless steel and mild steel respectively as well as both wet paint and paint after 5 days of drying.

The tests are carried out with 3 types of equipment:

Cleaning plant of the type "SKM"
A closed system for cleaning of vessels of varying diameter is in question. Cleaning is made by means of a rotating spray system on both the inner and outer side of the vessel. Possible cleaning agents are water, alkaline media (i.e. sodium hydroxide) and solvents.

The plant has integrated tank for cleaning agent (800 l) and exhaust of the residual cleaning agent, so that the vessel is left dry. The cleaning takes place during pressure (8-80 bar) and at increased temperature (approx. 60-80^{o}C) for water and caustic cleaning agents.

During cleaning of vessels with valve additional manual cleaning may be necessary.

The system will demand subsequent treatment of waste. By use of solvents distillation equipment is demanded.

Wastewater cleaning/precipitation will be a necessary by use of water and caustic cleaning agents.

"Robus" cleaning equipment with brushes
The system is for cleaning of the inside of the vessel and tanks with valve. The cleaning takes place with rotating brushes being changeable dependent on type of vessel and tank.

A tight adapter works as lid during the cleaning process. The system is designed for non-pressure cleaning with solvent (or water) and usually takes place at ambient temperature. A subsequent drying of the vessel is possible. The cleaning medium recirculates and will at some point require distillation equipment for treatment of waste (solvents) or wastewater cleaning/precipitation (water-based).

High-pressure washer equipment – type "SP50 / SP80"
The system is for cleaning of inside of containers and mobile tanks with valve.

The cleaning takes place by pressure washing at 50 bar by use of solvent and 80 bar by use of water as cleaning media. A tight adapter is required as lid adjusted for each type of tank/container. The cleaning media recirculates and will at some point require distillation equipment for treatment of waste (solvents) or wastewater cleaning/precipitation (water-based).

The following 3 cleaning media are used for tests in full-scale:

- *Stripper 303 G/E (from Foster Chemical GmbH)*
  Alkaline mixture of glycol ether and sodium hydroxide in concentration 5-6%
- *Sodium hydroxide solution 12%*
- *Teknosolv 601 (from Teknos Technology A/S)*
  Multilevel thinner for cleaning

Based on Renzmann's experiences fixed parameters have been chosen for each plant. Moreover, the tests have been carried out with combinations of vessels in stainless/plain black steel, lacquer film dry/wet, washing media and washing time. Dry lacquer film is after drying/hardening in 5 days. The numerous combinations can be grouped after type of plant in series of experiments a, b and c.

Each combination has been tested on a number of lacquers and paints chosen by Teknos Technology A/S. The chosen types are mentioned together with the test results in table 2.

Water-based cleaning (Stripper 303 G/E and NaOH-solution) is carried out in cleaning plant SKM. By way of comparison the same types of lacquer and paint are cleaned by means of equipment with brushes or pressure washer by use of multilevel thinner.

Besides use for standard of comparison for water-based cleaning, the tests with multilevel thinner explain something about effect of different pressures and cleaning times.

The test combinations are stated in table 1.

Table 1
Test parameters and variants

A – Cleaning plant type "SKM"
Fix parameters:

- Cleaning of solvent-containing
- Cleaning of solvent-containing and water-borne lacquers concurrently
- Washing media temperature of 75-80 °C
- Consumption of washing media of 3-5 l
- Consumption of rinsing water of approx. 40 l

Test	Type of steel on vessels		Lacquer film		Washing media		Pressure			Time		
	Rust-proof	Plain black	Dry	Wet	Alkaline stripper	NaOH-opl.	1 bar	10 bar	50 bar	5 min	15 min	30 min.
a1	X		X		X			X		X	X	
a2		X	X		X			X		X	X	
a3		X		X	X			X		X	X	
a4		X	X			X		X			X	X

B – "Robus" washing equipment with brushes
Fix parameters:

- Cleaning of solvent-containing and water-borne lacquers concurrently
- Tests at ambient temperature

Test	Type of steel on vessels		Lacquer film		Washing media	Pressure			Time		
	Rust-proof	Plain black	Dry	Wet	Teknosolv 601 (water.-borne)	1 bar	10 bar	50 bar	5 min.	15 min.	30 min.
b1		X	X		X	X				X	
b2		X	X		X	X					X
b3		X		X	X	X				X	

C – Pressure washer - type "SP50"
Fix parameters:

- Cleaning of solvent-containing and water-borne lacquers concurrently
- Tests at ambient temperature

Test	Type of steel on vessels		Lacquer film		Washing media	Pressure			Time		
	Rust-proof	Plain black	Dry	Wet	Teknosolv 601 (multilevel thinned.)	1 bar	10 bar	50 bar	5 min.	15. min.	30 min.
c1		X	X		X		X		X		
c2		X	X		X		X			X	
c3		X	X		X			X	X		

Table 2
Test results

		SKM-washing machine				**"Robus" washing equipment**			**"SP50" washing equipment**		
Lacquer no.		Test a1	Test a2	Test a3	Test a4	Test b1	Test b2	Test b3	Test c1	Test c2	Test c3
1	Isocyanate, solvent, Reaction	+	+	++	+	+	+	+++	+	+	+
2	Vinyl/epoxy, solvent, air drying	+++	+++	+++	+++	+++	+++	+++	++	++	++
3	Alkyd, solvent, air drying	+++	+++	+++	+++	+++	+++	+++	++	+++	+++
4	Alkyd, solvent, kiln drying	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
5	Polyester, solvent, kiln drying	+++	+++	+++	+++	+++	+++	+++	++	++	++
6	Epoxy, solvent, reaction	+++	+++	+++	+++	+++	+++	+++	++	++	++
7	Vinyl, solvent, air drying	+++	+++	+++	+	+	+	+	-	+	++
8	Acryl, solvent, reaction	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
9	Epoxide-fatty acid, solvent, reaction	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
10	Polyester, solvent, reaction	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
11/12	Polyester/isocyanate, solvent, reaction	+++	+++	+++	+++	+++	+++	+++	++	+++	+++
13	Alkyd, water, air drying	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
14	Acrylic, water, reaction	+++	+++	+++	+?	+++	+++	+++	++	++	+++
15	Acrylic/alkyd, water, air drying	+++	+++	+++	+?	+	+	+	-	+	++
16	Acrylic, water, air drying	+++	+++	+++	+++	+	+	+	+++	+++	+++
17	Acrylic/epoxy ester, water, air drying	+++	+++	+++	+	+	+	+	-	+	++

List of signs:
+++ completely removed corresponding to suitable washing method
++ almost removed completely – trace of lacquer
+ almost removed completely – residues on the bottom of the vessel/or the top edge
(+) partly removed
- poorly removed
- - nothing or very little removed – corresponds to unsuitable washing method
? marking of result subject to uncertainty

Assessment

The results of the project

Water-based cleaning with alkaline special product (Stipper 303 G/E) is generally suitable. As to isocyanate it is not absolutely suitable, however it should be noted that isocyanate generally is difficult to clean which is also the fact with multilevel thinner, cf. the test results.

As for a large number of the investigated types of lacquer the NaOH-solution is suitable. However, a longer washing time than with Stripper 303 G/E is required. For the types of lacquer with limited efficiency, similar or other problems can be seen also by use of multilevel thinner. For some of these types of lacquer solution-based cleaning requires a mechanical impact for instance high pressure (50 bar) in order to be efficient/partly efficient.

The NaOH-solution is somewhat cheaper than Stripper 303 G/E both as to buying and to subsequent treatment/removal of waste.

In case complete or partly cleaning with solvents is chosen tests show that the best efficiency is reached due to a mechanical impact with brushes in stead of pressure washing. A plant like "Robus" will not reduce the emission of VOC considerably compared to known more manual cleaning methods, however depending on the construction of the plant an improvement of the working environment may take place.

Table 3 indicates the main results of a comparison of costs carried out in the report. In case further information about preconditions is required please see the project report.

Table 3

Comparison of costs by use of solvents and water-based cleaning. Cleaning plant of the type SKM (Renzmann, Germany) with 20 washing operations per day is provided. For water-based cleaning a system is provided for recirculation of rinsing water.

Capital investment			
	Solvent (multilevel thinner)	Sodium hydroxide 12%	Stripper 303 G/E
Capital costs incl. installations etc. (SKM 15/16), kr. excl. of VAT	952,000 kr.	1,276,000 kr.	1,276,000 kr.
Annual costs			
Depreciation (10 years)	95,200 kr.	127,600 kr.	127,600 kr.
Interest (6% per year of one half of investment costs)	28,560 kr.	38,280 kr.	38,280 kr.
Operating costs	433,293 kr.	331,776 kr.	472,320 kr.
Total annual costs	557,053 kr.	497,656 kr.	638,200 kr.
Total costs per washing	116 kr.	104 kr.	133 kr.

1 Introduction

In the production and use of solvent-borne paints and coatings, substantial quantities of VOCs are emitted to the surroundings. Therefore, for environmental protection, measures must be implemented to reduce these emissions.

The best and most practical measure for reducing VOC emissions is substitution by alternative and less critical solvents. In this connection, water-borne paints and coatings are gaining in importance. Where substitution of organic solvents is not possible, as a further measure reduction of the proportion of organic solvents in the products may be considered, such as the development of so-called “high solids” coatings.

Nevertheless, for certain applications currently no substitution possibilities for organic solvents are foreseeable. For this reason, over both the short and medium terms, solvent-borne products will continue to be used. When manufacturing solvent-borne paints and coatings, VOCs are emitted at various points of the production process.

Prior to constructing costly air pollution purification plants, measures for reducing the emissions of VOCs as well as for reducing the volumetric flow should be implemented. Apart from these purely economic considerations, regarding the implementation of emission reduction measures, also other criteria like practicability (no negative effects on operation, access, etc.), ecology (abatement of solvent emissions), safety, and so on have to be taken into account.

To give manufacturers of solvent-borne paints and coatings a basis for coming to a decision on new investments in production facilities and/or pollution abatement technology, the **Danish Paintmakers’ Association** has initiated in the project:

"**Cleaner technology in the lacquer and paint industry**"

with one report concerned with “VOC emissions from manufacturing processes” and another report with “Water-based cleaning of mixing vessels and equipment”.

The general aim of the project is to qualify the individual companies within the industry to handle an additional product liability and at the same time to implement technology in the manufacturing phase that is actually cleaner.

The results of “VOC emissions from manufacturing processes” are described in a separate study. The study deals with measures for preventing or reducing solvent-containing emissions.

In this report “Water-based cleaning of mixing vessels and equipment”- the focus will be on the possibilities of using water-based cleaning of mixing vessels and equipment, and to provide companies with a sound basis when confronted with new investments in cleaner water-based technology. This will benefit both the general environment and the working environment. Both reports are available on the Internet - www.mst.dk - homepage of the Danish EPA (Danish versions) and on – www.fdlf.dk - homepage of the Danish Paintmakers' Association (English versions).

The project period was from January 1999 to February 2000.

The project has been carried out by Fichtner · Carl Bro a|s, with the participation of representatives from the company Teknos Technology A/S. Laboratory and full-scale tests were conducted by two suppliers of cleaning technology, Renzmann, Germany, and Riobeer, Switzerland.

1.1 Description of problem

The application and release, of volatile organic compounds can, due to their properties, cause harm to human health and/or contribute to local or trans-boundary formation of photochemical oxidants in the boundary layers of the troposphere, leading to environmental degradation.

To prevent, or mitigate, emissions of volatile organic compounds over the long term, in March 1999 the European Union issued *Directive 1999/13/EC of the Commission on the Limitation of Emissions of Volatile Organic Compounds*, referred to in the following as the VOC Directive. This requires registration of all plants or plant components covered by this Directive. Furthermore, their operators must initiate measures, within the stated transition periods and as far as necessary, to prevent or reduce VOC emissions.

VOC emissions from cleaning mobile mixing vessels and equipment are estimated to amount to 25-30% of the total VOC emissions from the production of solvent-borne paint /Appendix B/.

The total VOC emissions from the Danish paint and coating production are estimated as approx. 450 tons per year /Appendix B/.

It might be possible to abate emissions of VOC by an amount of some 110 tons per year by changing to water-based cleaning of the mixing vessels and equipment.

The purpose of this study

The purpose of this study is to verify the possibility of water-based cleaning (e.g. water and detergents) of mobile mixing vessels.

Based on the know-how of manufacturers and suppliers in implementing and operating water-based cleaning technology and based on laboratory tests and full-scale tests, the technology has to be evaluated to determine whether it would be practicable to scale it up for installation in factories dealing with similar products and raw materials. Furthermore, the environmental impact and costs for implementation and operation have to be described.

Laboratory tests and full-scale tests are carried out with Teknos Technology A/S products.

2 Environmental Regulation

2.1 National legislation and EC directives

As noted in the introduction, March 1999 Directive 1999/13/EG of the European Commission was promulgated. This addresses limitation of emissions of volatile organic compounds arising due to certain activities and in specific plants when organic solvents are used.

The VOC Directive will be implemented in national legislation before 30 March 2001.

Danish legislation

Granting of a permit to operate a plant for the manufacture of paints and coatings in Denmark is currently regulated essentially by the following guidelines, laws and ordinances:

- Order regarding approval of listed activities (Bekendtgørelse nr. 807 af 25. oktober 1999 om godkendelse af listevirksomhed)[1]
- Guidelines for approval of listed activities (Vejledning nr. 3, 1993 om godkendelse af listevirksomhed[2])
- DEPA: Industrial Air Pollution Control Guidelines No. 9/1992 (Vejledning nr. 6 1990 om begrænsning af luftforurening fra virksomheder)
- Information from DEPA, no. 15, 1996 C-values - Industrial Air Pollution (B-værdier)

Subject to their amendment in connection with implementation of Directive 1999/13/EG, these ordinances and guidelines will continue to apply in national legislation.

The VOC Directive

The VOC Directive affects in particular small and medium-sized plants, for which up to now national legislation does not require the installation of post-production clean-up equipment, or which have been operating at or below the limits of VOC standards and threshold values due to their product ranges and quantities.

The paint and coatings industry, that is the manufacturers of coating substances, clear varnishes, printing inks and adhesives, are, according to Appendix I of the VOC Directive, affected if they use more than 100 t/a of solvents. These enterprises are now confronted with the challenging tasks of:

- Documenting their solvent situation with a high degree of transparency so as to permit tracking of these substances
- Projecting their market situation in 2007 - product range, production volumes - under the aspect of the future solvent balance
- Identifying measures needed for compliance with the VOC Directive and evaluating these under their cost aspects
- As far as necessary, initiating measures to cut VOC emissions

[1] For plants with production capacity exceeding 3000 tons per year
[2] Compiled under the previous regulation.

