Federal Environmental Agency, Berlin

Integrated Pollution Prevention and Control in selected Industrial Activities

- Installations for Surface Treatment using organic solvents for Dressing, Impregnating, Printing, Coating -

Part I

"Dressing, Impregnating, Coating"

Final Report

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Contents

1. Background and objectives

Council Directive 96/61/EC concerning integrated pollution prevention and control aims at the EU-wide harmonisation of licensing procedures of certain industrial installations.

In this context the "Best Available Techniques" (BAT) are of special importance. The Commission organises an information exchange for the establishment of specific BATs at European level (article 16 (2) IPPC-Directive). The resulting BAT-Documents will be published.

The information about the state of techniques and the related consumption and emission values as they are currently applied in Germany for IPPC-relevant industrial activities shall be considered for the establishment of the BAT-Documents.

Having this in mind, the present project aims to investigate and demonstrate systematically the German state of techniques as they are applied for the IPPC-relevant industrial activities “dressing, impregnating, printing, coating”. In particular information on up-to-date production installations are important. Thus a basis for the German position in the EU-wide information exchange is established.

The UBA carries out a parallel research project with comparable objectives for installations in the field of processing of varnishes and glues. Same as in the present report, the parallel project discusses primary and secondary measures as BAT aiming at the reduction of VOC emissions. Several secondary measures such as thermal post-combustion, dust filters, etc. are similar in both fields. For an efficient sharing of the workload no technical annex with such end-of-pipe techniques has been attached to the present report. However, the possible emission reductions due to the use of such secondary techniques are described for all investigated types of installations.

The results have been established to an important degree on a co-operation with enterprises and industry associations. By means of workshops within the concerned branches up-to-date and precise information on the current state of technique has been obtained. The project team would like to thank all participants who supported the realisation of the project.

2. General information and methodology

2.1. Data sources

The information procurement has been based on the following sources:

1. Bilateral interviews with plant operators and evaluation of plant specific documents
2. Information from competent authorities of the German “Bundesländer”
3. Workshops with industry associations and enterprises concerned
4. Overarching workshops with experts from different industry branches
5. Information provision from European associations
6. Literature

The bilateral interviews with plant operators have been an important source for precise data on the German installations. In particular current consumption and emission levels could be established and particularities with respect to applied processes and techniques could be derived. This information has been completed by competent authorities of the Bundesländer that provided among other information data and documents from actual licensing procedures.

A further important data basis have been workshops with industry associations and enterprises concerned. To this end prepared materials have been provided to the participants as discussion basis for general information (such as number of relevant plants, market volume, etc.) applied techniques (in particular production processes and process flow-charts) possible BAT-candidates, advanced future oriented techniques and last but not least economic consequences.

The overarching workshops with experts from different industry branches have been organised under participation of representatives from industries, authorities and project team members of the parallel research projects. Main objective of these workshops has been the clarification of methodological questions, the evaluation of techniques that are applied in several branches and the delimitation of the several research projects.

The corresponding literature has been taken into account in all investigated branches. However, literature information is usually less important as it is often not up-to-date and often there is no sufficient information on installations and industrial activities with only a limited number of plants.

2.2. Structure of the chapters and applied methodology

The structure of the chapters corresponds to the given structure of the UBA for the establishment of BAT-Documents. Accordingly it contains for all investigated industrial activities the following points:

1. General information
2. Processes and techniques in manufacturing
3. Current consumption and emission values
4. Determination of BAT-candidates
5. Selection and recommendation of BATs
6. New advanced processes

In the frame of general information the IPPC-relevance of the activity is investigated. Furthermore data such as production and sales figures, characterisation of the products and corresponding quality requirements are given. This information is required for the assessment of the importance of each industrial activity and for eventually necessary differentiations. The quality requirements are of particular importance because in certain cases the required standards already define the use of certain techniques and components.

The sub-chapter "Processes and techniques in manufacturing" first gives an overview on the corresponding production process and describes the main components of processing. Process steps that include the use of organic solvents are highlighted.

In the following all process steps are analysed in detail with the help of process flow charts. The single process steps which involve the use of solvent are again designated and the solvents used are specified. Furthermore the single plant components are described in detail and a differentiation of the plants according to the project aims is made.

Under the heading "Current consumption and emission values" the German state of technique is quantified by means of specific values of advanced plants. To this end an input-output-balance is established that includes not only materials but also energy related aspects. The consumption and emission values correspond to actual production conditions in Germany. For the majority of the production procedures these values have not yet been public available due to competitive reasons in particular if only a limited number of enterprises are concerned. Due to the established cooperation with industry associations and single enterprises it was also possible to demonstrate the state of old installations that do not yet comply with the limit values as specified in the German legislation (31. BImSchV) for new installations. For reasons of confidentiality the names of the enterprises concerned are not given and all values are related to specific production amounts. Thus the work load factor and the actual production amounts need not to be specified. Both are not required for the objectives of BAT-Documents.

In the next sub-chapter the BAT-candidates are determined on the basis of the technical description and the consumption and emission values. To this end the prescriptions of the IPPC directive, annexe IV are aggregated for the emissions into air and water, waste, energy and risk and those techniques are described that are appropriate to reduce the environmental pollution in these fields. The field “risk” includes points 2, 10 and 11 of the annexe IV of the directive.

The next sub-chapter aims at the overall evaluation of the BAT-candidates. In order to give a comprising overview a table has been established that enables to indicate the qualitative influence of each BAT-candidate in the fields

air (A)

waste (W)

water (WA)

energy (E)

resources (R)

noise

risk

Thus also cross-media effects can be outlined. A quantification would require plant-specific considerations and is not taken into account in the table but has been realised as sum-value of the applied BAT-candidates in the sub-chapter on “current consumption and emission values”.

Furthermore the table contains a column “cost/benefit relation” where it is indicated whether the BAT-candidate is “available” in the sense of the IPPC-directive or in other words, whether the technique is “developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator”. As far as this is only true under certain conditions, this is separately treated.

Technique	A	W	WA	E	R	noise	risk	cost/ benefit

A = Air, W = Waste, WA = Water, E = Energy, R = Resources

Table 2-1 Table for qualitative evaluation of BAT-candidates

The sub-chapter concludes with recommendations for the selection of BATs.

The next section is related to new and advanced production procedures that are currently not technically and economically viable in the industrial sector but that may demonstrate a “vision” for the future development of the techniques.

2.3. Basic methodological problems and approaches for solutions

During the investigations for the present project the following basic methodological problems occurred:

1. In certain industrial sectors the currently applied techniques are not appropriate to achieve the limit values as specified in the German legislation for new installations (31. BImSchV). Can those techniques be taken into account for the determination of BATs in Germany?

2. Does it make sense against the background of international competition to describe a certain technique if there is only one single enterprise that carries out the corresponding production procedure?

3. How to deal with installations that are below the threshold values as specified in the IPPC-directive as a consequence of the use of appropriate techniques whereas in other countries the thresholds are exceeded as those techniques are not applied?

4. How to proceed with installations where the emissions depend to a large degree on the product specifications? The prescription of specific consumption and emission values would have consequences on the spectrum of manufactured products.

With respect to question 1. the project team suggests that plants that do not comply with legal prescriptions for new installations should not be designated as BAT. Those cases have been intensively discussed with the corresponding operators. It turned out that within those installations the future use of nowadays “new and advanced techniques” will enable to achieve the maximum limits within the foreseen time frame.

Concerning questions 2. and 3. a description of the applied techniques only was made if the enterprise whose competitiveness was concerned agreed to the publication.

For several installations where German installation were below the relevant threshold values, a short description was made (see German version).

