Volume 8A
Pilot Project No.3 Solvent Reduction Document

Table of Contents

Part 1

Solvent Degreasing Improvement Reports

1.1 FEA S.A.
1.2 AMCO S.A.
1.3 KOYO S.A.

1.1 FEA S.A.

TECHNICAL REPORT
regarding the Solvent Degreasing System(SDS) with PCE at FEA-Bucharest

1. Introduction

1.1. Company profile

FEA S.A. Bucharest, a member of the ROMENERGO Group, is a specialized enterprise producing complex equipment for industrial automations in energetic field, chemistry, petrochemistry, metallurgy, telecommunications, and weighing systems as well.

1.2. Actual degreasing facility

FEA is equipped with two perchloroethylene degreasing units having the sizes (L x w x h) = 1410 mm x 630 mm x 1300 mm, respectively 1010 mm x 520 mm x 1000 mm and provided with electrical resistances for solvent heating mounted beneath their bottom, grid for parts baskets setting into the vapour zone, water cooling coil and hinged lid for unit covering. The PCE vapour are exhausted by means of a 1500 cu.m/h flow rate fan connected to the top and of a hood mounted there over, both of them in relation with the general system venting the entire shed.

The plant comprises one more still for solvent recovery after soiling with grease, oils, water, etc., but this one is not used anymore for long time ago.

The operator is the one who manually handles the parts baskets and during the degreasing cycle the lid remains open.

The solvent heated at 121 °C is vaporized and condenses onto the parts surface. At the moment of the equalization of parts and vapours temperature, the degreasing operation is deemed finished.

The degreasing machines are used along 1 – 1.5 shifts and the annual perchloroethylene consumption is variable in relation with the production structure ranging within the limits 7200 – 12500 kg.

2. Analysis of the existing system and solvent losses

2.1. Disadvantages of the system and actual degreasing procedure

The degreasing tools used and their operation way presented several deviations from the designing and operation rules of the equipment in this category:

- the vapours cooling coil is undersized, this leading to a high concentration in the fan extraction zone;
- the freeboard height is not sufficient resulting in the absence of a protection zone between the vapours layer and air draughts, as well as in the non-provision of a space where the residual liquid evaporate from the parts;
- it is used an inadequate lid with a hinged covering system, located above the vent slots which does not fulfil this way its role aiming the losses diminution during the solvent heating and during the plant stand-by and stop periods; all the same, the closing and opening manoeuvres for this type of lid result in an effect of vapour extraction from the sump;

- due to the absence of a mechanized system loading-discharging the parts baskets, the maximum allowable speed of 3.3 m/min is not provided for this operation and, subsequently, it is not avoided the piston effect, thus resulting in solvent losses;
- the fan flow rate exceeds 20 cu.m./min for 1 sq.m. of air-solvent contact surface leads to a high solvent consumption due to the strong vapours exhaustion;
- it is not provided a water-solvent separator connected to the trough collecting the vapours condensed onto the cooling coil;
- there is no installation to fill and for topping-up the plant with solvent, using the manual handling which results in leaking losses;
- there are no measure and control instruments to monitor the working parameters of the plant, respectively:
    - thermostat for liquid solvent;
    - thermostats for vapours;
    - thermostat and flow sensor for cooling water;
- the solvent is not recovered by distilling after soiling;
- existing hood above the machine leads to solvent vapour losses by draught means.

2.2. Measurements of vapours concentration and fan flow rate

The PCE vapour concentration measuring has been executed in different points having certain relevance for the solvent consumption and microclimate conditions of the operators.

The results of the vapors concentration measurements executed at the existing degreasing plant are presented further on:

- fan exhausting pipe: 160 ppm
- hood opening: 130 ppm
- upper opening of the machine: 350 – 400 ppm
- operator place: 30 ppm.

2.3. Assessment of solvent losses

The analysis of the measured vapours concentrations shows that the main ways of PCE losses are the following:

- fan and hood – by suction (50%);
- upper opening of the machine – by emission (20%);
- lack of solvent recovery – by distillation (20%);
- piston effect when introducing and withdrawing the parts basket (15%);
- solvent leakage during the manual filling out and due to the non-tightening (5%);

The brackets contain the per cent participation in losses of each cause as it is appraised within the specialized literature and resulting from the estimations made on the spot or by calculation means.