2.2 VOC limits and threshold values

According to the Danish legislation the limits and threshold values in Table 2.1 apply.

Table 2.1
Mass flow limits and emission limits for companies that emit organics substances (Industrial Air Pollution Control Guidelines No. 9/1992). In the air pollution guidelines a C-value is fixed as a mean hourly value that must not be exceeded by more than about seven hours a month, i.e. 1% of the time.

Class	**C-value** mg/m³	**Mass flow** g/h	**Emission limit** mg/Nm³
I	≤ 0,01	100	5
II	> 0,01 ≤ 0,2	2.000	100
III	> 0,2	6.250	300

Additionally, enterprises in the paint and coatings industry as well as manufacturers of coating materials, clear lacquers, printing inks and adhesives using more than 100 t/a solvent must, according to the new VOC Directive and after the transition limits stipulated in this have elapsed, comply as a minimum with the threshold values and limits for solvents as shown in Table *2.2*.

Table 2.2
Threshold values and limits for solvents in accordance with Directive 1999/13/EG, Appendix II A. The regulation means that each company shall fulfill the limits for exhaust gases and diffuse emissions ***or*** *the total emission limit (then the limit for exhaust gases can be exceeded.)*

No.	**Activity**	**Threshold value t/a**	**Emissions limit for exhaust gases mg C/Nm³**	**Limits for diffuse emissions %**	**Total emission limit %**
17	Manufacture of coating materials, clear lacquers, printing inks and adhesives	100-1,000 >1,000	150 150	5 3	5 3

It may be assumed that more stringent limit or threshold values arising from the specific situation at the site or from any other officially imposed conditions will continue to apply.

2.3 Implementation of the VOC Directive

Key components of the VOC Directive

Apart from the above threshold and limit values, key components of the VOC Directive are:

- Elaboration of a *reduction plan* as per Appendix II B, which will allow operators to take other measures to cut emissions by the same amount that would have been attained by application of the emission standards (in this connection, operators can apply any emissions reduction plan)

- Compilation of a *solvent balance*, to serve for the responsible regulatory authorities as a basis for checking compliance with emissions standards and for determining which reduction options are open

The key concerns faced by enterprises in the paint and coating industry emanating from the VOC Directive, and the resulting measures, are summarized in Figure 2.1.

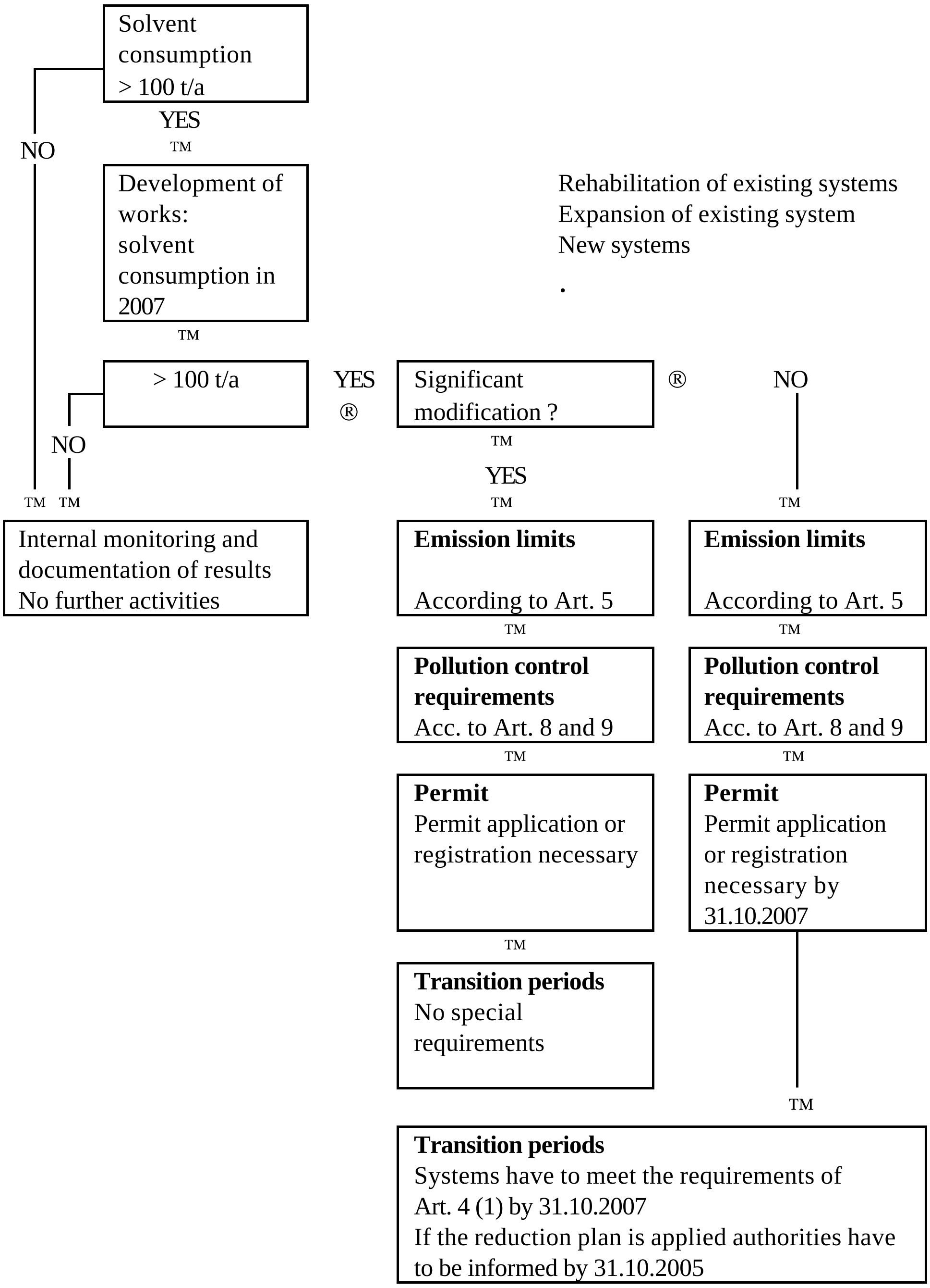


Figure 2.1
Decision flowchart for implementing the VOC Directive.

3 Approaches to Cutting VOC Emissions

Emissions can be grouped depending on how they leave the production facility:

- in the effluent water or via a wastewater treatment plant
- in the solid waste hauled away for external disposal
- in the fumes exhausted to atmosphere or via an exhaust fume treatment plant

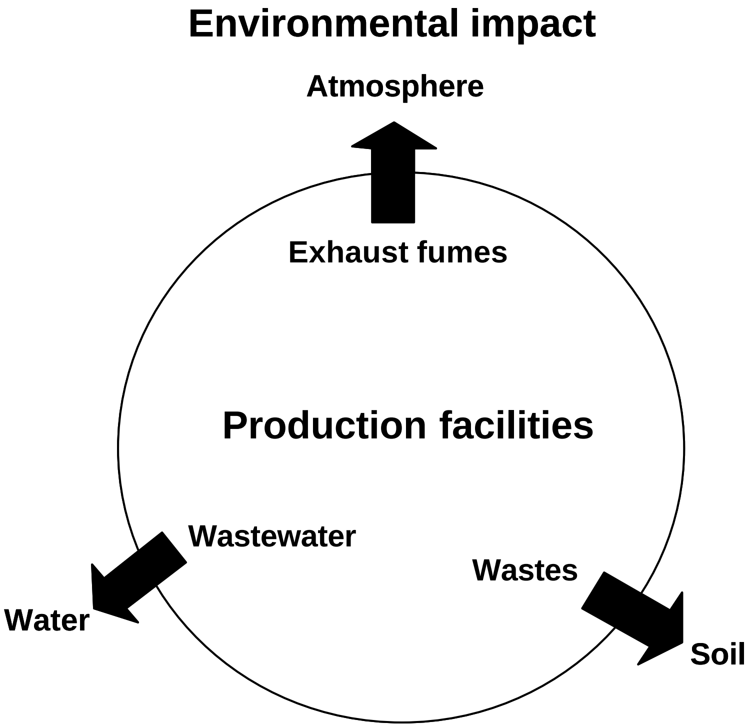


Figure 3.1
Solvent emissions

Wastewater

Wastewater from a plant manufacturing paint and coatings on a solvent basis comprises essentially cleaning effluent from washing the floors of the production buildings and cleaning equipment as well as the transportation and traffic routes. Under the aspect of the solvent balance, this will only be of significance in isolated cases, as the solvent loadings being transported are generally very low, and consequently production modification measures for reduction or prevention will have little influence on the overall emission situation.

For this reason, wastewater as an emission path is eliminated from further consideration in this study.

Solid waste

The solid waste arising in a paints and coatings manufacturing plant comprise essentially disposable packaging, transportation drums as well as sedimentation and filtration residues. These are likewise of importance for the solvent balance and the overall emissions situation only in isolated cases, and are therefore not considered further.

Fume extraction and exhaust

Effective prevention and/or reduction of solvent emissions is only possible in connection with fume extraction and exhaust.

A basic distinction is made between point and diffuse emission sources. A point source is a specific outlet through pipe or stack. Point sources are often established by compulsory ventilation. Diffuse emissions are not related to specific outlets. For instance diffuse discharges, such as emissions from vessels and tanks not furnished with compulsory ventilation.

Causes of emissions

The determining causes of emissions in a paints and coatings manufacturing plant are:

- displacements of solvent-laden air when filling and emptying road and rail tankers
- respiration losses at tanks in general
- displacement of solvent-laden air when dosing tanks and dissolvers with feedstocks
- emissions as temperature rises due to chemical reactions or shearing forces in reactors and dissolvers
- displacement of solvent-laden air when decanting and filling intermediate and final products
- diffuse emissions from systems and components that are open or only partially closed
- cleaning of stationary tanks and dissolvers
- cleaning of mobile tanks and small parts

As a rule, the originators of emissions of volatile organic compounds are solvents and binding agents.

4 Procedure and Methodology

Previous activities under the project "Cleaner Technology in the Lacquer and Paint Industry" form the basis for the present project.

In 1997 Teknos Technology A/S initiated investigations of possibilities for water-based cleaning.

Cleaning techniques and chemistry were screened for feasible solutions, and laboratory as well as full-scale testing has been carried out. To verify reproducibility of the results and to obtain more detailed information it was agreed to perform further laboratory and full-scale testing.

Earlier results provided the basis

The results of laboratory tests and full-scale testing in 1997 as well as experiences made by potential suppliers and operators with implementation and operation of water-based cleaning technologies provided the basis for devising the program and carrying it out within the framework of this study.

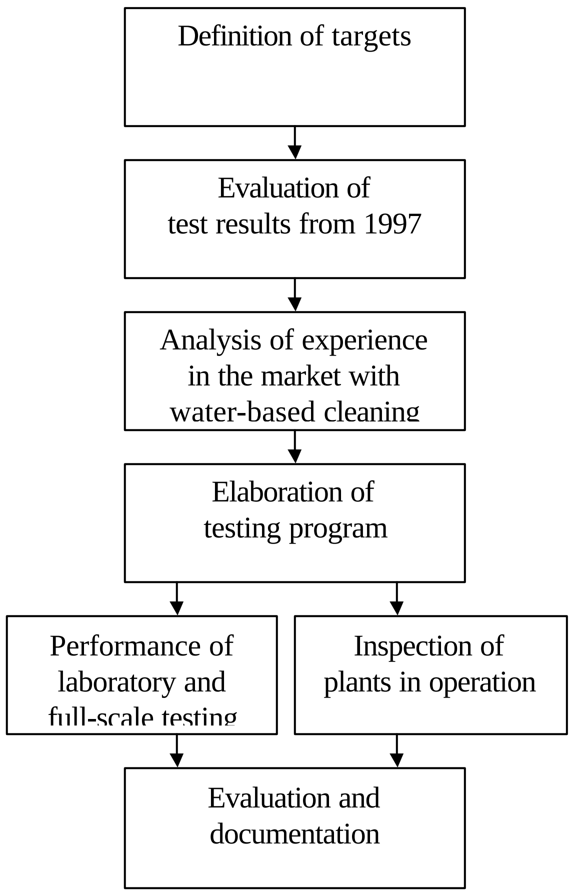


Figure 4.1
Procedure and Methodology

Interviews and on-site visits

During the course of the study, several enterprises and suppliers with experience in implementation and operation of water-based cleaning technology were interviewed. Two plants in operation (one water/alkaline-bases and one solvent-based) were visited on-site for completion and verification of information. The collection of experience and ideas was rounded off by a workshop arranged by a supplier in which various actors from the paint and coatings industry participated. The results can be summarized as follows:

- All enterprises with operating experience of water-based cleaning technology use hot alkalis as cleaning chemicals. Operating experience has been consistently favorable, as long as build-up of hardened encrustations due to lengthy periods of standing is avoided. If cleaning is attempted after the paint residues have been allowed to harden for too long, these adhere firmly to the surface, and subsequent manual cleaning, possibly involving the use of solvents, may become necessary

- All companies have implemented a trials phase before adopting water-based cleaning processes

- Suppliers of water-based cleaning technology recommend laboratory and full-scale testing prior to its implementation, so that a cleaning concept matched to the customer-specific technical and economic conditions can be developed. Both manufacturers have available appropriate facilities for conducting laboratory and full-scale tests on their premises

Because supply and erection of a trials plant would involve relatively high costs and would be time-consuming, for purposes of this study, it was decided to conduct the laboratory and full-scale tests directly in the development centers of potential manufacturers.

These tests were conducted by the companies Renzmann, Germany, and Riobeer, Switzerland.

Full-scale tests at Riobeer were not possible within the timescale of the project.

Laboratory tests and full-scale trials are carried out with Teknos Technology A/S products.

5 Investigation Program

Taking as a starting basis the results of the laboratory tests and full-scale tests of 1997, as set out in Appendix B, together with the experience of operators and manufacturers of corresponding plants, the following schedule of trials was drawn up.

5.1 Preliminary tests

The aim of the preliminary tests was to determine which media could be used to attain acceptable cleanliness within a reasonable time.

Preliminary tests had been carried out by the supplier companies Renzmann and Riobeer, using samples of solvent-borne paints supplied by Teknos Technology A/S.

Teknos Technology A/S chose paints that are problematic under the aspect of their adhesion to the vessel material and their drying time.

Ten samples, each of about 1 litre, were sent by Teknos Technology A/S to both supplier companies together with Material Safety Data Sheets and product descriptions.

Products in preliminary tests

Preliminary tests were performed with the following products:

- air-drying topcoat (two types)
- air-drying shop primer
- base for two-component epoxy system
- base for two-component polyurethane system (two types)
- base for two-component isocyanate-free system
- oven-drying topcoat (two types)
- isocyanate reactor

Cleaning had to be done:

- when the paint is still wet and
- after allowing the paint to dry for a maximum period of one week

The materials of the containers were mild steel and stainless steel.