What concerns question 4. it was the intention to demonstrate as far as possible the relations between parameters of products and the corresponding emissions in order to provide a decision basis that is as complete as possible.

For all four questions it would be helpful with respect to the overall objective to organise another workshop with the relevant actors taking into account the discussion in Seville and European results before the background of the progressing state of technique. The project team would be prepared for such a task also after the termination of the present project.

3. Production of Abrasives

3.1. General Information

Depending on the production processes and the types of the abrasives organic solvents are used in manufacturing of abrasives in IPPC-relevant amounts. However, the major share of manufacturing plants is not concerned by the IPPC-Directive as the prescribed threshold values are not achieved or organic solvents are used not at all.

Areas of application

Grinding is one of the oldest production processes. Principal characteristic of grinding is the effect of numerous, not orientated cutting materials in the work piece. Contemporary abrasive materials are synthetic corundum or silicon carbide often already cubic boron nitride (CBN) or diamond.

A big variety of work piece materials can be processed such as ferrous and non-ferrous metals, glass, ceramics, natural stone, concrete, plastics and wood. The application field of grinding is wide and includes activities such as rough grinding of cast iron or high accuracy grinding of tubular needles for medicinal purposes. Numerous products in tool manufacturing, construction of vehicles, aircrafts, power plants or furniture obtain only through grinding their finish and high quality surface.

Production and sales

Currently more than 100 companies in Germany are manufacturing all kinds of abrasives. Thereof around 70 enterprises are represented by the association of German abrasive manufacturers (VDS – Verband Deutscher Schleifmittelwerke).

According to VDS data the German abrasive industry plays a leading role in Europe. The following table gives a rough overview of its economical importance.

Production of bonded abrasives	~ 305 Mio Euro
imports	~ 82 Mio Euro
exports	~ 170 Mio Euro
Production of coated abrasives	~ 385 Mio Euro
imports	~ 205 Mio Euro
exports	~ 310 Mio Euro

Table 3-1 Abrasive production1999 (Source: association of German abrasive manufacturers)

Characterisation of the product "abrasive" and its quality demands

Basically it can be distinguished between bonded abrasives ("grinding wheels") and coated abrasives ("abrasive paper and tissues"). Furthermore there exist loose abrasives, which do not have any solid linkage to a backing (e.g. polishing pastes).

The following illustration shows a simplified overview on the development and allocation of the different kinds of abrasives.

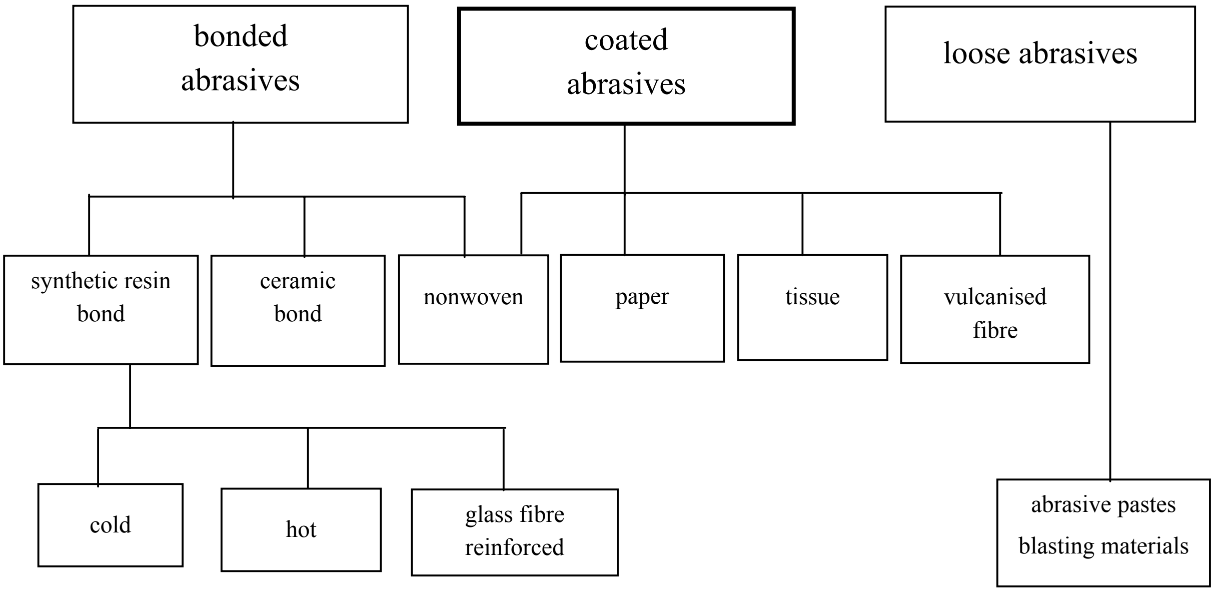

Figure 3-1 Overview on different types of abrasives

Organic solvents are partially used in the fabrication of bonded and loose abrasives. It can be assumed that the German installations do not represent an activity in the sense of the IPPC-Directive annex I point 6.7. Consequently production processes related to these activities will not be treated in the following.

The activity of manufacturing coated abrasives may be subject to the IPPC-Directive due to the use of considerable amounts of organic solvents and the threshold limits as set in the Directive. Coated abrasives are a basic material for many grinding machines with plane elements such as blades, stripes, page disks or assembled from those elements (e.g. peel shims, fan grinding wheels, belts). According to the purpose of use and basic material a large number of bonding systems can be differentiated.

Nonwoven abrasives take a special position between coated abrasives and bonded abrasives as they can be used both as abrasive body as well as plane abrasive element. They consist for example of polyamide fibres to which the grinding material is fixed via bonding material. The production processes are comparable to the production of the coated abrasives.

Composition of coated abrasives

1. *backing,* e.g. paper, finished fabric, vulcanised fibre**,** film
2. *Bonding material*, e.g. glue systems, phenolic resin, epoxy resin, polyurethane, urea resin
3. *Abrasive grain,* e.g. flint, silicon carbide, corundum, zirconia alumina, seldom used: diamond, cubic boron nitride (CBN)

ad. 1. backing

The term "coated abrasives" refers to the importance of the backing. According to the purpose of use and the strain of a flexible abrasive the backing has to show specific properties. At off-hand grinding for example special flexibility and high buckling resistance are required. On the contrary, excellent mechanical properties such as swell-resistance; tenacity; resistance against abrasion or alternating stress are required for high performance grinding with abrasive belts, abrasive disks and cylindrical sleeves.

To meet all these requirements following groups of backing materials are used in particular:

- ⇨ Paper
- ⇨ Fabric
- ⇨ Combination of paper/fabric
- ⇨ Vulcanised fibre

Table 3-2 shows an exemplary classification of the used backing materials:

	Weight class equipped [g/m²]
A - paper	≤ 85
B - paper	86-110
C - paper	111-135
D - paper	136-220
E - paper	221-270
F - paper	271-350

	Weight class equipped [g/m²]
G - paper	351-500
H - paper	> 500
A - paper water resistant	≤ 115
C - paper water resistant	> 115
Heavy cotton - X- weight	370-400
Flexible cotton - J-tissue	270-290
High flexible cotton - J-flex-tissue	200-220
Heavy polyester - X-tissue	475-505
Very heavy polyester - Y-tissue	630-665

Table 3-2 Selected backing materials for coated abrasives

Paper

The papers used in the production of coated abrasives consist of extremely firm and tenacious fibres. They are processed in different quality, weight, size and width according to the property of their use. It can be distinguished between flexible, single layer paper with a homogenous tensile strength in any direction of straining and heavy, multi-layer cylinder paper which has an especially high stability in any direction of rolling (long direction).

All types of backings (A to F) are adjusted to dry grinding. Furthermore, A- and C-papers with water resistant impregnation (latex or varnish) are appropriate for wet grinding.