Thus, the losses resulted from the ventilation and the hood draught are calculated by means of the relation:

$$P = \frac{C_P \times Q_V + h \times G_{solv.}}{V_{solv.} \times 1000000}$$

where,

P	= solvent losses [kg/h]
Cp	= vapours concentration [ppm]
Qv+h	= fan flow rate + hood draught [cu.m,/h]
Gsolv	= molecular weight of solvent [kg/kg - mol]
Vsolv.	= molecular volume of solvent [cu.m./kg-mol, 25°C]

In the given case, it results an hourly loss of PCE:

$$P = \frac{150 \times 1400 \times 165.8}{22.4 \times 1000000} = 1.55 kg/h$$

and the monthly and annual losses:

Pl = 1,55 kg/h x 192 h/month = 298 kg/month
Pa = 298 kg/month x 12 months = 3575 kg/year

3. Conception of the new solvent degreasing system

The establishing of constructive and technological solutions in order to lead to important reductions of PCE consumption is based upon the most recent designing rules observed by the manufacturers of machines in this category and required by the organisms of environmental protection in the developed countries.

The main characteristics of the PCE vapours degreasing system are presented further on:

- double water cooling coil for solvent vapours condensation which ensures a sufficient freeboard height as well as a freeboard ratio of 1 : 1.5; this way, the vapours are in a large measure prevented to reach the fan and lid suction zone;
- segmented sliding lid covering the machine, with sides and ends seals and between the segments, actuated by motor-reductor;
- stainless steel sump for liquid solvent provided with 6 electrical resistances for heating;
- automatic system loading-discharging the parts baskets;
- water-solvent separator;
- 900 cu.m/h fan connected to the adjustable suction slots located above the lid;
- measure and control instruments and PLC degreasing cycle monitoring:
  - thermostat for limitation of solvent temperature in the sump;
  - minim and maxim level sensor of solvent in the sump;
  - thermostat in vapor zone for solvent heating reduction during the stand-by periods;
  - thermostat for heating reduction/stop located over the cooling coils in case of the vapours layer level increasing;
  - thermostat and flow sensors for cooling water in the coil;
  - timing devices for observing the periods necessary to the degreasing cycle, including the dwell-time, in the coil zone for residual solvent leakage from the parts;
- solvent recovery still after soiling, provided with electrical heating, cooling coil and water-solvent separator
- solvent storage tank

- solvent transport system provided with pump and impurities filter
- thermal insulation for degreasing machine and still
- PLC automation installation which ensures the fully automatic working cycle with no operator involvement.

The new degreasing system allows the work under maximum protection conditions for the equipment and operator as well and with no environmental pollution this way contributing to the so-called clean technologies application.

4. Estimations of solvent losses level

By adopting the issues presented in the chapter 3., the following levels of solvent concentration and losses are estimated:

- vapours concentration in the machine proximity, including the operator working zone: 0- 5 ppm
- vapours concentration at the exit of the ventilation duct into the atmosphere: 0-10 ppm
- soil and underground water pollution: 0
- solvent consumption in comparison with the present one: <10 % (coming from losses by distillation)

1.2 AMCO S.A.

TECHNICAL REPORT
regarding the conveyored degreasing system with TCE at AMCO-Otopeni

1. Introduction

1.1. Company profile

AMCO S.A. Otopeni is an enterprise producing measure and control instruments, fitting parts, car valves, relays and special products for metallurgic and chemical industries.