5.2 Full-scale tests

Questions for full-scale tests

Full-scale testing was performed to answer the following more detailed questions:

- Which process in combination with which cleaning agent has the most effective cleaning action?
- For what types of paint and coatings is water-based cleaning suitable and what aspects have to be taken into account?
- Which materials are suitable?

- When and to what extent is it to be expected that subsequent manual cleaning will be necessary?
- How must valves and lids of vessels be cleaned?
- What must be done with the spent concentrated washing media?
- How high are the operating and capital costs?

Full-scale testing was performed by Renzmann during December 1999. Including preparations and work subsequent to the actual trials, these required a period of around three months.

The tests were followed and supervised by representatives from Teknos Technology A/S and Fichtner.

It was agreed that full-scale tests would be performed for 17 industrial wet paints (quick air-drying paints) including both water-borne and solvent-borne paints.

Procedures for full-scale tests

The following procedure was adopted for the full-scale tests:

A total of 17 products (12 solvent-borne and 5 waterborne paints) were tested.

Data on the chemical and physical characteristics of the paints and the formulas for the solvent mixtures as well as the materials of valves and vessels actually used, had to be supplied to the supplier company before full-scale testing, so that a suitable chemistry could be chosen.

Testing was performed with mild and stainless steel vessels, and with two types of films: film that was still wet and film that had been allowed to dry out over five days.

An important component of the tests, apart from identifying suitable washing solutions, was to determine the results when alternative cleaning processes are applied, employing brushes or high-pressure jets. Particular attention was to be paid to how well corners, valves and vessel lids could be cleaned.

6 Results of Tests at Manufacturers' Plants

6.1 Results of test program carried out in 1997

In 1997 laboratory tests and full-scale tests for water-based cleaning were carried out by Teknos Technology A/S in co-operation with a supplier company.

The aim of these tests was to develop a suitable technique for water-based cleaning and, based on the test results, to show the impact on the environment and establish the economics.

The detailed results of the test program (screening of cleaning techniques, chemistry and full scale testing) are presented in Appendix B.

Laboratory and full-scale tests

The results can be summarized as follows:

- In principle, water-based cleaning of equipment contaminated with paints and coatings is possible
- Hot alkaline cleaning in combination with surface-active agents is applicable for a very wide range of products and raw materials
- Removal efficiency can be promoted by employing, for example, mechanical cleaning equipment like brushes
- Alternatives to hot alkaline cleaning are possible (e.g. acidic paint remover, neutral paint remover), but these as a rule will only work for a narrow range of products and feedstocks
- Removal of paint and coatings by mechanical and thermal processes is ineffective in most cases and is uneconomic
- Solvent-based removal is in general effective, but emission abatement has to be considered

Because it was not possible to reproduce the positive results of laboratory tests during full-scale testing it was decided to repeat full-scale testing under different conditions.

6.2 Preliminary tests

The basic initial trials were conducted with ten problematic coatings from Teknos Technology A/S. The results of these trials at Renzmann and Riobeer are described in the following.

6.2.1 Results of preliminary tests at Renzmann

Preparations for trials

Several stainless steel plates and a mild steel vessel (800 l) had a coating applied to them from each paint system and these were allowed to dry under shop working temperatures. From this it is assumed that hardening of the coatings will be at the maximum possible.

The tests were conducted making exclusive use of a special cleaning agent (Stripper 303 G/E) with high-pressure cleaning nozzles.

For all paints with the exception of the isocyanate product, the cleaning results were satisfactory. The isocyanate specimen could be cleaned down to a small residue of paint (reaction between isocyanate and water) on the floor of the vessel.

Cleaning of the remaining nine products was successful for both mild and stainless steel.

The time for cleaning amounted to about 15 minutes.

Photos from the preliminary tests are shown in Appendix C.

6.2.2 **Results of preliminary tests at Riobeer**

Preparations for testing

Several stainless and mild steel plates were coated by each paint system, and allowed to dry for between 15 and 90 minutes under the working temperatures prevailing in the shop.

Test phase I – soaking process

First the soaking process of each of the media was tested as described in the following. For reasons of environmental protection, the test using special cleaning agent was omitted; the action of this cleaning medium is in any case widely known from its use in practice.

- Solvents:
  Three different regenerates are employed with admixture of approximately 5% NMP (n-methyl-pyrrolidone). Although solution behaviors varied between them, for all three it was favorable and rapid.

- Caustic soda (NaOH 60°C, 8% solution):
  The universal and favorable, but relatively slow, action of caustic soda was confirmed in the tested products.

- Alkaline cleaning additive:
  For the trials, an alkaline cleaning additive produced in Switzerland was tested at a concentration of around 15% at 75°C. If cleaning is carried out within some 15 to 20 minutes, the results are acceptable, if not altogether complete. After 30 to 60 minutes, the action of this medium progressively drops off.

For all tests, a known soaking behavior was observed.

Alkaline cleaning media were not employed for isocyanate containing substances, since firstly isocyanate reacts strongly with water and caustic solutions and, secondly, it is not permissible for moisture to be introduced into isocyanate production.

The solvent mixtures also tested demonstrated in all respects better solution results in comparison to the alkaline cleaning agents.

Test Phase II – jetting and brushing

During Test Phase II, hydrodynamic jetting and brushing were included in small-scale trials.

Despite high pressures, with solvents greater than 50 bar and alkaline solutions greater than 350 bar, with none of the media it was possible to attain a complete and satisfactory result within an acceptable timeframe. The results did not differ essentially from those of the tests conducted in 1997.

With mechanical support by the use of brushes, it transpired that by continuous rubbing of the metal surface, it is possible to achieve the required removal of residues within the specified time. It was possible to attain complete removal of dried on paint and coating residues in combination with both solvents and caustic soda.

It proved impossible to completely remove these residues with just the usual mechanically applied brush pressures combined with an alkaline cleaning agent.

With both solvents and caustic soda, it is possible to achieve rapid and thorough cleaning when supported by appropriately designed brushes.

6.3 **Results of full-scale tests at Renzmann**

During 2 days in December 1999 a combination of washing equipment and washing media was tested at Renzmann in Germany. The test includes equipment being traded by Renzmann and suitable for the special requirements of the customers.

6.3.1 **Equipment used for the tests**

The tests are conducted with 3 types of equipment:

Cleaning plant of the type "SKM"
It is a closed system for cleaning of vessels of different diameters. The cleaning is performed by means of a rotating spraying system on both the inside and outside of the vessel. Photos of "SKM" can be seen in Appendix A.2. Possible washing media are water, alkaline media (for instance sodium hydroxide) and solvents.

The plant has an integrated tank for cleaning agent (800 l) and exhaust of the residual cleaning agent, so that the vessel is left dry. The cleaning takes place during pressure (8-80 bar) and increased temperature (approx. 60-80^{o}C) for water and caustic cleaning agents.

The system requires subsequent treatment of waste. By use of solvents distillation equipment is required. Wastewater cleaning/precipitation will be required by use of water and caustic cleaning agents. See chapter 7.6.2 concerning wastewater treatment.

"Robus" washing equipment with brushes
The system is designed for cleaning of the inside of the vessel and tanks with valve. The cleaning takes places with rotating brushes variable depending of type of vessel and tank. Photos of the "Robus" system is shown in Appendix A.2.

A tight adapter works as lid during the cleaning process. The system is designed for non-pressure cleaning with solvent (or water) and usually takes place at ambient temperature. A subsequent drying of the vessel is possible. The cleaning media recirculates and at some point it will require distillation equipment for treatment of waste (solvents) or wastewater cleaning/precipitation (water-based).

Pressure washer equipment - type "SP50 / SP80"
The system is for cleaning of the inside of containers and mobile tanks with valve. Photos can be seen in Appendix A.2.

The cleaning takes place by high-pressure washing at 50 bar by use of solvent and 80 bar by use of water as cleaning media. A tight adapter is required as lid adjustable for each type of tank/container. The cleaning media recirculates and at some point it will require distillation equipment for treatment of waste (solvents) wastewater cleaning/precipitation (water-based).

6.3.2 **Cleaning media**
For tests in full-scale the following 3 cleaning media are used:

- *Stripper 303 G/E (from Foster Chemicals GmbH)*
  Alkaline mixture of glycol ether and caustic potash/potassium hydroxide in concentration 5-6%
- *Sodium hydroxide solvent, 12%*
- *Teknosolv 601 (from Teknos technology A/S)*
  Mixed/multilevel thinner for cleaning

The cleaning media are further described and assessed in chapter 7.2.

6.3.3 **Tests and test results**
Based on Renzmann's experiences fixed parameters have been chosen for each plant. Moreover, the tests have been conducted with combinations of vessels in stainless/plain black steel, lacquer film dry/wet, washing media and washing time. Dry lacquer film is after drying/hardening for 5 days. The numerous combinations can be grouped according to type of plant in series tests a, b and c.

Each combination has been tested on a number of lacquer and paints chosen by Teknos Technology A/S. The chosen types are stated together with the test results in table 6.2.

Water-based cleaning (Stripper 303 G/E and NaOH-solvent) is carried out in cleaning plant SKM. For comparison the same lacquer and paints are cleaned by means of equipment with brushes or pressure washing by use of mixed/multilevel thinner.

Besides use as standard of comparison for water-based cleaning the tests with multilevel thinner can inform something about efficiency of different pressure and cleaning times.

The test combinations are shown in table 6.1.

Table 6.1
Test parameters and variants

A – Cleaning plant type ”SKM”
Fix parameters:
- Cleaning of solvent-containing
- Cleaning of solvent-containing and water-borne lacquers concurrently
- Washing media temperature of 75-80 ^{o}C
- Consumption of washing media of 3-5 l
- Consumption of rinsing water of approx. 40 l

Test	Type of steel on vessels		Lacquer film		Washing media		Pressure			Time		
	Rust-proof	Plain black	Dry	Wet	Alkaline stripper	NaOH-opl.	1 bar	10 bar	50 bar	5 min	15 min	30 min.
a1	X		X		X			X		X	X	
a2		X	X		X			X		X	X	
a3		X		X	X			X		X	X	
a4		X	X			X		X			X	X

B – ”Robus” washing equipment with brushes
Fix parameters:
- Cleaning of solvent-containing and water-borne lacquers concurrently
- Tests at ambient temperature

Test	Type of steel on vessels		Lacquer film		Washing media	Pressure			Time		
	Rust-proof	Plain black	Dry	Wet	Teknosolv 601 (water.-borne)	1 bar	10 bar	50 bar	5 min.	15 min.	30 min.
b1		X	X		X	X				X	
b2		X	X		X	X					X
b3		X		X	X	X				X	

C – Pressure washer - type ”SP50”
Fix parameters:
- Cleaning of solvent-containing and water-borne lacquers concurrently
- Tests at ambient temperature

Test	Type of steel on vessels		Lacquer film		Washing media	Pressure			Time		
	Rust-proof	Plain black	Dry	Wet	Teknosolv 601 (multilevel thinned.)	1 bar	10 bar	50 bar	5 min.	15. min.	30 min.
c1		X	X		X		X		X		
c2		X	X		X		X			X	
c3		X	X		X			X	X		

Table 6.2
Test results

		SKM-washing machine				”Robus” washing equipment			”SP50” washing equipment		
Lacquer no.		Test a1	Test a2	Test a3	Test a4	Test b1	Test b2	Test b3	Test c1	Test c2	Test c3
1	Isocyanate, solvent, Reaction	+	+	++	+	+	+	+++	+	+	+
2	Vinyl/epoxy, solvent, air-drying	+++	+++	+++	+++	+++	+++	+++	++	++	++
3	Alkyd, solvent, air-drying	+++	+++	+++	+++	+++	+++	+++	++	+++	+++
4	Alkyd, solvent, kiln drying	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
5	Polyester, solvent, kiln drying	+++	+++	+++	+++	+++	+++	+++	++	++	++
6	Epoxy, solvent, reaction	+++	+++	+++	+++	+++	+++	+++	++	++	++
7	Vinyl, solvent, air drying	+++	+++	+++	+	+	+	+	-	+	++
8	Acryl, solvent, reaction	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
9	Epoxide-fatty acid, solvent, reaction	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
10	Polyester, solvent, reaction	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
11/ 12	Polyester/isocyanat e, solvent, reaction	+++	+++	+++	+++	+++	+++	+++	++	+++	+++
13	Alkyd, water, air-drying	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
14	Acrylic, water, reaction	+++	+++	+++	+?	+++	+++	+++	++	++	+++
15	Acrylic/alkyd, water, air-drying	+++	+++	+++	+?	+	+	+	-	+	++
16	Acrylic, water, air-drying	+++	+++	+++	+++	+	+	+	+++	+++	+++
17	Acrylic/epoxy ester, water, air-drying	+++	+++	+++	+	+	+	+	-	+	++

List of signs:
+++ completely removed corresponding to suitable washing method
++ almost removed completely – trace of lacquer
+ almost removed completely – residues on the bottom of the vessel/or the top edge
(+) partly removed
- poorly removed
- - nothing or very little removed – corresponds to unsuitable washing method
? marking of result subject to uncertainty

6.3.4 **Assessment of test results**

Water-based cleaning with alkaline special product (Stipper 303 G/E) is generally suitable. For isocyanate it is not absolutely suitable, however it should be noted that isocyanate generally is difficult to clean which is also the fact with multilevel thinner, cf. the test results.

As for a large number of the investigated types of lacquer the NaOH-solution is suitable. However, there is a demand for longer washing time than with Stripper 303 G/E. For the types of lacquer with limited efficiency, similar or other problems appear also by use of multilevel thinner. For some of these types of lacquer solution-based cleaning demands at the same time a mechanical impact.

The NaOH-solution is somewhat cheaper than Stripper 303 G/E both as to buying and as to subsequent treatment/removal of waste.

In case complete or partly cleaning with solvents is chosen tests show that the best efficiency is reached with a mechanical impact with brushes instead of pressure washing. A plant like “Robus” will not reduce the VOC emission considerably compared to known and more manual cleaning methods, however depending on the construction of the plant an improvement of the working environment may take place.

Each company has to assess relevant cleaning methods and cleaning media based on types of lacquer. It might be necessary to choose more methods and media, in case the product mix of the company is very different and varied. After choice of method the cleaning time can be optimized to each type of lacquer.

It would also be relevant to let existing types of vessels, materials and sizes be part of an overall assessment. Valves may demand additional cleaning. A general replacement of vessels will be very costly.

Chapter 8 shows a calculating example of the economy by using water-based cleaning in the “SKM” plant.