Abrasives on A-, B-, and C- paper basis are used in off-hand grinding and for hand operated grinding machines (e.g. grinding pencil). D- and E-papers are necessary as backings for stationary/fixed grinding machines up to the highest demand [Lit. 2].

Textile backing

Coated abrasives that are processed into wide bands or used in belt-, surface- and plunge grinding have to consist of fabric (as backing) as a result of the high strain they are exposed to. These so-called technical fabrics are made of raw cotton (woven or stitch bonded). It can be distinguished between heavy X-tissue and light J-tissue. This differentiation is made due to the thread layer that means the number of fibres in warp and weft wise. Heavy X-tissue has a comparatively low, light J-tissue a higher thread count.

Before being treated with abrasive grains the tissue has to be subjected to a special treatment. The raw tissue is first de-sized and dyed and afterwards shrinked to its final density. Hereafter the fabric is finished on its thrust face with adhesives, synthetic resins/plastics or similar substances and finally calendered (flattened) [Lit. 2].

Vulcanised fibre

Numerous industrial manufacturing processes require special high-performance abrasives with a high wear resistance. In this case vulcanised fibre is used as backing-material. Vulcanised fibre is a very hard, multi-layer fibre material. At the course of its fabrication numerous nonwoven-like paper webs are connected through calendaring with a contact adhesive. Vulcanised fibre can be manufactured in every thickness. In the abrasive industry the vulcanised fibre strengths 0,8–0,6–0,4 mm are most important, whereby the stronger material is used for high wear resistance and thinner material for larger flexibility. Abrasives on vulcanised fibre backing mechanically extremely high stress resistant. Therefore they are applied in almost all industrial branches, primarily in the automobile -, machines -, ship or apparatus engineering [Lit. 2].

ad 2. Bonding material:

The efficiency of coated abrasives depends to a large degree on the bond (grain adhesion) of the abrasive grain. Consequently bonding materials play an important role. In order to achieve a good adhesion of the grain and other required properties the bonding materials are applied successively in several layers.

Following bonding materials are most important:

- ⇨ hide glue
- ⇨ synthetic resin
- ⇨ varnish

With consideration to the used bonding agents the following types of bonding systems are differentiated:

Glue bond (solvent free)

In the case of glue bond abrasives the bond consists of hide glue. The backing consists of paper or fabric. These coated abrasives are used for lower shear forces or if the long lasting utilization of the material is not important (e.g. for the treatment of lubricating materials) [Lit. 2].

Partial synthetic resin bond (resin over glue, solvent free)

Here the abrasive bond system consists of a hide glue make coat and a size coat of synthetic resin. Such abrasive papers or fabrics can be used universal especially for medium grinding operations. Due to the elastic make coat of hide glue and the resistant size coat synthetic resins the qualities are very suitable for the surfacing of formed work pieces. [Lit. 2].

Synthetic resin bond (where possible solvent free)

Abrasives for high stock removal capacity are bonded with synthetic resins. The abrasive grains are bound extremely fix to the backing by the comparatively strong resin bond. Thus they are resistant to very high cutting forces. Consequently high performance rates can be obtained. [Lit. 2]

Varnishes: waterproof bond (solvent containing)

Numerous work pieces and specific application methods require watery cooling or flushing agents. Therefore the above mentioned methods can not be used because either the bonding material or the appret will be dissolved by the cooling agent. These reasons require absolutely waterproof qualities. Consequently tissue qualities with waterproof finish are applied. As bonding material special synthetic resins are used. Such waterproof abrasives are applied for wet grinding of steel, glass, ceramic, natural or artificial stone and plastics.

When grinding primers, fillers, clear or pigmented lacquers often dusty or clogging grinding residues result and loads or glazes the abrasive. Therefore it is necessary to work with waterproof abrasive papers in wet grinding. These papers have a flexible paper backing, which is impregnated with latex or lacquer to make them water resistant. The make- and size coat is realised with special resins and – lacquers. Waterproof abrasive papers are therefore not only water resistant but also to a large extent resistant against loading and glazing.

ad 3. Abrasive grain:

Aluminium oxide:

	Corundum [%]	semi special fused alumina [%]	special fused alumina rose [%]	special fused alumina red [%]	special fused alumina white [%]	ceramic conrundum	zircon-corundum [%]
Al_2O_3	95,83	97,69	99,52	97,50	99,50	99,6	60,0
ZrO_2	-	-	-	-	-	-	39,0
SiO_2	0,60	0,38	-	0,02	0,05	0,07	0,30
TiO_2	3,12	1,45	-	-	0,02	0,2	0,25
Fe_2O_3	0,10	0,15	0,05	0,05	0,05	0,02	0,25
Na_2O	-	-	0,18	0,3	0,30	0,01	0,03
CaO	0,05	0,03	-	-	0,05	0,01	0,09
MgO	0,20	0,15	-	-	0,01	0,015	0,02

	Corundum [%]	semi special fused alumina [%]	special fused alumina rose [%]	special fused alumina red [%]	special fused alumina white [%]	ceramic conrundum	zircon-corundum [%]
CrO_2			0,25	2,0			
Others	0,10	0,15	-	0,13	0,02	0,075	0,06
Colour	dark-brown	light brown	rose	ruby-red	white	white	light grey

Table 3-1 Alumina applied as inert abrasive grain (typical values)

silicon carbide:

	black SiC	green SiC
SiC [%]	98,26	99,66
free Carbon [C] [%]	0,19	0,29
Fe [%]	0,10	0,02
Si [%]	0,19	0,03
Others [%]	1,26	-

Table 3-2 silicon carbide applied as abrasive grain (typical values)

Use of solvents attributed to products

Base	Product	Formed part	Application	Bonding material systems	Solvent
A-Paper	dry grinding paper	sheets, rolls	lacquer and wood grinding (paint)	hide gluehide glue, synthetic resin bond	no
B-Paper	dry grinding paper	sheets, rolls	lacquer and wood grinding (paint)	hide glue, synthetic resin bond	no
C-Paper	dry grinding paper	sheets, rolls, belts	lacquer, wood and metal grinding (machine)	partial or complete synthetic resin bond	no
D-Paper	dry grinding paper	sheets, rolls, belts	lacquer, wood and metal grinding (machine)	partial or complete synthetic resin bond	no
E-Paper	dry grinding paper	sheets, rolls, belts	lacquer, wood and metal grinding (machine)	partial or complete synthetic resin bond	no
F-Paper	dry grinding paper	sheets, rolls, belts	lacquer, wood and metal grinding (machine)	partial or complete synthetic resin bond	no
A-Paper waterproof	wet grinding paper	sheets	common grinding of lacquer (hand)	synthetic resin bond	**yes**
C-Paper waterproof	wet grinding paper	sheets, belts	common grinding of lacquer (hand) machine grinding	synthetic resin bond	**yes**
X-tissue cotton	dry grinding; wet grinding	sheets, rolls, belts	grinding of metal, glass, wood (machines)	synthetic resin bond	**partially**
J-tissue cotton	dry grinding	sheets, rolls, belts	grinding of metal, glass, wood (machine)	synthetic resin bond	**partially**
J-flex-tissue	dry grinding	sheets, rolls, belts	grinding of metal, glass, wood (machine)	synthetic resin bond	**partially**
X-tissue polyester	dry grinding; wet grinding	sheets, rolls, belts	grinding of metal, glass, wood (machine)	synthetic resin bond	**partially**
Y-tissue polyester	dry grinding; wet grinding	sheets, rolls, belts	grinding of metal, glass, wood (machine)	synthetic resin bond	**partially**

Table 3-3 Use of solvents in manufacturing attributed to products

Quality requirements

The most important quality criterion is the keeping of the standardized grain size (DIN.6344, sheet 1 to 3, grain size for coated abrasives. DIN 8486; sheet 1 a. 2, grain size for abrasive wheels. DIN 9136; grain density). Also important are toughness, hardness, low dust content, no components of quartz or fibrous parts and the grain structure.