1.2. Existing degreasing facility

The factory is equipped with a degreasing conveyored system with TCE of the metallic parts (valves, taps) having a closed metallic case of 4000 mm x 2000 mm x 3200 mm provided with 3 sumps and one loading-discharging chamber:

I. Pre-washing sump (1000 mm x 1000 mm x 300 mm) with liquid solvent
II. Rinsing sump with liquid solvent (900 mm x 450 mm x 600 mm)
III. Degreasing sump with solvent vapour (1000 mm x 1000 mm x 300 mm)

The liquid solvent is heated with electric resistances mounted onto the sump bottom.
The parts to be degreased are loaded into bored metallic boxes. The boxes are put in and out of the plant through a door with 400 mmx500 mm sizes and during the degreasing operation they are carried by a double chained conveyor with an about 2.9 m/min. speed bringing them down successively into these 3 sumps; a special device provides the boxes rotation movement. The working rate is 8 hours per day with continuous operation without batches.

The degreasing plant was initially equipped with a cooling-cooling coil, but this was given up afterwards.

The plant is provided with a ventilation system having a 1500 cu.m/h flow rate that sucks the solvent vapour by means of 2 holes bored into the case ceiling.

The soiled solvent is let out from the degreasing plant and processed inside a recovery still with an about 300 l/h capacity.

The work regime practiced for parts degreasing is as follows:
a). pre-washing into the sump I with liquid solvent at the temperature of 20 °C
b). rinsing into the sump II with liquid solvent heated at the temperature of 60 °C
c). degreasing into the sump III with solvent vapour of medium concentration as a result of TCE heating at the temperature of 80°C.

The annual TCE consumption ranges within the limits of 4400- 26000 kg function of degreased parts quantities, of production level respectively.

Annual specific consumption of 0.096 - 0.132 kg of TCE/kg of parts was recorded.

2. Analysis of the existing system and solvent losses

2.1. Disadvantages of the system and actual degreasing procedure

The main drawbacks resulting in the actual degreasing plant operation such as it was conceived and utilized are as follow:

- the lack of the vapour cooling coil determines their high concentration in the fan extraction zone thus entailing major losses of TCE;
- the degreasing procedure used, respectively the absence of a dense vapour zone into the sump III, draws as effect an incomplete cleaning of the parts;
- the fan flow rate exceeding 20 cu.m./min for 1 sq.m. of air-solvent contact area generates an exaggerated consumption of solvent by a strong vapour exhaustion;
- losses of solvent are also produced, among others, by the constructive or operation aspects:
    - lack of tightening;
    - errors of solvent handling.

2.2. Measurements of vapour concentration and fan flow rate

The measuring of TCE vapour concentration could not be carried out before taking modernization steps based upon administrative reasons.

2.3. Evaluation of solvent losses

The causes generating a high consumption of solvent are described within the chapter 2.1., but it can be estimated that, out of these, the most important is the loss as a result of ventilation. Its calculation is based on a formula with a high degree of accuracy:

$$P = \frac{C_P \times Q_V \times G_{solv.}}{V_{solv.} \times 1000000}$$

where,

P	= losses of solvent [kg/h]
Cp	= concentration of vapour [ppm]
Q	= fan flow rate [cu.m./h]
Gsolv.	= molecular weight of solvent [kg/kg - mol]
Vsolv.	= molecular volume of solvent [cu.m./kg-mol, 25°C]

The impossibility to carry out measurements before the plant modernization generated the lack of some calculated values of the losses by excessive ventilation and the absence of the vapour cooling coil.

3. Measures with view on the existing system improvement

Establishing the constructive and technological measures leading to important reductions of TCE consumption needs to be based on the analysis of the circumstances under which the plant operated before modernization. This analysis is presented within the chapter 2.

There are further listed the main works resulting in the pollution diminution and solvent losses reduction:

a. Reduction of machine fan flow rate by mounting a frequency adjuster
b. Uniformalization the vapour extraction by the fan by way of equipping the degreasing machine with additional additional vents rim
c. Improvement of working parameters monitoring by way of mounting a flow sensor on the cooling water outlet and a minim solvent level sensor into the degreasing sump

d. Mounting the solvent vapour cooling coils and the condensed solvent-collecting trough
e. Mounting a water – solvent separator in connection with the collecting trough
f. Identification and remediation of plant non-tightening
g. Machine utilization in compliance with the working regime recommended for parts degreasing with solvent vapour, respectively the three sumps utilization as follows:
    I) parts washing with liquid solvent at about 20 °C;
    II) parts rinsing with liquid solvent at about 80 °C;
    III) parts degreasing with solvent vapour at 87 – 91 °C
h. Daily record of the TCE consumption and of the waste quantities resulted for this machine.
i. Frequent verification of the used solvent quality in respect of its soiling degree ratio (not to exceed 25%, but optimal 15%) and of pH level (to be neutral).
j. Restoration of pipes system for solvent transfer from – to the machine, recovery still, storage and drums so that the manual handling of the solvent is avoided.