Subsequently advantages and disadvantages for the tested plants are stated.

A – Cleaning plant of the type “SKM”

Advantages:

- Efficient cleaning of the vessels
- Can be used with vessels of different sizes. However, it will be relatively costly to clean very small vessels
- Closed system, considering the working environment
- The vessel is completely dry after the process

Limitations/disadvantages:

- Possible problems with cleaning of the valves
- The process leaves invisible, basic film on the vessel – requires increased amount of rinsing water

B – "Robus" washing equipment with brushes

Advantages:
- Satisfactory cleaning with the most solvent–born lacquers
- Cleaning of the valve
- The process runs at ambient temperature and atmospheric pressure
- Can be extended with equipment for drying after cleaning

Limitations/disadvantages:
- Problematic as for air-drying lacquers and partly as for isocyanate reactor
- The system is not completely tight
- Can only be used for vessels/containers with valve
- Cleaning at the top edge is unsatisfactory
- Loose residues of lacquer at the bottom of the vessel is difficult to flush out
- Brushes shall be chosen/replaced according to the size of the vessel

C – Pressure washer equipment – type "SP50/80"

Advantages:
- The process runs at ambient temperature
- Cleaning of valve
- Can be extended with equipment for emptying after cleaning

Limitations/disadvantages:
- Not suitable for all types of lacquers
- Can only be used for vessels/containers with valve or manhole
- Requires adapter adjustable for each type of vessel
- Cleaning at the top edge is unsatisfactory
- Vessels and containers of plastic may be problematic due to static electricity (when using solvent as washing medium)
- Loose residues of lacquer at the bottom of the vessel is difficult to flush out

7 Experience with Implementation and Operation of Water-based Cleaning Technology

7.1 General remarks

Because many manufacturers of solvent-borne paints and coatings will, as a rule, have a wide range of products, the technology selected for cleaning mixing vessels and equipment as well as the rinsing solutions used must be suitable for a broad spectrum of products and feedstocks.

Differentiation of cleaning processes

For conceptual design of a cleaning plant, generally a range of basic aspects must be considered.

So, for quality reasons it may be necessary to employ different processes for cleaning colored and clear pigmented painting systems. For water-borne coating materials, as a rule the same washing medium may be used, but at most supported by admixing (*NMP,* n-methyl-pyrrolidone), which forms an azeotrope with water.

For cleaning of isocyanate containing coatings, these processes should be segregated from other systems for known reasons, such as their reaction with water.

As a rule, water-borne paints can only be removed with water or alkaline media while they are still in a wet condition.

Process segregation is to be understood as separation of both stocked materials and the complete piping system in the shop, right up to different nozzle installations. Only this will ensure complete segregation.

Storage

Past experience of operation with alkaline or pure water-based systems has shown that in certain cases unwanted reactions (strong generation of heat) in the rinsing tanks may occur. Frequently, the resulting sediments must be disposed of at great expense.

By deploying an appropriately designed filter system and, as far as needed, additionally equipping the tank farms with agitators, this can be counteracted.

To save investment costs in this area, centralized storage of washing and rinsing media would be desirable. This is widely accepted today as the state of the art.

Logistics

When selecting the washing medium that is optimal for the operator, the existing production logistics must also be considered.

For water-borne paints and air-drying coating systems in particular, the period between filling/emptying and cleaning is decisive. For example, water-borne paints, while still wet, can be relatively easily cleaned with water. But as soon as they become tacky or even dried out completely, they can only be removed with appropriately effective media.

It is best to clean production equipment, such as mixing vessels, immediately after they have been emptied, or at least as long as the paint residues are still wet.

Cleaning of solvent-borne paints while they are still wet using high-pressure water-based jets is problematic, as it is not possible to completely remove the solvent film from the vessel. Cleaning with the paint residues when they are already tacky is therefore usually more satisfactory.

Staff qualifications

Which cleaning medium is optimum in a specific application depends not only on technical and economic considerations, but also on acceptance by the shop floor personnel. A high degree of acceptance will also generally be combined with satisfactory operation as well as high quality servicing and maintenance.

Experience from past practice shows that staff acceptance of an installation for water-based cleaning is greater if personnel receive intensive training, repeated at regular intervals, in handling the equipment, or if they are already familiar with the technology. This applies particularly for companies previously applying solvent-based cleaning processes, and now wish to switch to a water-based system. This is because handling of such systems and coping with the associated risks differ greatly from solvent-based systems.

Regulatory conditions, regulations etc.

When switching from solvent- to water-based cleaning systems in particular, statutory requirements and regulations, for example pertaining to pollution control, maximum allow concentrations (MAC) at places of work, protection of land and water resources etc., must be included in the considerations.

General considerations for cleaning installations

When selecting the optimum cleaning medium, generally operational trade-offs must be accepted. When choosing the cleaning technology, this should not be the case. The cleaning technology must be matched to the specific technical and economic constraints and conditions prevailing at the site and for the production facilities.

7.2 **Cleaning Agents**

Water

Due to its low cost and easy handling, water without additives is always a very economical cleaning medium. It is primarily used for cleaning emulsion paints in washing installations equipped with brushes or with pressurized jets.

Alkaline solution (NaOH)

Alkaline solution is a mixture of water and, for example, caustic soda at a concentration of 5% to 15%. For maximum effectiveness, this has to be brought up to a temperature of 60^{o} to $80^{o}C$. Hot water with a low content of carbonate and magnesium is used for rinsing.

Up to about 20 years ago, caustic soda was used primarily for cleaning. Such media are suitable for cleaning off most water- and solvent-borne paints for protection of structures, wood, motor vehicles, general industrial applications, household needs and most printing inks. Heightened risks to persons, loss of quality due to solution residues, increased operating and capital costs as well as stricter legislation governing their disposal meant that these washing media have little chance of survival over the long term.

Special cleaning agents

These cleaning agents are usually a mixture of potassium hydroxide, tensides and high-boiling point solvents. They are highly effective, and may be used in nearly all sectors. They find application wherever all other media have produced unsatisfactory cleaning results. Basically, these are very efficient cleaning agents, suitable for universal application. Originally, these products were created for stripping paint from wood and metal surfaces etc. Usually, they are supplied in the form of gels. It must be borne in mind that these special cleaning agents cost three to four times as much as NaOH solution, and their disposal is more problematic.

Flammable solvents

Where flammable solvents are used, they consist usually of a regenerate (blend) of several solvent components that are normally contained in the paint and coating products. To reduce costs in general, a non-volatile base solvent is employed, which is then enriched with efficient solvents. Preferably the operator optimizes the composition.

The following must be borne in mind when selecting the composition:

- low toxicity
- inflammability
- non-volatile
- rapid, effective action

For rinsing, a regenerate of identical composition is used.

Problems arise because of the high vapor pressure of the solvents used for cleaning, they must be explosion-proof and cleaning pressure is limited to 50 bar so that static electricity will not build up. A system for nitrogen purging could be installed, but this is not necessary if equipment and installations are designed according to the regulations.

Non-flammable solvents

Non-flammable solvents exhibit a high flash point (according to the manufacturer's information). Among the solvents falling under this classification are:

- DBE = di-basic ester (dimethyl esters of adipic acid, glutaric acid and succinic acid).
  DBE is classified non-hazardous according to all EC criteria and its handling is therefore straightforward. This solvent has a very low vapor pressure, a high flash point and high solvency. Consequently the emissions associated with the use of this solvent are well within the limits required by law
- NMP = n-methyl-pyrrolidone

For rinsing, a non-hazardous solvent of identical structure is used.

A disadvantage of both these chemicals is that because of their low vapor pressures these solvents do not dry as quickly as the previous mixtures of volatile and quickly evaporating solvents. A film remains on the vessel surface and needs to be washed away with warm water after the solvent cleaning process. A wastewater treatment plant for this rinsing water is required.

Solvent-based cleaning equipment therefore needs a certain amount of redesign of the cleaning process.

A further decisive factor is the high costs for capital investment and for residues disposal.

Washing medium containing active substances

To be understood by this term products by ALKAREN etc. ALKAREN were used as cleaning agent in earlier tests, see Appendix B.

For rinsing, hot water with a low content of carbonate and magnesium is used.

7.3 Cleaning technology

7.3.1 Technical process

The cleaning medium is allowed to soak into the residue on the equipment to be washed - a chemico-physical process - and this is then dislodged by the mechanical action of the jet and/or rotating brushes. The washing process consists of several steps that are combined and varied depending on plant type, equipment design and cleaning task. Common to all washing processes is the strict separation of cleaning medium from rinsing water, so that there will be no dilution or concentration of the media and they can continue in use for longer without the need for replacement. Optimized technology will result in proper functioning of the equipment.

Appendix A.1 shows a schematic of water-based and alternative cleaning processes. Examples of implemented cleaning plants are shown in Appendix A.2.

The usual washing process is as follows:

- main wash with alkaline solution (NaOH 15% or KOH; stripper) at a temperature of 60°C to 80°C and pressure up to 80 bar
- rinsing step of approx. 10 s with water (with recirculated rinsing water) to remove most of the alkaline solution and to cool down the vessel
- final rinsing step with fresh water to remove all remaining alkaline solution from the vessel
- venting of steam from the closed washing chamber to atmosphere (drying step)

The cleaning time is 5 to 15 minutes, dependent on chemical and physical characteristics of the paints or coatings.

The washing water has to be directed to a wastewater treatment plant (e.g. chemico-physical treatment and/or thermal treatment). This wastewater treatment plant has to be attended by skilled personnel. After about four months, alkaline solution becomes spent, and has to be disposed of. Recovery of spent alkaline solution would be very expensive, and is not economic.

The washing action could be provided by a high pressure rotating nozzle or by a rotary brush. Cleaning with brushes is usually done at a lower pressure of up to 10 bar. The advantage of brushes is the mechanical cleaning action and dislodging of paints adhering to the vessel wall. Their disadvantage is that they are subject to wear and have to be changed after approximately 100 –150 cleaning operations.
A further factor to consider is the material of the vessel and the valves. Posing a problem is mild steel, since the cleaning process will also scrape away the surface protection layer, so that it will be exposed to moisture in the ambient air and will corrode. Non-ferrous metals are problematic because they are not resistant to hot alkaline solutions.

This means that if the operator switches to or adopts water-based cleaning, the mild steel vessels will have to be replaced completely with stainless steel ones, giving rise to high costs.

7.3.2 Action of pressure jet and mechanical cleaning using brushes

Pressure jets

The pressure jet technique is based on a combination of hydrodynamic energy, admixed chemicals that decompose and dissolve paint and coating compounds, the time factor as well as effective guidance of the pressure jet itself.

Pressure, flow rate and temperature of the washing medium likewise play important parts.

The harder the residues have become, the better is the action of the liquid jet. Example: cleaning of residues that have become rubbery in their consistency is generally only possible with difficulty, or with the application of a very high hydrodynamic energy.

Brush cleaning technique

The brush technique is based on a combination of mechanical surface treatment, admixed chemicals that decompose and dissolve paint and coating compounds, the time factor as well as contact of brushes with the entire surface to be cleaned.

The washing medium itself is generally of lesser importance, as the actual removal action is achieved by mechanical means. Basically it has two functions: supporting destruction and softening of the residue compounds and transportation away of the residue-medium mixture.

Alternative technologies

Alternative technologies, like sandblasting, ultrasonic cleaning, plasma cleaning, freezing and application of dry ice pellets are tried out from time to time, but up to now have not met with any notable acceptance.

7.4 Personnel protection and safety precautions

The risk of handling solvents is well known. Much effort has to be done to protect the operators against inhalation (neuro toxic effects) and physical contact (absorption through skin). Risks due to inflammability and explosions have to be eliminated.

The risk when handling cleaning processes with water-based/alternative cleaning agents, depending on the aggressiveness, can also be high, out of another character.

Dangers arise less during the actual washing process in the closed system or covered vessels and containers and more when filling and emptying mobile tanks and due to the risk of coming into contact with cleaning media during maintenance work.

Appropriate protection equipment and training of the operating staff are necessary, both for solvents and water-based/alternative cleaning agents.

7.5 Environmental impact

7.5.1 Emissions to surroundings and within working areas

Emissions of fumes to the surroundings or within working areas are appreciably less than when working with solvent cleaning equipment. Instead, pollutant emissions are shifted to the wastewater as shown in Figure 7.1.

During operation of the equipment as intended, there shall be no possibility of emissions to the working areas.

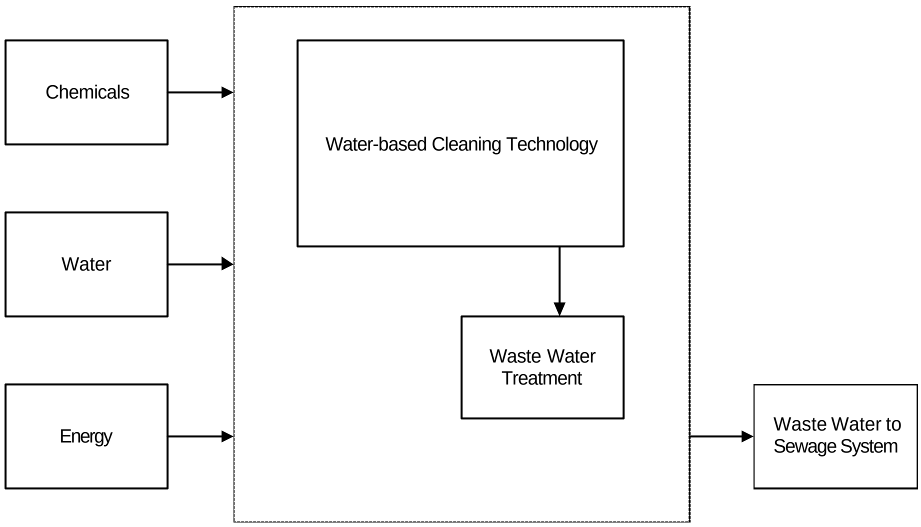


Figure 7.1
Emissions to surroundings.

7.5.2 Wastewater treatment

The rinsing water with its content of cleaning medium as well as the spent cleaning medium, must be directed to a wastewater treatment facility before discharge to the sewer system, or disposed of in some alternative way.

Possibilities are:
- disposal of wastewaters by a specialist company
- directing the water to an on-site wastewater treatment plant
- distillation of wastewater, recycling the distillate as rinsing water and disposal of residues through a specialist company
- chemico-physical wastewater treatment (precipitation/flocculation)

The wastewaters contain primarily paint and coating constituents, such as resins, pigments, small amounts of solvent etc. and residues of cleaning agents, like alkalies, tensides, salts and small amounts of solvent.