More quality requirements: Check of phenolic resin, DIN 16916.

DIN/ISO-Standards for the production of abrasive papers and tissues are not available.

Quality requirements that arise from clients are furthermore the range of flexibility, good allergologic properties for hand-wet-grinding and the amount of grains applied to the abrasive in the case of very fine grains. Due to these requirements the use of organic solvents is currently necessary in the case of abrasives for wet grinding.

3.2. Processes and technologies in manufacturing

3.2.1. Process overview

Coated abrasives are produced in the following way:

- ⇨ coating of a backing with bonding materials
- ⇨ electrostatic or mechanical grain coating with grains as specified above
- ⇨ pre-drying
- ⇨ repeated coating with bonding materials
- ⇨ drying
- ⇨ spooling to jumbo roll

Differences in the procedures are mainly the type of the drying ovens (festoon drier or tensionless drier), the application procedure and of the elimination of emissions from the drying ovens (biological treatment, thermal combustion or without any treatment).

More solvent used coating can be found at the converting of jumbo rolls to self-adhesive products or endless abrasive belts.

Coated abrasives in constant quality are manufactured in production plants with high production amounts. Such plants usually consists of the following units:

1. Base coat part (Maker)
2. Pre-drier
3. Size coat part (Sizer)
4. Drier
5. Spooler

In a first step the backing back side is printed in the so-called “maker” with required information (e.g. brand, quality labels, etc.). Afterwards the make coat is applied on the front side of the backing. Then it is coated with abrasive grains. In the second part of the plant – the pre-drier – hot air dries or hardens the make coat. In the third production unit – the “sizer” – the backing that is now coated with abrasive grains is furnished with a size coat. The fourth unit is the also with hot air heated drier. The finished abrasive material runs through it for a specific time. After this procedure the material leaves the plant dried and cured and is rolled up to big rolls (jumbo rolls).

A multitude of electronical and thermal measuring units control the whole procedure and ascertain specific tolerance limits. This refers among other to the grain coating of the backing.

3.2.2. Detailed process steps

The following figure shows an overview of a typical plant.

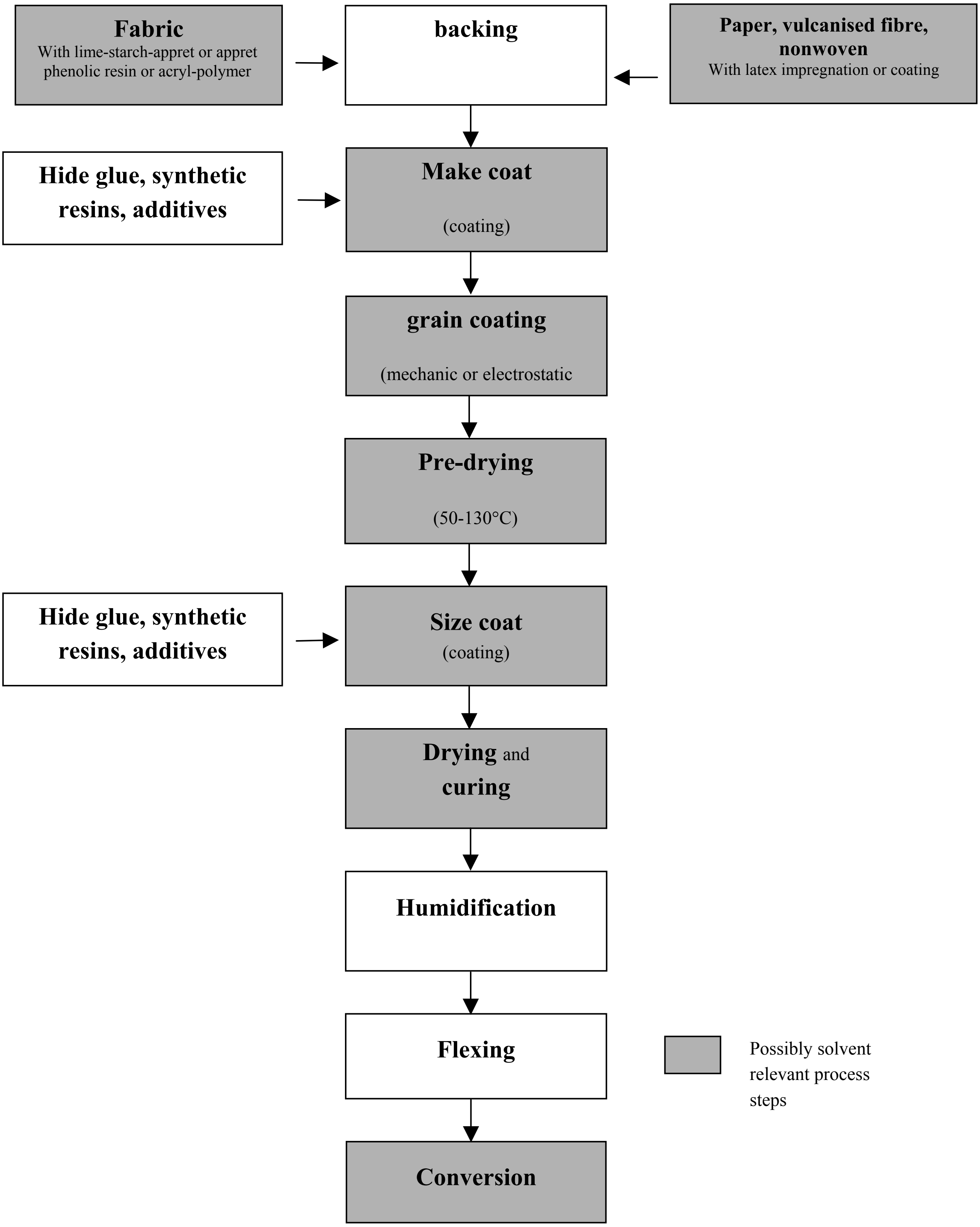

Figure 3-2 Schematic process flow for coated abrasives (Source: industrial plant)

Pre-treatment of backings

The pre-treatment is an optional process step in an abrasive production plant.

a) Paper

Depending on the further application of the paper the pre-treatment differs. For example the backing for waterproof abrasive papers is impregnated with long chain alkyd resins. Latex-dispersion sometimes in combination with water dilutable phenolic resins (for better heat resistance) may be a solvent-free alternative option.

b) Fabrics

Following fabrics are used as backing:

- ⇨ Cotton
- ⇨ Synthetic- and mixed fibre

The modification of the bonding material for the tissue depends on the requested (mechanical) flexibility of the product. Phenolic resins, caoutchouc or dispersions of synthetics are the common materials for that purpose.

c) Vulcanised fibre

Vulcanised fibre is commonly not pre-treated.

Coating of the backing with bonding materials

The backings is coated with the bonding material in a coating machine e.g. by the means of a spreader roll (application of the make coat).

Depending on the application profile of the abrasive there are different bonding materials possible. In addition to natural products such as hide glue and starch or resins (epoxy-, urea-, alkyd- and polyurethane resins) mostly phenolic resins are applied. Advantages of phenolic resins compared to other bonding materials are a better adherence, lower sensibility against humidity and higher thermal resistance. Aqueous phenolic resins are often preferred to the slightly more flexible products with solvent content because of their easier process handling.