4. Analysis of the modified system and solvent losses

4.1. Measurement of vapour concentration and fan flow rate

After the implementation of all the measures provided in the chapter 3, measurements of solvent vapour concentration were carried out within different points of the plant, namely:

- Fan exhaustion pipe - point A
- In – out door for the parts coming in/out from the plant – operator working position – point B
- Vapour extraction tubes connected to the case ceiling – point C.

There are further presented the results of the measurements recorded for different fan flow rates:

No.	Flow rate (c.m./h)	Concentration of solvents (ppm)		
		A	B	C
1	850	100	0-5	120
2	360	90	0-5	80
3	190	65	0-5	40

4.2. Evaluation of solvent losses

It is estimated that at a correct utilization of the plant after the implementation of the measures improving its operation – as shown within the chapter 3 – the solvent losses by distillation, evaporation, handling and ventilation will not exceed 10%.

Thus, the calculation of solvent losses by ventilation, using the relation in the chapter 2.3., leads to the following results:

	Fan flow rate	Vapour concentration	Solvent losses	
	cu.m./h	ppm	Kg/h	kg/year (*)
1	850	120	0.5	1149
2	360	80	0.17	389
3	190	40	0.05	103

(*) 192 h/month

5. Economic aspects

5.1. Cost of existing plant modernization

Modernizing a present degreasing plant is a difficult problem when the aim is to comply with all the regulations leading to a very low solvent loss. In most cases it is however possible to adopt some constructive and technological measures having as result a good efficiency and low cost of implementation.

Generally, it can be said that it is more efficient to modernize the large degreasing machines, while for the small plants it is sometimes recommended to replace with a new machine rather than to improve the existing one. Anyhow, the technical decision must be made by an expert within the field.

The conveyored degreasing plant from AMCO Otopeni was a subject of the modifications described in the chapter 3. The cost, financed by JICA, was of about 5500 EUR.

5.2. Estimation of savings as a result of solvent consumption reduction

At the present level of the factory production, the annual TCE consumption is about 4400 kg meaning 3100 EUR.

Implementing all the proposed measures, the reduction with about 90% of the solvent consumption generates a cost diminution with 2800 EUR, respectively an investment recovery duration of about 2 years.

1.3 KOYO S.A.

TECHNICAL REPORT
regarding the conveyored degreasing system with TCE at KOYO Alexandria

1.Introduction

1.1. Company profile

KOYO ROMANIA S.A. Alexandria is an enterprise specialised in small and medium bearings manufacturing with balls and rollers.

1.2. Existing degreasing facility

The factory is equipped with a conveyored degreasing system with TCE of bearings rollers consisting in a closed frame provided with 3 compartments:

I. Pre-rinsing sump (600 mm x 450 mm x 280 mm) with liquid solvent (aprox. 65 l) which in first place was provided with an ultrasonic generator of 500 m in order to improve the cleaning and which was dismantled subsequently.

II. Rinsing sump (540 mm x 450 mm x 300 mm) with liquid solvent (aprox. 65 l)

III. Degreasing sump (540 mm x 450 mm x 200 mm) with solvent vapours (aprox. 40 l)

The liquid solvent is heated with electric resistance mounted on the sump bottom. The rollers to be degreased are loaded in 8 metallic baskets for a batch containing about 500 pieces each in case of big rollers, respective 4000 pieces in case of small rollers. The working schedule is of 3 shifts per day with 8 batches per shift. The baskets are introduced through an entrance door and carried by a double chain conveyor having a speed of about 4 m/ min which successively lets them down in those 3 sumps and than took out through the exit door.