Characteristic parameters are:

- pH from 9.5 to14
- solids content up to 3%
- COD value up to 40 g/l

For treatment, chemico-physical processes or distillation are suitable. However, thermal wastewater treatment is only economic if primary energy is already available.

Manufacturers of water-based cleaning systems normally also supply the required wastewater treatment plants in collaboration with qualified suppliers.

In Appendix A.3 a standard solution of wastewater treatment is shown. The plant consists of buffer tank, reactor for neutralization and coagulation, belt filter for dewatering.

The treated water can normally be let to the municipal sewage system. Sludge from the belt filter has to be disposed of as chemical water.

Normal operation time for treatment of 900 l will be approx. 1 hour.

7.5.3 **Residues**

The spent alkaline solution has to be disposed of after around four months' use. Recovery of spent alkaline solution is very expensive and is not economic.

8 Cost Comparison between Water– and Solvent-based Cleaning

For a water-based cleaning plant, depending on its design, the procurement costs may be higher than for a solvent-based plant of equivalent capacity. But if all operating costs are taken into consideration, for example explosion protection, fume treatment, disposal of spent solvent etc., then the total costs for water-based cleaning are comparable. However, use of comparatively expensive special cleaning agents will lead to increased operating costs.

There follows, by way of example, a tabulated comparison of the specific costs as well as of the operating and capital costs for water- and solvent-based cleaning. These examples are taken from the practical experience of Renzmann, and are accordingly customer specific. Precise figures for capital and operating costs can only be determined when the prevailing constraints and conditions are known.

The capital costs stated in this project are based on costs in Germany and are converted from DM to DKK with a conversion rate of 4. Differences in the size of taxes etc. are not included.

8.1 Costs for water-based and alternative cleaning agents

The cost example is based on a cleaning system “SKM”, manufactured by Renzmann. Further description of this plant can be seen in section 6.3.

Table 8.1
Assumptions for cost comparison in Table 8.2 and Table 8.4. Further assumptions and explanations can be seen in Table 8.3 and Table 8.5.

Details of washing process		
- number of washing operations per day		10 or 20
- working days per year		240
- electricity cost	Kr./kWh	0.4
- cost of operator per hour	Kr.	200

Details of solvent		
- type of solvent	Ethanol/Ethylacetat	
- cost of fresh solvent	Kr./l	4.80
- cost of solvent treatment	Kr./l	1.00
- solvent recovery rate	%	90
- operating costs of fume treatment	Kr./annually	40,000

Details of water-based cleaning agent		
- type of cleaning agent	Lauge	
- concentration	%	13
- cost of mixing cleaning agent	Kr./l	0.68
- cost of rinsing water	Kr./m^3	10
- cost of disposal of wastewater	Kr./m^3	1000

Details of water-based cleaning agent		
- type of cleaning agent	Special cleaning agent (Stripper 303)	
- concentration	%	50
- cost of mixing cleaning agent	Kr./l	9
- cost of rinsing water	Kr./m^3	10
- cost of disposal of wastewater	Kr./m^3	1000

Table 8.2
Cost comparison between solvent- and water-based cleaning agents for type SKM washing equipment. 20 washing operations per day.

Capital investment			
	Solvent	**Alkali**	**Stripper 303**
Plant modules		with closed-circuit rinsing	with closed-circuit rinsing
SKM 15/16	672,520 kr.	641,360 kr.	641,360 kr.
Self-cleaning	11,040 kr.	12,480 kr.	12,480 kr.
Post-wash rinsing		27,560 kr.	27,560 kr.
Supply of cleaning solvent	9,200 kr.		
Filling/emptying equipment	32,320 kr.	44,880 kr.	44,880 kr.
Heating		46,320 kr.	46,320 kr.
Equipment for alkali		124,400 kr.	124,400 kr.
Fume extraction	67,520 kr.	23,800 kr.	23,800 kr.
Separate rinsing circuit		139,880 kr.	139,880 kr.
Total plant investment	792,600 kr.	1,060,680 kr.	1,060,680 kr.
Including installation etc.	952,000 kr.	1,276,000 kr.	1,276,000 kr.

Annual costs			
1. Depreciation (10 years)	**95,200 kr.**	**127,600 kr.**	**127,600 kr.**
2. Interest (6% annually of one half of investments costs)	**28,560 kr.**	**38,280 kr.**	**38,280 kr.**
3. Operating costs (for 4800 washing operations, annually)			
Making up solvent losses	111,053 kr.		
Making up cleaning agent + rinse water		14,976 kr.	155,520 kr.
Solvent preparation	167,040 kr.		
Disposal of rinse water		192,000 kr.	192,000 kr.
Electricity consumption	19,200 kr.	28,800 kr.	28,800 kr.
Fume treatment	40,000 kr.		
Operator	96,000 kr.	96,000 kr.	96,000 kr.
Total operating costs	433,293 kr.	331,776 kr.	472,320 kr.
Total annual costs	557,053 kr.	497,656 kr.	638,200 kr.
Total costs per washing operation	116 kr.	104 kr.	133 kr.

Table 8.3
Assumptions/explanations.

Assumptions/explanations			
General assumptions			**Notes**
Number washing operations/day	20		
Working days/year	240	4800	
Wetting of machine + vessels to be washed			
Solvent	3	l	
Water-based cleaning agent	4	l	
Volumetric capacity of equipment	4	m³	
Electricity costs	0.40	Kr./kWh	
Hourly cost of operator	200	Kr.	
Operator handling time per vessel	0.1	h	
Solvent			
Specific assumptions for solvent			
Costs of fresh solvent	4.80	Kr./l	
Saturation concentration of solvent	80	g/m³	Loading of equipment atmosphere before fume extraction
Quantity washing solvent per washing operation	30	l	
Costs for solvent treatment	1.00	Kr./l	On-site distillation (excl. disposal)
Solvent recovery rate	95%		
Disposal of distillation residue	3,200	Kr./m³	
Electricity consumption per washing operation	10	kWh	For a pure washing time of 10 min
Operating costs of fume post-treatment, annually	40,000	Kr.	
Operating costs "Solvent" per washing operation			
Make-up of solvent losses	23.14	Kr.	Losses from wetting equipment and vessels, loading of atmosphere
Treatment of solvent	34.80	Kr.	Including residue disposal
Electricity consumption	4.00	Kr.	
Fume treatment	8.33	Kr.	Operating cost share
Operator	20.00	Kr.	
Operating costs per washing operation	**90.27**	Kr.	
Annual operating costs	**433,296**	Kr.	

Water-based cleaning agent			
Specific assumptions for water-based cleaning agent			
Costs of cleaning agent solution			
Alkali	0.68	Kr./l	12% NaOH
Stripper 303	8.00	Kr./l	Mixed 1:1 with water
"Consumption" cleaning agent solution/washing operation	3	l	Corresponds to wetting of equipment and vessels to be cleaned
Costs of rinsing water	10.00	Kr./m³	Excluding charges for discharge
Quantity of rinsing water per washing operation			
- without closed-loop rinsing	60	l	
- with closed-loop rinsing	40	l	
Disposal costs rinsing water/cleaning agent	1,000	Kr./m³	External disposal, chemico-physical treatment
Electricity consumption/washing operation	15	kWh	Incl. heating and heat losses, for a pure washing time of 10 min
Operating costs "Alkali" per washing operation			
Make-up of cleaning agent			Make-up of carry-over losses of cleaning agent + rinsing water consumption
- without closed-loop rinsing	3.32	Kr.	
- with closed-loop rinsing	3.12	Kr.	
Disposal of rinsing water			Due to carry-over, the "spent cleaning agent" is disposed of through the rinsing water
- without closed-loop rinsing	60.00	Kr.	
- with closed-loop rinsing	40.00	Kr.	
Electricity consumption	6.00	Kr.	
Operator	20.00	Kr.	
Operating costs per washing operation	**89.32**	Kr.	Without closed-loop rinsing circuit
Annual operating costs	**428,736**	Kr.	Without closed-loop rinsing circuit
Operating costs per washing operation	**69.12**	Kr.	With closed-loop rinsing circuit
Annual operating costs	**331,776**	Kr.	With closed-loop rinsing circuit
Operating costs "Stripper" per washing operation			
Make-up of cleaning agent			Make-up of carry-over losses of cleaning agent + rinsing water
- without closed-loop rinsing	32.60	Kr.	
- with closed-loop rinsing	32.40	Kr.	
Disposal of rinsing water			Due to carry-over, the "spent cleaning agent" is disposed of through the rinsing water
- without closed-loop rinsing	60.00	Kr.	
- with closed-loop rinsing	40.00	Kr.	
Electricity consumption	6.00	Kr.	
Operator	20.00	Kr.	
Operating costs per washing operation	**118.60**	Kr.	Without closed-loop rinsing circuit
Annual operating costs	**569,280**	Kr.	Without closed-loop rinsing circuit
Operating costs per washing operation	**98.40**	Kr.	With closed-loop rinsing circuit

Table 8.4

Cost comparison between solvent- and water-based cleaning agents for type SKM washing equipment. 10 washing operations per day

Capital investment			
	Solvent	**Alkali**	**Stripper 303**
Plant modules		with closed-circuit rinsing	with closed-circuit rinsing
SKM 15/16	672,520 kr.	641,360 kr.	641,360 kr.
Self-cleaning	11,040 kr.	12,480 kr.	12,480 kr.
Post-wash rinsing		27,560 kr.	27,560 kr.
Supply of cleaning solvent	9,200 kr.		
Filling/emptying equipment	32,320 kr.	44,880 kr.	44,880 kr.
Heating		46,320 kr.	46,320 kr.
Equipment for alkali		124,400 kr.	124,400 kr.
Fume extraction	67,520 kr.	23,800 kr.	23,800 kr.
Separate rinsing circuit		139,880 kr.	139,880 kr.
Total plant investment	792,600 kr.	1,060,680 kr.	1,060,680 kr.
Including installation etc.	952,000 kr.	1,276,000 kr.	1,276,000 kr.

Annual costs			
1. Depreciation (10 years)	95,200 kr.	127,600 kr.	127,600 kr.
2. Interest (6% of one half of investment costs)	**28,560 kr.**	**38,280 kr.**	**38,280 kr.**
3. Operating costs (for 2400 washing operations, annually)			
Making up solvent losses	55,520 kr.		
Making up cleaning agent		7,488 kr.	77,760 kr.
Solvent preparation	83,520 kr.		
Disposal of rinse water		96,000 kr.	96,000 kr.
Electricity consumption	9,600 kr.	14,400 kr.	14,400 kr.
Fume treatment	40,000 kr.		
Operator	48,000 kr.	48,000 kr.	48,000 kr.
Total operating costs	**236,640 kr.**	**165,888 kr.**	**236,160 kr.**
Total annual costs	**360,400 kr.**	**331,768 kr.**	**402,040 kr.**
Total costs per washing operation	**150 kr.**	**138 kr.**	**167 kr.**

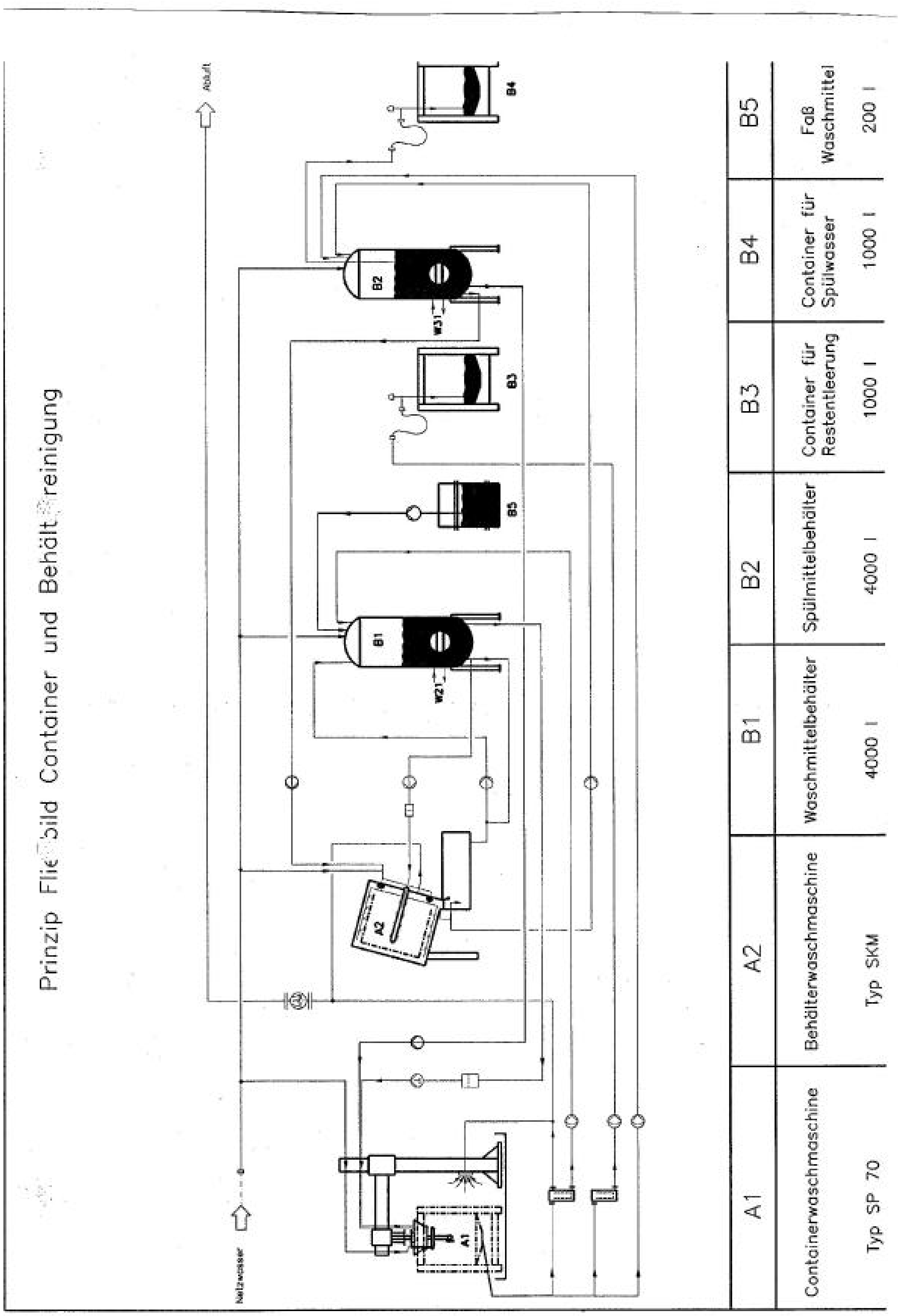
Table 8.5
Assumptions/explanations.