Subsequently the drying and hardening process is effected in the festoon pre-dryer. The backing material runs in large loops over sticks through the various temperature zones of the drier or hardener, which is heated with circulating hot air. Thus a specific dwell time corresponding to the bonding material is guaranteed.

If necessary the web is stretched at the end of the drier. For the final imbedding and fixing (size coating) several binding layers may be applied.

The conclusive hardening of phenolic resins is carried out at temperatures up to 100-140°C, depending on the bonding and the abrasive grain. This procedure takes places in a drying channel (such as in pre-drying) or after spooling in the hardening oven.

Coating of backings with grain

Electrostatic grain coating

Here the backing runs through an electrostatic field. The side with the make coat shows downwards. At the same time the abrasive grain runs in a certain distance under the coated backing on a conveying belt. When the abrasive grain enters the electrostatic flied it is charged and thus attracted by the backing above. It reaches the coated backing and trickles into the make coat. During this process the grains are oriented with its sharp ends vertical to the backing. As a consequence the abrasive obtains outstanding cutting characteristics.

Mechanical grain coating

Before the electrostatic grain coating, the coated abrasives were coated with the so-called gravity grain coating. This procedure is still in use in some special fields. The abrasive grain falls over a hopper loose in free fall on the make coat coated backing. Most of the grain clings in the binding layer. The surplus grain falls in a collecting funnel when the direction of the backing web is changed. From there the abrasive grain can be recycled and used again.

Other coatings

For special applications where fine grain sizes are needed the abrasives are coated in a third procedure – the elutriating process. Here the grain, polish powder or filling material is directly added to the bonding material. In a sizer the well-mixed mass runs over reverse rolls and is there applied to the backing material. The application of a make coat is not necessary here.

Flexing

After the spooler the rolls of abrasive tissue, -paper or –fibre (Jumbos) have to be further treated in order to guarantee the quality of the products depending on its further purpose. To this end the rigid coating with grain and bonding materials is flexinged (rendered flexible) after the hardening and conditioning. Depending on the kind of abrasive there are several particular methods for flexing.

It can be differentiated between 90°- flexing and cross-flexing. For the 90°- flexing the non-sprinkled side of the abrasive is drawn over a flexing roll.

The degree of flexing depends on the radius of the flexing roll. The flexing is realised according to the specific purpose and properties of each abrasive. If the layer of bond material and abrasive grain is broken too often due to very high flexing leads to reduced abrasive capacity of the product. [Lit. 2].

3.2.3. Impact of volatile organic solvents

Pre-treatment of backing material:

Important organic solvents that are used are:

- Alcohols (e.g. ethanol)
- Ester (acetic ether)

backing coating:

Important organic solvents that are used are:

- Ester (acetic ether)
- Alcohols (e.g. butane, propanol, glycols)
- Aromatic compounds (e.g. xylene)

3.2.4. Components of installations and required differentiation

The described processes are typically realised in installations with the following components:

Unrolling	In use are unroll stands with a working width of 900 to1.650 mm and a speed of 10 to 50 m/min
Printing	Used are standardized two to three printing rolls
Roll coating (alternative: spraying)	Realised through a two printing roller with ladle tank or alternatively with jet spraying
grain coating field (electrostatic or mechanic)	Use of a grain coating field with plate capacitor (around 30 kV or more voltage) or grain coating hopper (hopper gate on the backing)
Drier (loop drier or tensionless drier)	Temperature 35 to 110 °C (in the loop drier the coated web runs through in loops; in the tensionless drier the web is transported flat without contact through the drier)
Humidification	Usually at the end of the drier in a vapour zone
Spooling	Realised through a running lap winder
End drying	Use of a small-dimensioned drier, usually with the capacity for single jumbo rolls
Exhaust air treatment	Application of dust separators and thermal or regenerative post-combustion at 700 °C (or higher) with or without energy recovery (depending on site specific circumstances and energy or heat demand)
Water treatment	Biological water treatment plant or bioreactor
Flexing	Flex machine consisting of unrolling, flexing rod (the web runs with the back side in a narrow angle over the flexing rod in order to flexibilise the product), roll up
Conversion	Clueing of abrasive belts to overlapping endless belts is prepared in machines for cutting into sections before clueing under pressure and heat in pressure units. Solvent containing PU-clues may be used. Cutting and punching devices produce sheets, disks and rolls

Table 3-3 Components of installation and differentiation

System differentiations related to explosion protection

Production plants that include treatment of organic solvents are subject to the „guidelines to avoid hazard through potentially explosive atmosphere with examples – Explosion protection guidelines (EX-GL)“ and the “Safety rules for the explosion protection at continuous flow drier in paper processing, ZH 1/19”.

In order to assure appropriate explosion protection in the following some examples for he corresponding technical realisation are given. Other technologies may be applied and may also be regarded as best available technologies.

According to the corresponding prescriptions it is necessary to install explosion protection equipment around the applying units and the open run of webs. The applying units and the open run of webs are equipped with properly working suction units. Monitoring takes place by suitable measures appropriate to the site specific conditions.

Where required, all electrical equipment is explosion protected according to the EX-GL. All loop driving devices are situated outside the loop zone (Ex-zone 1). The loop zone is exclusively heated indirectly.

The solvent in the driers originates to 100% from the recipes. The maximum speed of the production line is at 50% of the LEB (lower explosion boundary) of the substance with the lowest inflammation point. To this end the speed is electronically blocked.

In order to achieve a negative pressure and to guarantee the 50 % LEB the dryer is constantly driven with a determined exhaust air amount.

The exhaust air streams are collected and led to the exhaust air treatment. The air streams are monitored. The installations reach emission values below 20 mg organic carbon/m^3 100 mg CO/m^3 and 100 mg NO$_x$/m^3. The maximum limits for phenol and formaldehyde (20 mg/m^3 are also kept.

The grain coating room is equipped with a suction unit and monitored as well.

The coating machines as well as the electrostatic grain coating installations are protected by fire extinguishing systems.

The pre- and the main drier are completely protected by inside fire extinguishing systems (dry ascending pipes).

3.3. Current consumption and emission values

Total balance of plant 1

Total balance of an abrasive production plant with a typical product mix of different binding types:

- hide glue (solvent free)
- partial synthetic resin (solvent free)
- synthetic resin (almost solvent free)
- water proof (solvent containing)

The balance has been established on real values with specific values related to 10.000 kg final product. The capacity of the actual plant corresponds approximately to this amount. Output values are half hour mean values.

Input		Output	
Raw materials			
paper/fabric	4.701 t/a	product	10.000 t/a
abrasive grain	3.214 t/a	waste for combustion	77 t/a
bonding material including phenols and other synthetic resins	2.436 t/a	waste for disposal	37 t/a
		hazardous waste	116 t/a
solvents			
water	827 t/a	water	827 t/a
organic solvents	275 t/a	diffuse emissions of VOC	38 t/a
		TOC after thermal post-combustion	< 20 mg/m^3
		NO$_x$ after thermal post-combustion	< 100 mg/m^3
		CO after thermal post-combustion	< 100 mg/m^3
		relative oxygen of a thermal or regenerative post-combustion 18 – 21%	
energy [in kWh/a]			
electric current	3.007.243		
gas	21.871.076		
hot water	16.379.075		

Table 3-4 Total balance Plant 1; production of abrasives

Total balance of plant 2

In plant 2 only fabric is assembled (impregnated). At the present state of knowledge, the plant is due to the threshold values of the IPPC –Directive not IPPC-relevant. However in order to demonstrate typical values for the described process the emission values are given here. The manufactured fabric is used as backing for coated abrasives (the production of the abrasives takes place in another plant). Light and heavy cotton and also heavy polyester tissues and hosieries are impregnated. The following values are exclusively values of the fabric impregnation. The corresponding abrasive production is described as plant 3. The balance has been established on real values with specific values related to 10.000 kg final product. The capacity of the actual plant is about 5.000 kg final product. Output values are half hour mean values.