The degreasing machine is equipped with a vapour cooling coil system and a fan having a flow rate of 1800 m3/h mounted on the top of frame, above the sump III. The contaminated solvent is took out from the machine and pumped into a recovery still having a capacity of 80l/h.

The working regime adopted for the degreasing parts is as follows:

a). pre-rinsing into another machine using a petroleum products

b).submerging of baskets with parts in sump I of the degreasing machine and washing into liquid solvent at a temperature of 35-40°C;

c) rinsing in sump II in liquid solvent at about 60°C;

d).sump III is not used for solvent vapour degreasing but only as a transit area. The TCE annual consumption is included with the limits of 14 - 23 tones, with important monthly fluctuations in accordance with the parts amount being degreased butaso according to their number; annual specific consumptions of 0,106 - 0,116 Kg TCE/1000 rollers, respective 0,0224 - 0,0247 kg TCE/ 1kg rollers have been recorded.

2. Analysis of the existing system and of solvent losses

2.1. Disadvantages of the system and of the existing degreasing procedure The main difficulties associated to the present degreasing system operation as it was designed and used are as follows:

- pre-washing of rollers in petroleum products results into the contamination of these ones having as effect the contamination of the solvent existing into the degreasing machine and the necessity of a frequent distillation of this one (up to 3 times per shift); it results a significant increasing of TCE consumption; - the used degreasing procedure has as result an inappropriate cleaning of parts and an important TCE consumption by discharging of

wet rollers (measured concentration is of 50 ppm) because the complete drying of the parts take place only during the vapours condensation of there surface;
- the fan flow rate exceeding 20 c.m./min for 1 sq.m. of the air-solvent contact surface determines an exagerate consumption by energic exhausting of vapours;
- the speed of 4 m/min of the parts basket in sumps causes by piston effect an increase of the TCE vapour circulation and consequently solvent losses; - the solvent losses are caused as well, among others, by the following constructive aspects or by operation:
- lack of sealing;
- lack of some doors at the entrance and exit doors for the stand-by period;
- sizes of the entrance and exit doors which exceeds more then 10% the clearance of the basket;
- mistakes of solvent handling .

2.2. Measuring of vapour concentration and fan flow rate

The TCE vapour concentration measuring has been executed in different points having certain relevance for the solvent consumption and micro-climate conditions of the operators. Further on are presented the results of the measurings executed before the application some technical measures for constructive and functional improvement of the existing installation:

· Point A – exhausting pipe of the fan: 600 – 650 ppm
· Point B – entrance door (open) of the parts in installation:
150 – 200 ppm
· Point C – exit door (open) of the parts in installation
80 – 100 ppm
· Point D – working position of the operator: 30 ppm

2.3. Assessment of solvent losses

In case of KOYO degreasing installation there is a hold of plurality of causes which determines solvent losses as there were described previously. While the quantification of each cause involves a very hard work, the estimation of losses by ventilation is based on a formula having a high level of accuracy:

$$L = \frac{C_P \times Q_V \times W_{solv.}}{V_{solv.} \times 1000000}$$

where,

L	= solvent losses [kg/h]
Cp	= vapour concentration [ppm]
Q	= fan flow rate [c.m./h]
W	= solvent molecular weight [kg/kg-mol]
V	= solvent molecular volume [c.m./kg-mol,25 grd.C]

In the given situation for TCE results an hour loss of:

$$L = \frac{600 \times 1800 \times 131.4}{22.4 \times 1000000} = 6.33 kg / h$$

and the monthly and annual losses are:

Lm = 6,33 kg/h x 192 h/month = 1216 kg
La = 1216 kg/m x 12 months = 14 596 kg

The assessment herein above takes into consideration a continue operation during one shift for 5 days per week and 12 months per year. In fact, the operation time is lower, so the losses by ventilation are lower as well. The remaining of solvent losses, until the amount recorded is based on the other causes as listed in chapter 2.1.