Assumptions/explanations			
General assumptions			**Notes**
Number washing operations/day	10		
Working days/year	240	2400	
Wetting of machine + vessels to be washed			
Solvent	3	l	
Water-based cleaning agent	4	l	
Volumetric capacity of equipment	4	m³	
Electricity costs	0.40	Kr./kWh	
Hourly cost of operator	200	Kr.	
Operator handling time per vessel	0.1	h	
Solvent			
Specific assumptions for solvent			
Costs of fresh solvent	4.80	Kr./l	
Saturation concentration of solvent	80	g/m³	Loading of equipment atmosphere before fume extraction
Quantity washing solvent per washing operation	30	l	
Costs for solvent treatment	1.00	Kr./l	On-site distillation (excl. disposal)
Solvent recovery rate	95%		
Disposal of distillation residue	3,200	Kr./m³	
Electricity consumption per washing operation	10	kWh	For a pure washing time of 10 min
Operating costs of fume post-treatment, annually	40,000	Kr.	
Operating costs "Solvent" per washing operation			
Make-up of solvent losses	23.14	Kr.	Losses from wetting equipment and vessels, loading of atmosphere
Treatment of solvent	34.80	Kr.	Including residue disposal
Electricity consumption	4.00	Kr.	
Fume treatment	16.67	Kr.	Operating cost share
Operator	20.00	Kr.	
Operating costs per washing operation	**98.60**	Kr.	
Annual operating costs	**236,640**	Kr.	
Water-based cleaning agent			
Specific assumptions for water-based cleaning agent			
Costs of cleaning agent solution			
Alkali	0.68	Kr./l	12% NaOH
Stripper 303	8.00	Kr./l	Mixed 1:1 with water
"Consumption" cleaning agent solution/washing operation	3	l	Corresponds to wetting of equipment and vessels to be cleaned
Costs of rinsing water	10,000	Kr./m³	Excluding charges for discharge to sewer
Quantity of rinsing water per washing operation			
- without closed-loop rinsing	60	l	
- with closed-loop rinsing	40	l	
Disposal costs rinsing water/cleaning agent	1,000	Kr./m³	External disposal, chemico-physical treatment

Operating costs "Alkali" per washing operation			
Make-up of cleaning agent			Make-up of carry-over losses of cleaning agent + rinsing water consumption
- without closed-loop rinsing	3.32	Kr.	
- with closed-loop rinsing	3.12	Kr.	
Disposal of rinsing water			Due to carry-over, the "spent cleaning agent" is disposed of through the rinsing water
- without closed-loop rinsing	60.00	Kr.	
- with closed-loop rinsing	40.00	Kr.	
Electricity consumption	6.00	Kr.	
Operator	20.00	Kr.	
Operating costs per washing operation	**89.32**	Kr.	Without closed-loop rinsing circuit
Annual operating costs	**214,368**	Kr.	Without closed-loop rinsing circuit
Operating costs per washing operation	**69.12**	Kr.	With closed-loop rinsing circuit
Annual operating costs	**165,888**	Kr.	With closed-loop rinsing circuit
Operating costs "Stripper" per washing operation			
Make-up of cleaning agent			Make-up of carry-over losses of cleaning agent + rinsing water consumption
- without closed-loop rinsing	32.60	Kr.	
- with closed-loop rinsing	32.40	Kr.	
Disposal of rinsing water			Due to carry-over, the "spent cleaning agent" is disposed of through the rinsing water
- without closed-loop rinsing	60.00	Kr.	
- with closed-loop rinsing	40.00	Kr.	
Electricity consumption	6.00	Kr.	
Operator	20.00	Kr.	
Operating costs per washing operation	**118.60**	Kr.	Without closed-loop rinsing circuit
Annual operating costs	**284,640**	Kr.	Without closed-loop rinsing circuit
Operating costs per washing operation	**98.40**	Kr.	With closed-loop rinsing circuit
Annual operating costs	**236,160**	Kr.	With closed-loop rinsing circuit

Appendix A.1

Flow sheet.



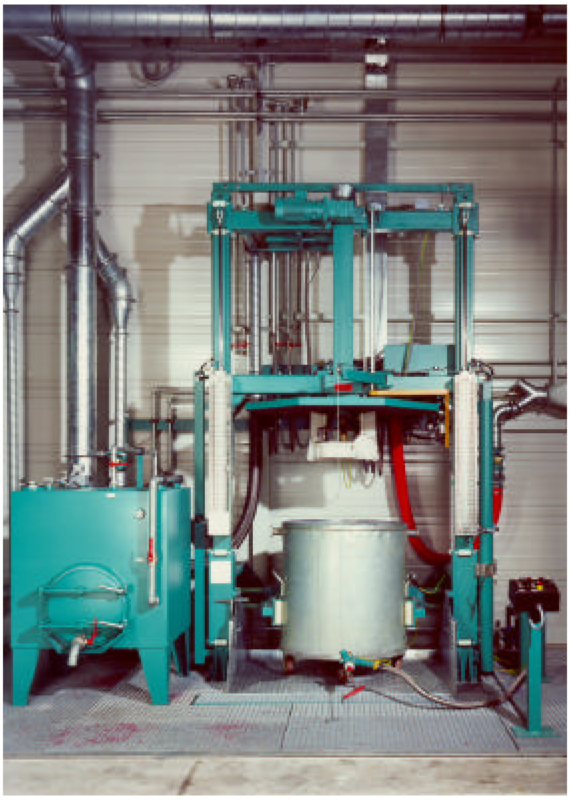


Photo 1:
Washing machine type Robus (SP70) for inside cleaning with brushes, (Renzmann).

Photo 2:

Washing machine type Robus (SP70) for inside cleaning with brushes, (Renzmann).

Photo 3:
Washing machine type SKM for inside and outside cleaning by spray (Renzmann).

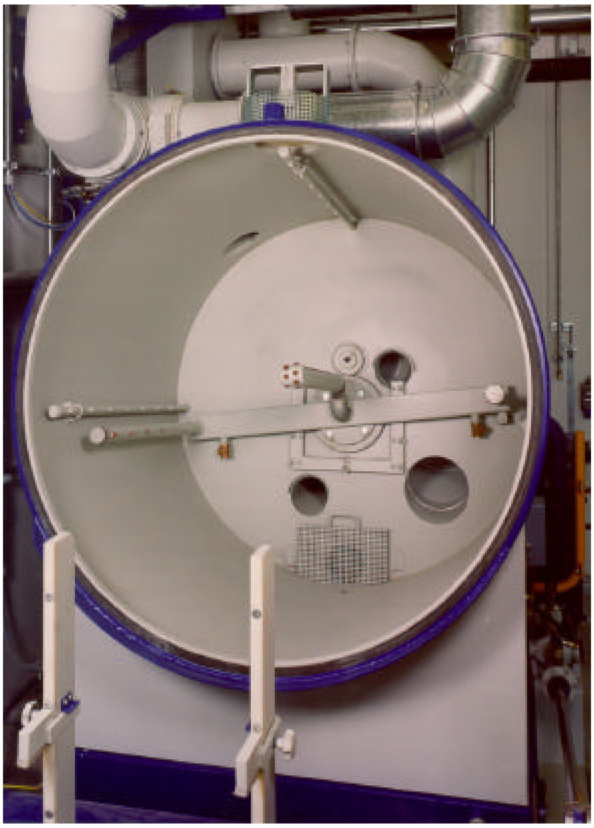


Photo 4:
Washing machine type SKM for inside and outside cleaning by spray (Renzmann).

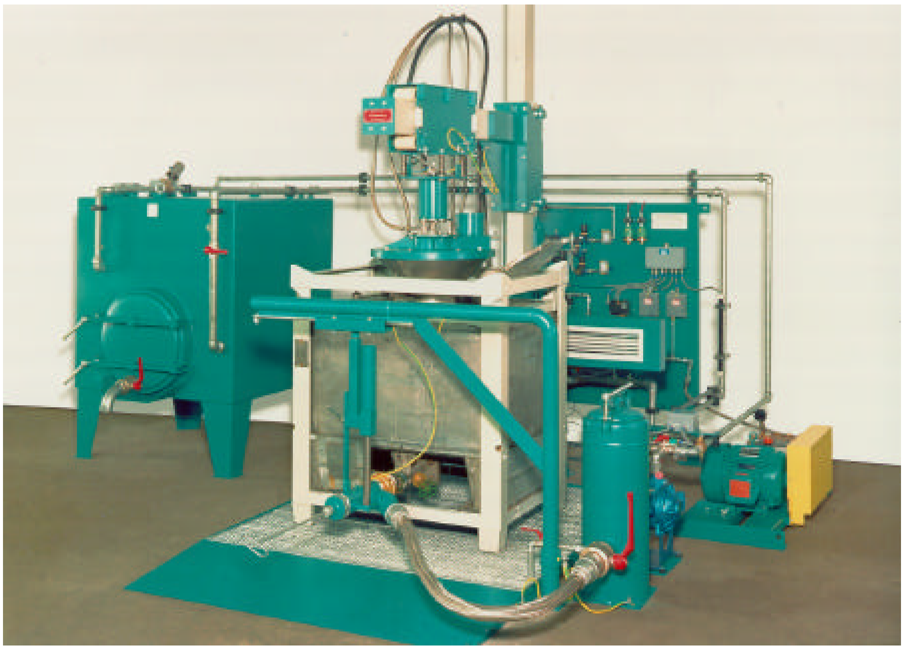


Photo 5:
Washing machine type SP50/SP80 for container and vessels by spray (Renzmann).

Photo 6:
External rinsing station (Riobeer, IBC cleaning plant CW-III-ex 3D).

Photo 7:
View of rear with runback unit and drying air unit, (Riobeer, IBC cleaning plant CW-III-ex 3D).

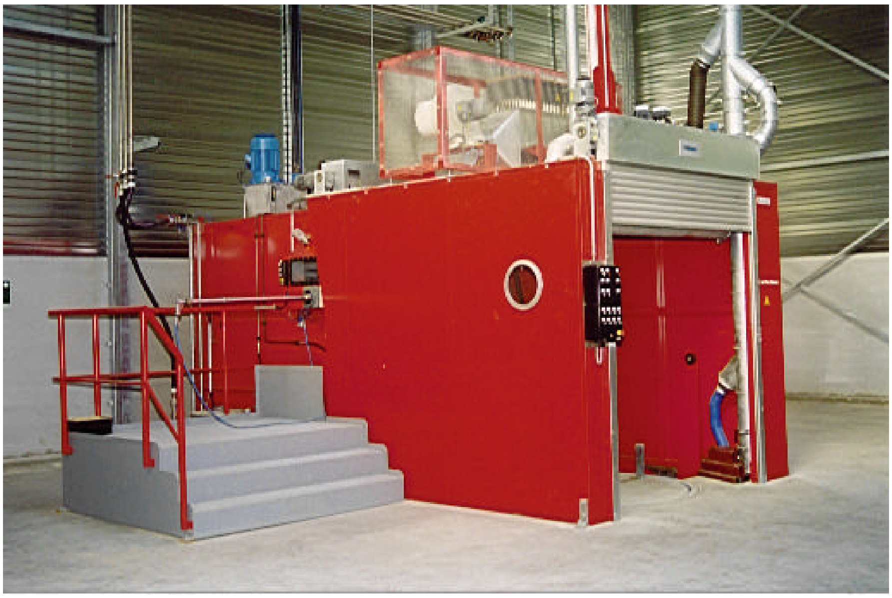


Photo 8:
Charging, side view, integrated valve cleaning with telescope brush, (Riobeer, Mixing vat cleaning plant F-ex 0I RMT).

Photo 9:
Charging, turntable, traversing radial brush, (Riobeer, Mixing vat cleaning plant F-ex 0I RMT).

Photo 10:
Additional equipment (from left):
Precleaning station, manual cleaning station, lid cleaner, agitator cleaner, precleaning station (Riobeer).

Photo 11:
Precleaning station (Riobeer).

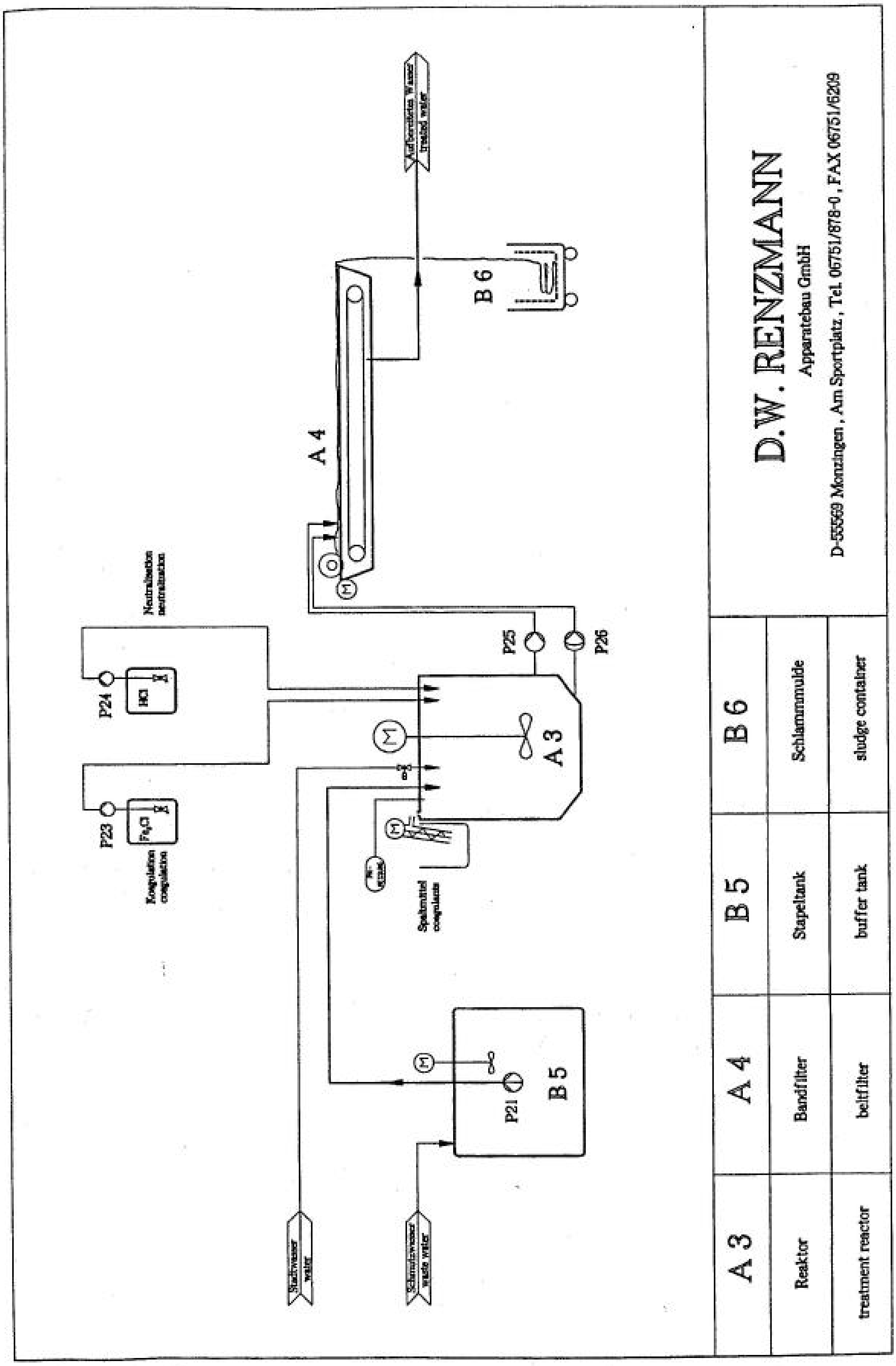
Photo 12:
Manual cleaning station (Riobeer).