Input		**Output**	
raw materials			
raw fabric	8.101 t/a	impregnated fabric	10.000 t/a
corresponding to m^2/a:	24.261.025	corresponding to m^2/a:	24.261.025
phenolic resins	1.002 t/a	hazardous waste	185 t/a
latices	2.104 t/a	waste for disposal	133 t/a
hide glue / starch	585 t/a	waste for further treatment	484 t/a
additives	670 t/a	paper waste	117 t/a
solvents			
organic solvents	125 t/a	diffuse emissions of VOC	12 t/a
		TOC after thermal post-combustion	< 20 mg/m^3
		NO_x after thermal post-combustion	< 100 mg/m^3
		CO after thermal post-combustion	< 100 mg/m^3
		dust	< 10 mg/m^3
		relative oxygen of a thermal or regenerative post-combustion 18 – 21%	
accessory agents			
water [m^3/a]	101.630	waste water	
		manufacturing	46.750 m^3/a
		cooling	8.794 m^3/a
		vapour	21.752 m^3/a

		sanitary	7.692 m^3/a
		cleaning	16.639 m^3/a
energy [in kWh/a]			
energy	46.258.325		

Table 3-5 Total balance Plant 2 – production of abrasives

Total balance plant 3

The following specifications refer to a production site for coated abrasives. It comprises several machines (without pre-treatment of the backings). The production includes hand grinding and dry grinding papers, waterproof paper and tissue abrasives, light and medium as well as heavy fabric qualities and abrasive nonwoven products. The balance has been established on real values with specific values related to 5.000.000 m^2/a final product. The capacity of the actual plant is slightly above this amount. Output values are half hour mean values.

Input		Output	
raw material			
impregnated backing	5.000.000 m^2/a	product	5.000.000 m^2/a
abrasive grain	992 t/a		
solvents			
organic solvents	259 t/a	diffuse emissions of VOC	30,1 t/a
		TOC after thermal post-combustion	< 20 mg/m^3
		NO_x after thermal post-combustion	< 100 mg/m^3
		CO after thermal post-combustion	< 100 mg/m^3
		dust	< 10 mg/m^3
		relative oxygen of a thermal or regenerative post-combustion 18 – 21%	
phenolic and other resins	520 t/a		
latices	22,2 t/a		
accessory agents			
water	32.063 m^3/a		
energy			
gas and current	34.831.581 kWh/a		

Table 3-6 Total balance plant 3 – production of abrasives

3.4. Determination of the BAT-candidates

The following technologies or measures can be considered as BAT candidates:

3.4.1. Emissions to air

Exhaust air treatment with thermal or regenerative post-combustion

At exhaust air volumes up to 66.000 Nm^3/h the installations achieve emission values below 20 mg organic TOC/m^3 (half hour mean value). During production regenerative post-combustion plants can typically work auto thermal (above 2 to 3 g/m^3 organic solvent in the exhaust gas).

Application of dust separators

Used are so-called bag filter in different styles for dust separation.

The obtained emission values depend on the dust characteristics, filter construction and the filter itself. A rest dust concentration below 10 mg/m^3 is sometimes possible. Typically 20 mg/m^3 can be achieved.

Application of low-solvent or solvent-free recipes

The use of solvent free recipes is at present state of the art in the case of dry grinding papers and in the case of fabrics it can be realised for specific product qualities. However, with respect to wet grinding abrasives and the corresponding product requirements, organic solvents are generally indispensably.

3.4.2. Emissions to water

During the cleaning of machine parts phenolic and fluoride containing waste water arises. Appropriate waste water treatment is carried out in the following process steps:

- ⇨ neutralisation
- ⇨ fluoride precipitation
- ⇨ filtration
- ⇨ biological clarification

Corresponding plant obtain or undergo constantly the following values (for treatment plants which pass to a public sewage treatment plant):

total phenol	75 mg/l
volatile in steam phenol	20 mg/l
fluoride	40 mg/l

sulphate	200 mg/l
iron	1 mg/l
aluminium	1 mg/l
zinc	1 mg/l

For waste water originating from production sites for various abrasives there are no German state wide requirements in the branch specific annexes of the German waste water regulation.

The competent licensing authorities are obliged to lay down input requirements for each sewage treatment plant. The above mentioned values are far below fixed threshold values.

The following technologies and measures may be considered for the improvement of waste water amounts:

- besides the biological waste water treatment plants (e.g. bio reactor) also bio filter systems would be appropriate
- an optimised separation of the concentrated bonding agents from the waste water would facilitate the further waste water treatment; this would contribute to reduced waste water amounts and the whole process would become more economic
- concentrated waste water may be classified as waste and may be burnt

3.4.3. Waste

According to the product spectrum waste arises during conversion in the form of cuttings (e.g. edges, punchings). A share of these cuttings may be separated, re-cutted and be sold on the market. This measure and corresponding possibilities is more of organisational character and is thus not considered as BAT-candidate.

3.4.4. Risk

- use of solvent free or low-solvent recipes
- effective suction installation where the web runs open and for bonding material applying units
- installation of loop driving devices outside the loop zone (Ex-zone 1); indirect loop zone heating by air-heat-exchanger
- operation of the dryer constantly with determined exhaust air amount
- protection of the bonding material applying units and electro static grain coating machines with fire extinguishing equipment

3.5. Selection and recommendation of best available technologies

Table 3-4 shows a rough evaluation of the BAT-candidates. The symbols “↓“ and “↑“ stand for decreasing and increasing environmental pollution respectively. Numbers in brackets ”(1)“ indicate the need for further differentiation which is given in a corresponding comment below the table. "ok" expresses that a technology is „available“ in the sense of the IPPC-Directive.

Technology	A	W	WA	E	R	noise	risk	cost/ benefit
Exhaust gas treatment by thermal or regenerative post-combustion	↓			↓				ok
Use of dust separators	↓	↑ (1)						ok
Use of solvent-free or low-solvent applications	↓						↓	(2)
Use of innovative waste water treatment plants			↓					ok
Effective suction installations where the web runs open and for bonding material applying units							↓	ok
Installation of loop driving devices outside the loop zone (Ex-zone 1); indirect loop zone heating by air-heat-exchanger							↓	ok
Operation of the dryer constantly with determined exhaust air amount							↓	ok
Protection of the bonding material applying units and electro static grain coating machines with fire extinguishing equipment							↓	ok

A = Air, W = Waste, WA = Water, E = Energy, R = Resources

Table 3-4 Evaluation of BAT-Candidates – production of abrasives

Comments

(1) An increased waste volume is a direct consequence of effective dust separation. The air pollution is reduced meanwhile dusts arise that can not be used for production. However, in the sense of an integrated approach the advantage of decreasing emissions to air is more important compared to the drawback of increased waste volumes.

(2) The use of solvent containing bonding systems for wet grinding abrasives may be necessary due to the following technological reasons:

- ⇨ high range of flexibility compared to other resin systems
- ⇨ minimized allergic reactions at the hand wet grinding
- ⇨ good characteristics for film building when very small quantities are applied; important for manufacturing abrasives with extra fine grain
- ⇨ energy saving processing; hardening at 60°C compared to 120 – 140°C for phenolic resin systems.

The cost/benefit relation and the technological restrictions shows that the use of organic solvents is currently necessary in the field of wet grinding abrasives. Apart from this restriction, the BAT-candidates can be recommended as BAT.

Technologies and measures as they are currently applied in Germany show comparatively high environmental standards and at the same time a reasonable cost/benefit relation.