3. IMPROVEMENT MEASURES OF THE EXISTING SYSTEM

The establishment of the constructive and technological measures which could lead to important minimization of the TCE consumption is based on the analysis of the conditions in which the installation has functioned before the retrofit and which has been presented in chapter 2. Further on are listed the main works that may have as effect the pollution minimization and decreasing of the solvent losses:

a. Reducing of the machine flow rate by mounting of a frequency converter.
b. Making uniform of the vapour extraction by the fan based on the degreasing unit providing with supplementary perimetral system of vents rim.
c. Improvement of working monitoring parameters by mounting of a sensor for solvent minimum level of the solvent in the machine sump.
d. Changing of the machine entrance and exit doors profile so that the distance between the basket with parts to be degreased and the inner edges of these ones to be at most 10% of the door width.
e. Changing of the displacement velocity of the conveyor of about 4 m/min to 3,1 – 3,3 m/min.
f. Provision of some sealed steel doors to door the opening of the entrance and exit doors during the period the machine is off.
g. Identification and removal of poor seals of the machine.
h. Machine operation in accordance to the working regime recommended for the parts degreasing in solvent vapour, respectively of those three sumps, as follows:
   I). Parts washing in liquid solvent at about 20°C
   II). Parts rinsing in liquid solvent at about 80°C
   III). Parts degreasing in solvent vapour at 87 - 91°C
i. Excluding the pre-rinsing of parts in oil products.
j. Checking of the solvent quality in relation to the contamination level (do not exceed 25%, optimum value 15%) and pH level (to be neutral).
k. Daily record of the TCE consumption and the waste quantity as resulted for that machine.

4. ANALYSIS OF THE MODIFIED SYSTEM AND OF SOLVENT LOSSES

4.1. Measuring of vapour concentration and fan flow rate

Further to the installation of the adjustment device for the fan flow rate and of the additional perimetral vents rim a series of measurings of solvent vapour concentration were performed, in different points of the unit as follows:

- Exhausting pipe of the fan – point A
- Entrance door of parts into the unit – point B
- Exit door of parts from the unit (opened)– point C
- Working position of the operator – point D.

Further on the results of the measuring recorded for various flowrate of the fan are presented:

No.	Flow rate (c.m./h)	Concentration of solvents (ppm)			
		A	B	C	D
1	500-800	80	<20	<20	<15
2	350-430	a) 65 stand-by b) 100 loading	<20	<20	<15
3	140-170	90	25	30	<15

It is important to be underlined a slight increase of the vapour concentration at the entrance and exit door area of the parts for very reduced flow rate in relation to the decreasing of the extraction level of the fan.

4.2. Assessment of the solvent losses

It is estimated that in case of a correct use of the unit, after the application of the improvement measures related to the operation of this one, as presented in chapter 3, the solvent losses by distillation, evaporation, handling and ventilation will not exceed 10%.
Thus, the calculation of the solvent losses by ventilation based on the use of the calculus relation as mentioned at chapter 2.3. leads to the following results:

	Fan flow rate	Vapour concentration	Solvent losses	
	cu.m./h	ppm	Kg/h	kg/year (*)
1	800	80	0.375	864
2	430	65	0.164	378
3	170	90	0.090	207

(* 192 h/month)

5. Economic aspects

5.1. Cost of the existing installation improvement

The improvement of an existing degreasing installation represents a difficult problem when the purpose is to comply with all the rules in order to lead to a very low solvent loss. Nevertheless, in most of the cases it is possible to be adopted some constructive and technologic measures having as main effect a good efficiency and low cost for execution.

The installation with conveyored degreasing system of KOYO Alexandria has been the subject of the changes as described at chapter 3, and the costs supported by JICA were of about 4000 EUR.

5.2. Assessment of savings achieved by solvent consumption minimization

At the actual production level of the factory, the TCE annual consumption is of about 14000 kg in an amount of 9800 EUR.
Further to the application of all the proposed measures, the minimization of about 90% of the solvent consumption results into a diminishing of the cost price with 8800 EUR, respectively a length of investment recovery of about 6 months.

Part 2

Solvent Vapour Degreasing Management Manual

(UK document "Vapour Degreasing GG15" under Environmental Technology Best Practice Programme)