Photo 13:
Lid cleaner (Riobeer).

Photo 14:
Agitator cleaner (Riobeer).

Photo 15:
Special washing tanks for transparent and isocyanate coatings (Riobeer).

Photo 16:
Equipment for cleaning of mobile bin (Riobeer).



Aufbereitetes Wasser
treated water
B 6
A 4
Neutralisation
neutralization
P24
HCl
P23
Koagulation
coagulation
P25
P26
A 3
Spaltmittel
coagulants
B 5
P21
Stadtwasser
water
Schmutzwasser
waste water
D.W. RENZMANN
Apparatebau GmbH
D-55569 Monzingen, Am Sportplatz, Tel. 06751/878-0, FAX 06751/6209
A 3
Reaktor
treatment reactor
A 4
Bandfilter
beltfilter
B 5
Stapeltank
buffer tank
B 6
Schlammmulde
sludge container

1997 Report

TRANSLATION of

CLEANER TECHNOLOGY WITHIN THE LACQUER AND PAINT INDUSTRY

Water-based cleaning of mixing vessels and equipment

by

Henrik Møller Jørgensen

1 Aim of the project

The mapping of waste flows from the lacquer and paint industry which was carried out by the Danish Paintmakers' Association for lacquer and paint manufacturers for the Danish National Environmental Protection Agency in 1996, shows that the VOC-emission is in an area where it is possible to reduce the environmental impact.

Based on the above an assessment of the VOC-emission has been carried out in each department of the reference company. The VOC-emission from cleaning the mobile mixing vessels is estimated to 25-30% of the total VOC-emission from the production of solvent-borne paint.

The total VOC-emission from the Danish lacquer and paint production is estimated to approx. 450 tons per year. In other words it will be possible to abate the emission of VOC with approx. 110 tons per year by changing to a water-based cleaning of the mixing vessels. The reduction will correspond to approx. 10% of the total VOC-emission from the chemical industry in Denmark.

Another considerable argument for transition to water-based cleaning of the mixing vessels is a significant improvement of the working environment in the vessel cleaning area.

2 Thinner-based cleaning

Today, the cleaning of the mixing vessels takes place in a heavily loaded working environment. The premises are equipped with powerful ventilation, but nevertheless it is necessary to wear personal respiratory protective device.

First the mixing vessel is cleaned manually with organic solvents in order to remove the major part of the paint residues. Subsequently the vessel is placed on the cleaning machine. The machine cleans the vessel with rotating brushes in presence of organic solvents.

Organic solvents and paint sludge are collected by means of a grating in the floor and are lead to distillation. The solvents distilled off are reused for cleaning of mixing vessels. Due to this process it is impossible to determine the exact composition and with that the dangerousness of this mixture of organic solvents.

The distillation residues are collected and sent to destruction at the Intermunicipal Chemical Waste Treatment Plant, “Kommunekemi”.

3 Removal of paint

Hot alkaline bath

Removal of paint can be carried out by alkaline cleaning (pH > 13), at a temperature of 50-95 degr. C.

The chemical paint binders are hydrolysed due to the high alkalinity. The penetration of the lacquer film and the migration during this can be increased by addition of surface-active agents.

Strong hydrolysed and aggressive leaching solutions can be used to remove paint from steel whereas strong organic bases are used for other metals.

Alkaline cleaning is very economical and is capable of removing most kinds of paints /2/, /3/.

Acid paint remover

These are based on strong inorganic acid. They are effective by degenerating the paint binder in the lacquer film. Sulphuric acid (pH < 1) is often used.

The acidic paint removers are used to remove epoxy and polyamide paint from hot sensitive items. By choice of acid, the acid resistance of the material must be considered. The temperature in the cleaning vessel is usually from 20-50 degr. C /2/, /3/.

Neutral paint removers

Neutral paint removers are based on glycol, glycol ether, N-Methyl-pyrrolidone or mixtures from this. The temperature of the cleaning vessel is 20-40 degr. C.

The use of neutral paint removers is confined to the physically drying lacquers /2/, /3/.

Mechanical removal of paint

By means of airless cleaning with water paint can be removed from hard surfaces (700 - 1000 bar).

Blasting with sand, plastic or other suitable materials may also be used /2/, /5/.

Thermal removal of paint

The methods are based on combustion and incineration of the paint at temperatures of 300-500 degr. C for 20-60 min.

The incineration may also take place in salt baths increasing the speed to 30-120 sec.

These pyrolytic methods are very energy-demanding and the construction and operating costs are considerable /2/, /4/.

Low temperature paint removers

Due to the fact that the paint shrinks by cooling with liquid nitrogen (-196 degr. C) this is also a suitable method for removal of paint (the cooling process last 1-3 min.) /2/.

4 Selction of cleaning methods

Airless cleaning with water

Airless cleaning with water and subsequent filtration must be considered the most pollution free cleaning method. This type of plant will approx. amount to DKK 250,000 (everything included).

WORMA in Düisburg, Germany is represented by O & J Højtryk in Esbjerg /5/.

The method is only reported used on soft lacquers, however it is considered suitable for the purpose.

CIP-cleaning with leaching solution/acid

These methods are well-known from among others the pharmaceutical industry and the food processing industry. The suppliers of the plant say/declare concurrently that approx. 2.5% ALKAREN 45 or a similar product is used. Based on this information the preliminary tests with this concentration are carried out.

The temperature in the cleaning vessels fluctuates from 70-80 degr. C. Søren Hauritz from Akzo Nobel is of the opinion that alkaline cleaning is the best solution. The reasons adduced for this opinion is the bad experience with alkaline CIP-cleaning of mixing vessels. Akzo Nobel use a 30% sodium hydroxide (corresponding to approx. 15% NaOH) with a bath temperature of approx. 70 degr. C.

However, it should be investigated if a combined product like ALKAREN 45 may be used in a lower concentration (possible 2.5% as stated by the suppliers of the plant).

Neutral paint removers

Glycols, glycol ethers and N-pyrrolidone are organic compounds acting as organic solvents. Due to their high boiling point and low evaporative pressure the substances are not defined as organic solvents. These substances will contribute to a strong increase of COD in the wastewater.

Preliminary laboratory tests are made to examine the efficiency of the substances.

Thermal methods

The pyrolytic methods will cause considerably initial costs and besides, these methods demand a lot of energy. Obviously, it is estimated that these methods are not applicable for this purpose.

Cooling with liquid nitrogen must be considered as a pure academic method, being possibly applicable within the laboratory area.

Nothing further will be done in relation to these methods.

5 Laboratory tests

The investigations are instituted with a view to prove that it is possible to remove paint with acidic or alkaline CIP-cleaning materials. Further the efficiency of the Neutral paint remover, especially developed for this project, is investigated.

Apply paint on the sheets and air-dry for one hour at ambient temperature. After this the sheets are dipped in the cleaning solvent while stirring carefully. The solvent has been heated to the temperature required.

The paint is completely removed after 10 min. In case the paint is not removed after expiration of the time, the test is repeated either with a higher temperature or a larger concentration of the cleaning solvent.

Alkaline bath: COMBIREN is a leaching-based combined cleaning solvent, which is widely used within the food processing industry. COMBIREN is mainly used in cases where most other alkaline CIP-cleaning materials cannot remove the paint.

COMBIREN contains: Sodium hydroxide, potassium hydroxide and complex agents.

Acid bath: NOVASYRE is based on sulphamic acid and a combination of organic acid. The product is used within the food processing industry where a strong phosphate free cleaning is required. The composition of the different organic acids provides a high acid strength without utilizing traditional acid such as phosphoric acid and nitric acid.

NOVASYRE contains: Sulphamic acid, organic acids and tensides.

Neutral bath: NOVALAK is a N-methyl-pyrrolidone based paint remover which is specially developed to comply with possible problems with leaching solution and acid. The product does not give rise to anxiety as regards corrosion and can be used on all metals.

NOVALAK contains: N-methyl-pyrrolidone and tensides.

The results carried out on steel sheets appear from enclosure 1.

Beyond the tests on steel, a number of tests have been made on teflon-coated aluminium. These sheets have been delivered from ACCOAT A/S.

However, results from these tests are not included. During the tests the aluminium corroded and after 1-2 preliminary tests it was impossible to make further tests.

6 Mechanical paint remover with water

IAT Kolding

The preliminary tests are carried out with a view to investigate if it is possible to remove the paint with water, pressure and heat.

The CIP-plant performs a constant pressure of 110 bar and the temperature can be adjusted from 8-100 degr. C.

The tests are carried out on teflon-coated vessels and steel vessels. Two types of teflon-coatings are used ACCOFAL 2G and ACCOPON 2G.

ACCOFAL 2G is softer and seems smoother (more dirt-repellant) than ACCOPON 2G. Alkyd simply crawls off when the coating is applied. It is possible to clean the vessel for paint having dried up for approx. 30 min. at ambient temperature. During the tests it appeared that it is very important with a cold rinse before the actual cleaning is carried out. In case the pre-rinse is left undone the paint will polymerize and become rubbery and it is then impossible to remove the paint (the results appear from enclosure 2).

ACCOPON 2G seems very hard and is rather rough to look at. After the cleaning a small edge was left, however it was easy to remove with a nail. During the test of removing the paint edge it turned out that the coating of the vessel left green pigments in the white lacquer. Later, ACCOAT A/S investigated the vessel and had to admit that the coating was not carried out properly - the teflon was undercured.

Generally speaking, the teflon-coating sticks very poorly and is easily removed. The coatings are “very” soft and that is why the production management in the reference company has expressed their doubts that teflon-coatings can be used in mobile mixing vessels. Today, the company utilizes teflon-coatings on stationary mixing vessels.

A test has been made on a steel vessel according to above conditions. Altogether the water had no effect on the paint (the results appear from enclosure 2).

O & J Højtryk, Esbjerg

Tests have been made with pressure from 400-1150 bar. It clearly appeared from the tests that it is impossible to remove a paint film from a steel surface with water and pressure being undercured (the paint was moved around in the vessel).

Tests on undercured epoxy were also carried out. At a pressure of 1150 bar it was very easy to remove the lacquer.

7 Alkaline paint remover

IAT Kolding

IAT Kolding undertakes cleaning of tankers and pallet tanks. We are in a position to rent the plant for cleaning of pallet tanks. The plant is a modified Kärcher high-pressure cleaner for industrial cleaning with a rotating spud.

First a pre-rinse for 5 min. The plant performs 18-20 litres of water/min. and a pressure of 90-100 bar. It is not possible either to adjust the pressure or the concentration of cleaning solvent on the plant.

Alkyd: After a total cleaning time of 30 min. a ALKAREN 45 concentration of 1.2% and a bath temperature of 70 degr. C the paint was completely removed from the steel surface.

Epoxy: After a cleaning time of 60 min. 75% of the paint was removed. The remaining 25% was easy to remove with a slight mechanical effect. The concentration of the cleaning solvent and the bath temperature was 1.2% ALKAREN 45 and 70 degr. C respectively.

Similar tests were carried out on the teflon-coatings. It was not possible to remove any of the paint from the teflon-coatings - even after 60 min.

Brüel International A/S

Brüel International manufactures tunnel washers and cabins for the chemical, pharmaceutical and food processing industries. The company has experiences with cleaning of mixing vessels from a Norwegian producer of paint and lacquer.

The Norwegian paint and lacquer manufacturer uses an alkaline combined cleaning solvent corresponding to ALKAREN 45 from NOVADAN A/S. The concentration of the cleaning solvent is approx. 2.5%, the bath temperature is 75 degr. C, and the pressure is approx. 7 bar.

Brüel International’s own experiences draw attention to the fact that a too high pressure (above 10 bar) makes the cleaning difficult. This fact is identical with our results with high pressure.

The tests are carried out on a Wemag washer. The machine is a cabinet washer, manufactured for washing butcher’s vans within the slaughterhouse industry, the so-called Wemag van (machine type CB1-42).

The machine performs 100 litres per min., the pressure is 7 bar and the temperature can be adjusted from 8-95 degr. C.

After some unsuccessful attempts a short pre-rinse for 300 sec. is chosen, the cleaning time is set to 900 sec. and the bath temperature is set to 80 degr. C.
During the unsuccessful attempts with temperatures below 80 degr. C, the ALKAREN 45 concentration was gradually increased from 3% to 5.7%. It was not possible to thin the leaching solution in the plant and due to lack of

time it was not possible to start up a new attempt (the plant had to be sent to Sweden).

Tests with above cleaning procedure were carried out on alkyd, epoxy, acrylic, and polyester. All types of lacquer were completely removed after the cleaning (the results appear from enclosure 5).

8 Discussion

The investigations show that the temperature plays an essential part as to the cleaning results. Thus, it was not possible to achieve a reasonable cleaning result without a cold pre-rinse. At a bath temperature below 80 degr. C it is impossible to remove the paint completely.

The total cleaning time of 20-25 min. must be considered as too long. However, it should be noted that neither time nor leaching solution is optimised. Therefore, future work should be concentrated about optimising these parameters.

The pre-rinse was set to 300 sec. in order to ensure a sufficient cooling of the paint film. During normal operation this time is probably too long. The reason for the longer rinse time is that the tests are carried out on the same vessel. Thus the vessel was not cold at the beginning of the test and due to this the drying time of the paint was also reduced. The vessel was approx. 80 degr. C by the time it was taken out of the cabin.

The cleaning cycle of 15 min. is also too long. A satisfactory cleaning result within a shorter period with the concentration of ALKAREN 45 should be obtainable.

It should be investigated how fast it is possible to clean a vessel with the chosen parameters. In case the time of the cleaning cycle is reduced to less than 300 sec. the following tests should concentrate about reducing the concentration of ALKAREN 45.

After optimizing the cleaning at 80 degr. C an investigation should take place aiming at the influence of a possible change of temperature on the cleaning result.