3.6. New progressive procedures

high-speed drying and hardening processes

Since several years patents have been established aiming at faster drying and hardening of the bond materials. The new processes include e.g. the application of UV-radiation or micro-waves. However it can be assumed that within the coming years none of the present developments will change or influence the production processes at existing abrasive production plants.

4. Production of tyres

4.1. General information

Significant quantities of organic solvents are used in the rubber manufacturing industry for the production of tyres. Solvents are used in the production of new tyres as well as in the full retreading of tyres. Since the tyres are to a large extent made from rubber (natural or synthetic) corresponding manufacturing processes are attributed to the rubber industry.

Production and sales

In Germany 5 companies produced a total amount of about 771.000 t of tyres in 1999. The largest share consisted of tyres for passenger cars – all in all about 50, 5 Mio tyres. The total turnover in 1999 was above 11 billions DM [Lit. 3].

A part of the total demand of tyres is met by the full re-treatment of tyres. Currently about 130 companies are retreating tyres. The percentage of retreated tyres in comparison to new tyres is about 11 % in 1998. In particular truck tyres – as being very expensive – are retreated.

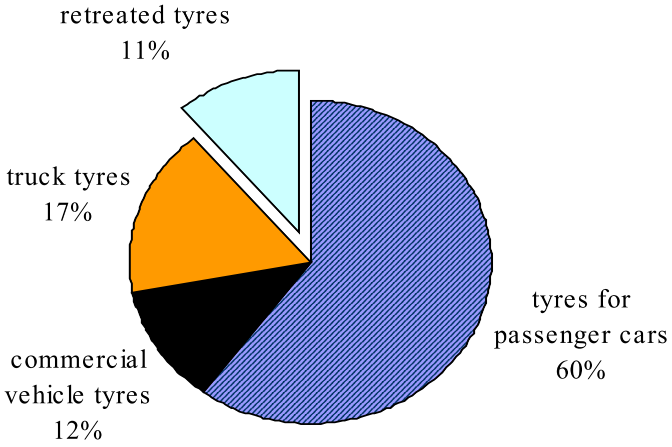

Figure 4-1 The percentage of retreated tyres related to the total amount of tyres production in 1998, Source: Association of German rubber industry

There is practically no production of conventional tyres in Germany. Thus radial tyres are the relevant basis for the production process description in the present study [Lit. 3].

Characterisation of the product ”tyre” and its quality demands

Basically, a tyre consists of the following components:

- Carcass (air volume capturing) substructure
- Belt of several layers (steel cord)
- Two beaded rings (bead cable)
- Tread
- Side walls
- Other components

Rubber ingredients and compounds can vary to a large extent corresponding to the manifold different requirements (e.g. passenger car tyres, truck tyres, commercial vehicle tyres, aircraft tyres, summer tyres, winter tyres). Therefore the consumption of organic solvents varies as well, all the more because the consumption depends largely on the production process.

Example for a typical rubber formulation used for passenger car tyres [Lit. 4]:

42,0 %	natural rubber
18,0 %	synthetic rubber (e.g. polybutadien)
28,5 %	active filler (carbon black)
0,1 %	peptizer (e.g. pentachlorthiophenol)
1,2 %	dispergator (e.g. stearic acid)
1,2 %	anti ageing agent (e.g. paraphenylendiamine)
0,9 %	UV protecting waxes (paraffin)
3,0 %	plasticizer (high aromatic oils)
1,5 %	cross-linking agents (in most cases: sulphur)
0,6 %	vulcanisation accelerator (e.g. sulphonamide)
3,0 %	accelerating activator (e.g. oxide of zinc)

Since a few years, efforts are made to use granulated or powdered rubber of used tyres as a secondary raw material in the production of the rubber compound. Up to 1 or 2 percent in weight can be added taking into account quality and safety requirements.

The most important raw material in the tyre production is natural rubber or synthetic rubber. By adding diverse fillers and additives a rubber compound is produced. Further materials used in the production of tyres are textile fibres and steel wire. Solvents are only used as process materials. They are required during manufacturing, but do not enter the product itself.

Quality requirements

Legal requirements and technical standards that have to be kept for tyre manufacturing are very extensive. The most important documents are the following:

- Directive 92/23/EC
- ECE standards (EU-wide standards on tyres):
  ECE 30 for utility vehicle tyres
  ECE 54 for motor car tyres
  ECE 75 for two wheelers
- ISO standards (e.g. ISO 4000, 4209, 34)
- FMVSS (Federal Motor Vehicle Safety Standards), US prescriptions
  these requirements have to be respected due to the fact that tyres are commercialised all over the world
- wdk-guidelines

4.2. Processes and technologies in manufacturing

4.2.1. Process overview

As well as for the production of new tyres as well as for full retreating of tyres several coating processes that include the use of organic solvents are required (e.g. coating with an adhesive layer).

Manufacturing of new tyres corresponds basically to the following scheme:

Manufacturing process	Solvent use
Production of base compound	no
Production of rubber coated textile cord	no
Production of rubber coated steel cord	no
Production of beads	partly
Production of tyre tread and side walls	partly
Finishing of tyre	partly
Secondary treatment	partly