After optimizing the total cleaning procedure a test on all colour and lacquer systems in the production at the reference company should be carried out (see enclosure 1).

During tests on the cabinet washer it should be investigated further how large a dirt load the cleaning solvent manages before it has to be replaced. This condition will not only affect the wastewater amount and the water amount on the plant, but also the usability of the procedure as such. If the cleaning solvent needs to be replaced more than two times a day this may affect the capacity of the plant considerably. It may be very time-consuming to heat up the 800 liters of cleaning solution. Pumping of liquid from and to the machine also takes a long time.

The optimal solution would be to replace the cleaning solution one time every 24 hours. The regeneration of the liquid may take place by means of filters.

9 Conclusion

It is conceivable that a considerable low leaching solution may clean the mixing vessels from the production of paint and lacquer.

However, the cleaning time of 20-25 min. per vessel is too long. The future work must therefore be concentrated about optimizing the cleaning procedure. The total cleaning time per vessel must be between 5 and 7 min. corresponding to a capacity of 8-12 vessels per hour.

The concentration of the cleaning solvent is reduced so that the cleaning solvent is non-corroding. Thus, the ALKAREN 45 concentration must be below 3% corresponding to a NaOH concentration less than 1% (local irritating).

The used cabinet washer must also be considered applicable for the purpose.

Reference list

/1/ Orientering fra Miljøstyrelsen Nr. 5 1996, Brancheorientering for lak- og farveindustrien (Information from the Danish Environmental Protection Agency No. 5 1996, Information from the trade association for the paint and lacquer industry

/2/ Ullmanns Encyclopedi, vol A 18, p 472-473

/3/ W. Antony, Oberfläche, JOT 8 (1988) p 16-18.
Chemische Entlackung: Medien und Anlagen

/4/ G. Hirschmann og R. Fronek, Lakiertechnik 5 (1996) p 424-426.
Thermische Reinigung und Entschichtung.

/5/ A. W. Momber, Oberfläche, JOT 4 (1997) p 58-62,
Entlacken mit Hochdruckwasserstrahl-Technik

Enclosure list

1. NOVADAN A/S, results from laboratory tests
2. IAT Kolding, results from cleaning tests with water
3. Data sheet on ALKAREN 45
4. IAT Kolding, results from cleaning tests with leaching solution
5. Brüel, results from cleaning tests with leaching solution in cabinet washer

Solubility tests carried out by NOVADAN A/S

The test results carried out on steel plates on 19 February 1997 by Mr. Ole Christensen.

Alkyd:	**Alkaline cleaning – 75% COMBIREN at 80 degr. C** 90% removed after 10 min., the residues can be flushed away with lukewarm water. Completely blank steel without any coatings. Good effect. On standing the paint settles.
Polyester:	**Alkaline cleaning – 75% COMBIREN at 80 degr. C** A slippery film is left which will not wash off immediately, however, the film can be removed by wiping with a piece of paper (in one touch). Presumably a mechanical effect (brush/flush) will manage that. Different acids have a poor effect. NOVALAK has some effect.
Acrylic:	**NOVALAK concentrated. At 30-40 degr. C** Different acid/bases had a poor effect. NOVALAK managed to remove 95% - after 20 min. NOVALAK cleans after approx. 5 min., however a thin film is left on the steel being easy to wipe off.
Acrylarnid:	**NOVASYRE at 80 degr. C/NOVALAK at 30-40 degr. C** Alkaline cleaning has no – poor effect. At the same time NOVASYRE demands some mechanical effect at which the paint loosens in large flakes. NOVALAK has a more convincing effect. However, a thin film is left which again is easy to wipe off. Problematic – as the type dries up incredibly fast.
Epoxy:	**NOVALAK 30-40 degr. C** Acid/basic cleaning – on the whole no effect. NOVALAK combined with slight mechanical effect is efficiently.
Isocyanat:	**Alkaline cleaning – COMBIREN at 80 degr. C** Non-problematic – 100% pure with no mechanical effect.
Nitro-: cellulose	**Alkaline cleaning – COMBIREN at 80 degr. C** Non-problematic – 100% pure with no mechanical effect.
Vinyl:	**NOVASYRE at 80 degr. C** COMBIREN/NOVALAK have generally speaking no effect. On the contrary NOVASYRE has an almost momentary effect. After 1-2 min. there is only a film left which, however, was not removable. Presumably a brushing/flushing effect may help. Again a very fast drying type. Rather problematic.

At temperatures below 80 degr. C acid and bases had no or only very pure effect.

Cleaning tests with water at IAT on 10 May 1997

The plant performs 18-20 litres of water/min. and performs a pressure of approx. 110 bar.

Alkyd	Temperature	Time	Result
	8 degr. C	5 min.	An edge of paint is left
	8 degr. C	10 min.	The edge is still not removed
	30 degr. C	5 min.	An edge of paint is left
	70 degr. C	5 min.	Almost clean – a small edge is left
	70 degr. C	5 min.	Clean – somewhat by welding

The tests have been carried out on a vessel coated with ACCOFAL 2G from ACCOAT. The cleaning time shall be considered with reservation as all the tests have been carried out on the same layer of paint (accumulated).

Alkyd	Temperature	Time	Result
	50 degr. C	5 min.	The paint gets lumpy
	New test		
	8 degr. C	5 min.	Edge of paint
	50 degr. C	5 min.	Edge of paint

The tests have been carried out on a vessel coated with ACCOPON 2G from ACCOAT.

Alkyd	Temperature	Time	Result
	8 degr. C	5 min.	No effect
	30 degr. C	5 min.	No effect

The test has been carried out on steel.

Epoxy	Temperature	Time	Result
	8 degr. C	5 min.	Good effect – small edge
	30 degr. C	5 min.	Small edge
	70 degr. C	5 min.	Small edge
	70 degr. C	5 min.	Small edge

The tests have been carried out on a vessel coated with ACCOFAL 2G from ACCOAT. The cleaning times shall be considered with reservation as all the tests have been carried out on the same layer of paint (accumulated).

Epoxy	**Temperature**	**Time**	**Result**
	8 degr. C	10 min.	Good effect – small edge
	30 degr. C	5 min.	Small edge
	70 degr. C	5 min.	Small edge

The tests have been carried out on a vessel coated with ACCOPON 2G from ACCOAT. The cleaning times shall be considered with reservation as all the tests have been carried out on the same layer of paint (accumulated).

Cleaning tests with leaching solution at IAT on 7 June 1997

The plant performs 18-20 liters of water/min. and performs a pressure of 90-100 bar.

Alkyd	**Temperature**	**ALKAREN 45**	**Time**	**Result**
	8 degr. C	0%	5 min.	No effect
	70 degr. C	1,2%	5 min.	A lot left
	70 degr. C	1,2%	5 min.	Approx. 50% removed
	70 degr. C	1,2%	5 min.	Approx. 95% removed
	70 degr. C	1,2%	15 min.	Completely clean

The test has been carried out on steel. The cleaning times shall be considered with reservation as all the tests have been carried out on the same layer of paint (accumulated).

Epoxy	**Temperature**	**ALKAREN 45**	**Time**	**Result**
	8 degr. C	0%	5 min.	No effect
	70 degr. C	1,2%	60 min.	75% removed

The test has been carried out on steel. The remaining 25% of paint shall easily be removed by means of mechanical effect (a nail). The cleaning times shall be considered with reservation as it has not been registered when the paint has become soft.

Similar tests have been carried out on teflon-coatings, but the leaching solution had no effect.

Enclosure 5

Cleaning tests in cabinet washer at Brüel on 18 June 1997

The cabinet washer performs a constant pressure of 7 bar.

Alkyd	Temperature	Time	ALKAREN 45	Result
	8 degr. C	15 sec.	0%	No effect
	70 degr. C	45 sec.	3%	Soft outside (old lacquer)
	64 degr. C	300 sec.	3%	No further effect
	64 degr. C	300 sec.	3%	No further effect
	64 degr. C	300 sec.	3%	No further effect
	64 degr. C	300 sec.	5,7%	No effect.

The test has been carried out on steel. The cleaning times shall be considered with reservation as all the tests have been carried out on the same layer of paint (accumulated).

Epoxy	Temperature	Time	ALKAREN 45	Result
	8 degr. C	300 sec.	0%	No effect
	80 degr. C	900 sec.	5,7%	Completely removed

The test has been carried out on steel.

Polyester	Temperature	Time	ALKAREN 45	Result
	8 degr. C	300 sec.	0%	No effect
	80 degr. C	900 sec.	5,7%	Completely removed

The test has been carried out on steel.

Acrylic	Temperature	Time	ALKAREN 45	Result
	8 degr. C	300 sec.	0%	No effect
	80 degr. C	900 sec.	5,7%	Completely removed

The test has been carried out on steel.

Alkyd	Temperature	Time	ALKAREN 45	Result
	8 degr. C	300 sec.	0%	No effect
	80 degr. C	900 sec.	5,7%	Completely removed

The test has been carried out on steel.

Photos from preliminary tests (Renzmann)

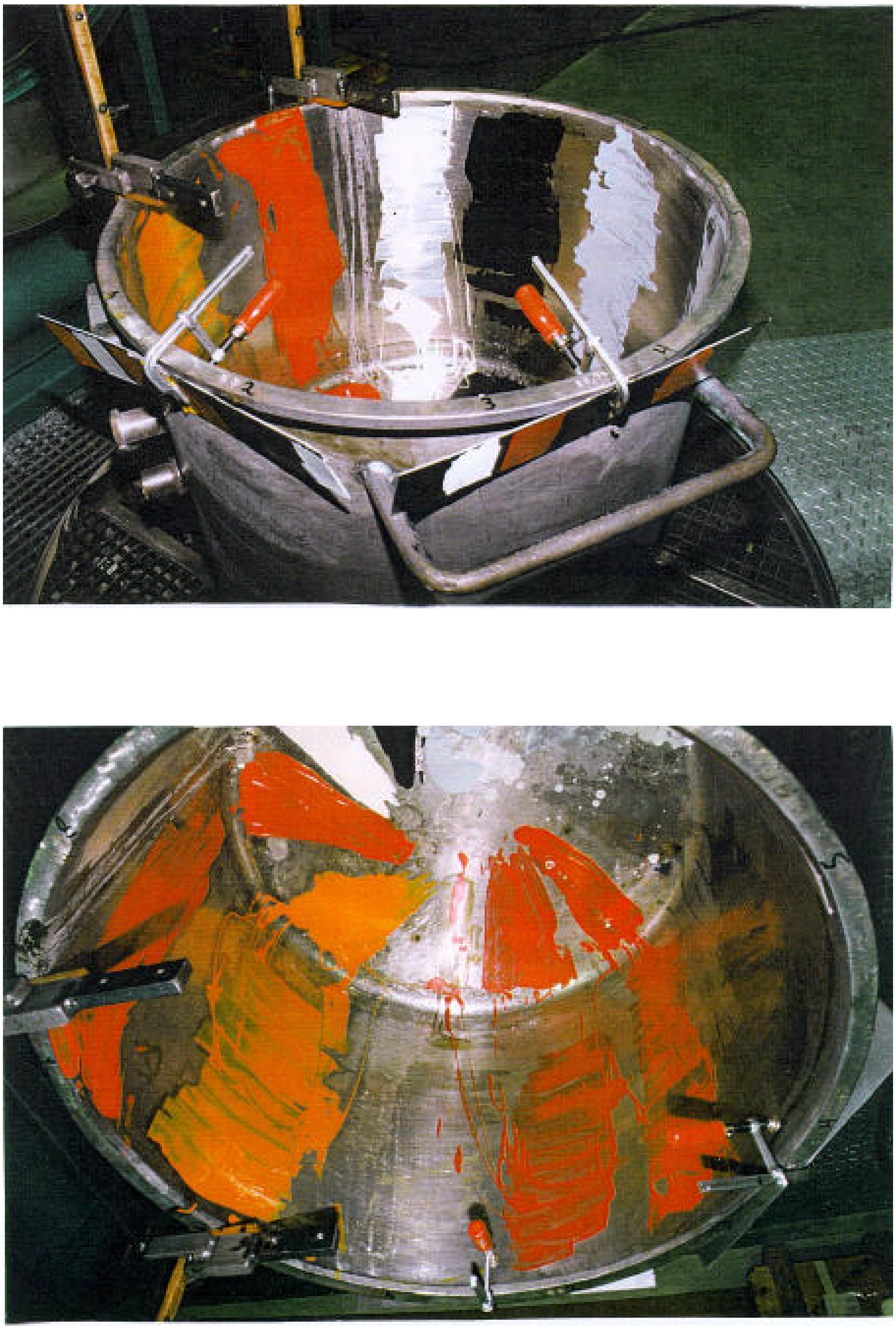


Figure 1
Mixing vessel applied with products from Teknos Technology A/S.

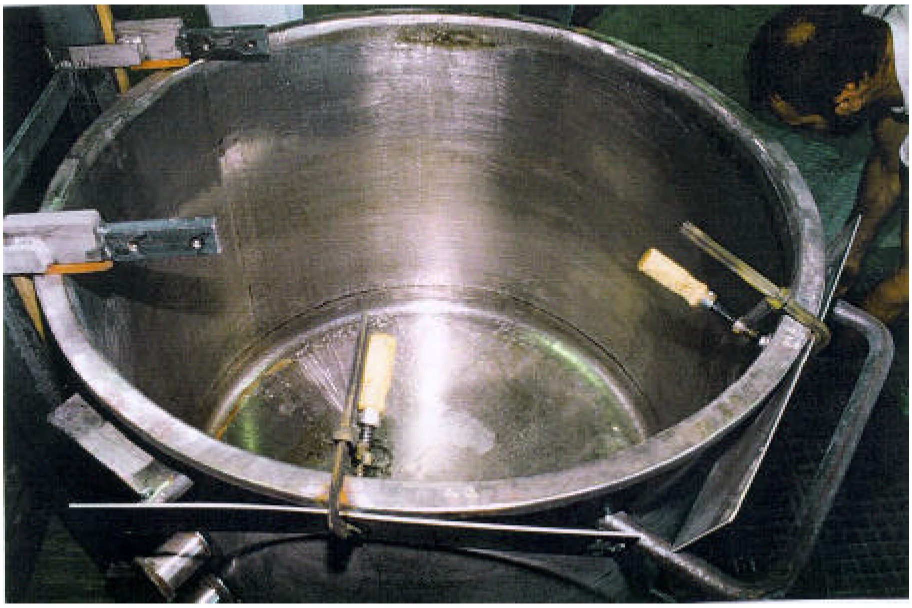


Figure 2
Mixing vessel after cleaning in SKM plant (Stripper 303 G/E, 80°C, 12 minutes).