Table 4-1 use of solvents in production steps of tyre manufacturing

The following figure illustrates how tyres are produced

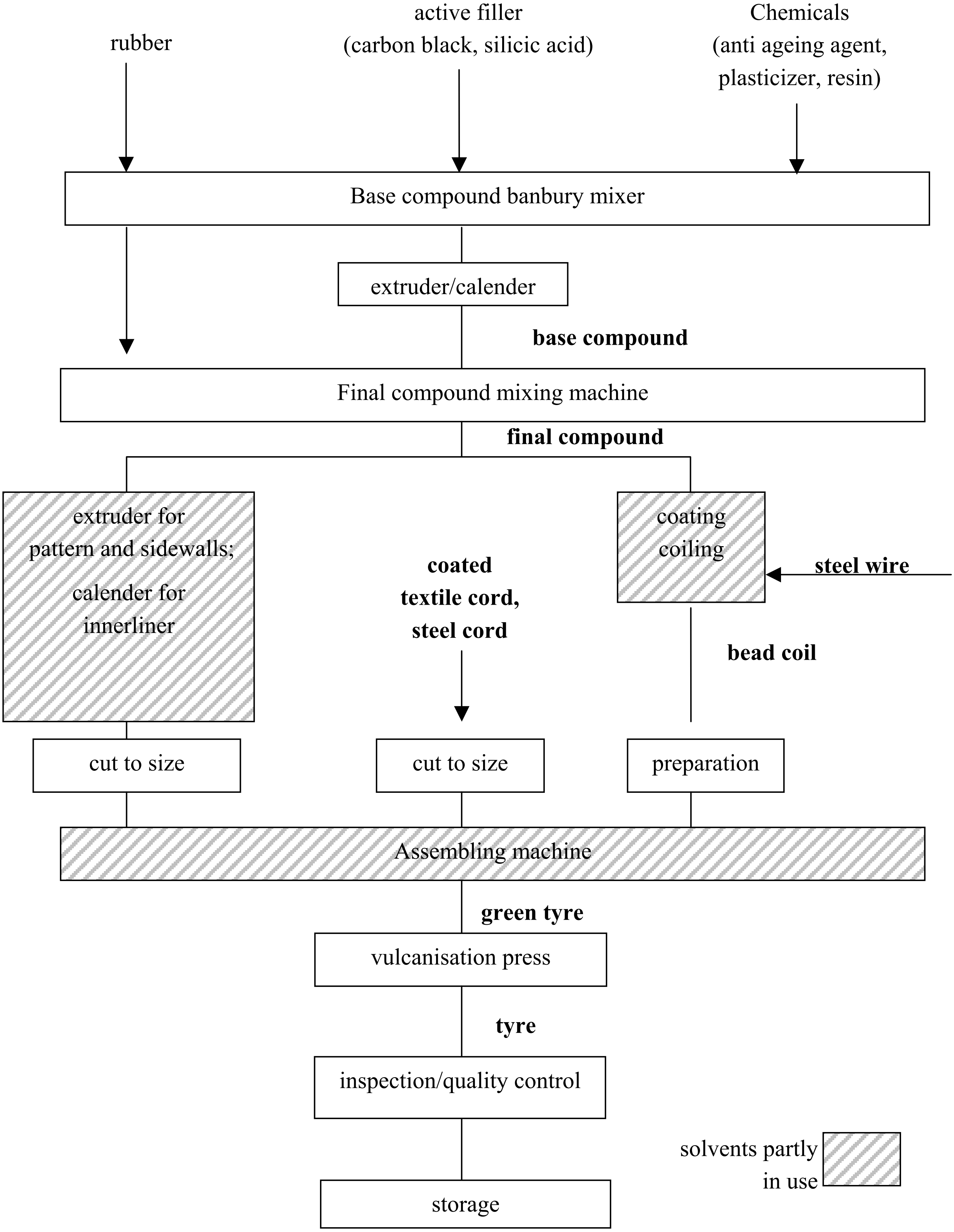

Figure 4-2 Manufacturing scheme for tyre production [Lit. 6]

4.2.2. Detailed process steps

Production of the base compound

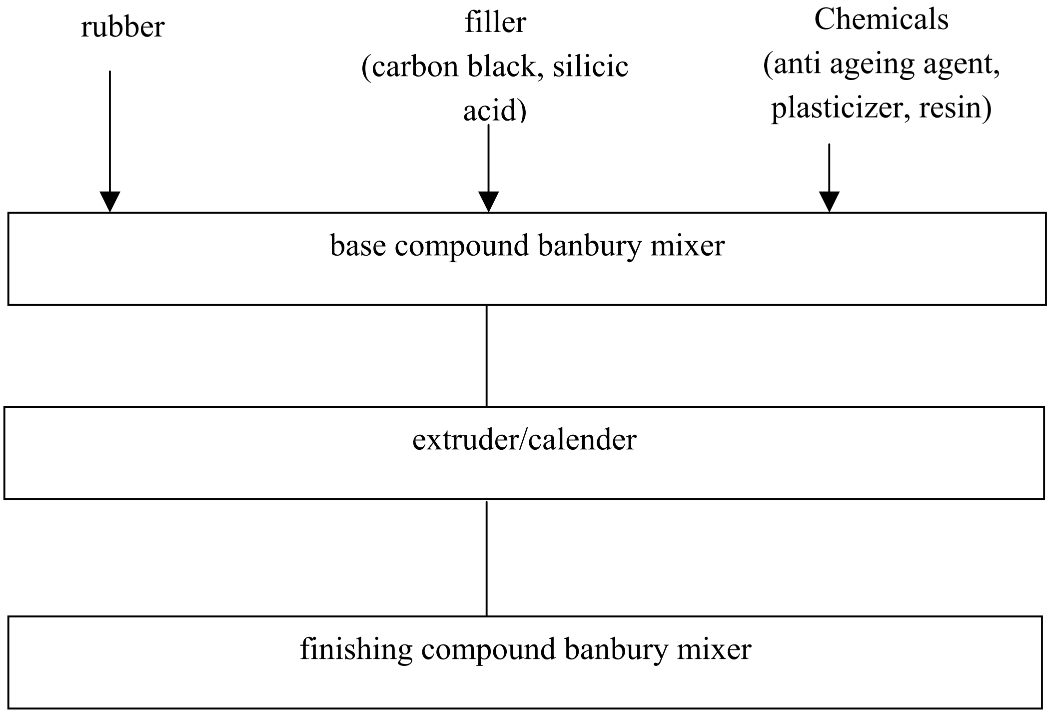

Figure 4-3 Production of the base compound

According to the different formulations, the raw materials are weighed and put into the banbury mixer, where they are manufactured to the basic compound. The base compound is fabricated to an endless circuit e.g. with the help of the conveying injection equipment (extruder) and a downstream calender.

In a second mixing step vulcanisation agents are added and a ready to use compound is produced [Lit. 6].

Production of the textile cord

Textile cord gives to the air capturing carcass of tyre it's required stability. It consists of coated cord textile layers, the fibres are arranged cross wards to the running direction of the tyre (so called radial tyre).

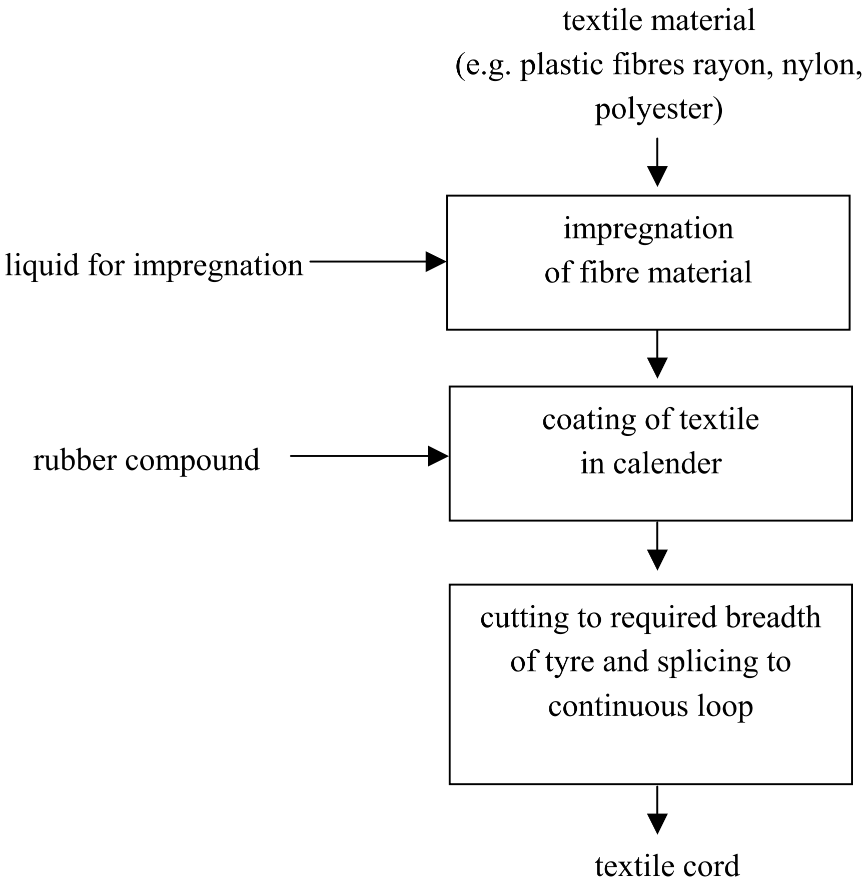

Figure 4-4 Production of textile cord

Predominantly full synthetic fibres are used for the production of the cord textile (e.g. nylon, rayon, polyester). The cord textile consists to a vast majority of length fibres. Only a few cross fibres keep the length fibres in parallel order.

In a first step the fibres are being impregnated or soaked with a solution, that makes the fibre "rubber-phil", that means capable to reception for the following coating with the rubber compound. Neither for impregnating nor for soaking the fibres organic solvents are used. Predominately, the impregnation of the textile fibre takes place in the textile industry.

The both sided coating of the textile with the rubber compound is done in a calender.

Afterwards, the broad textile web is cut to stripes corresponding to the tyre breadth and spliced to a continuous loop.

Production of steel cord

The supporting base of the tyre consists of steel cord and textile cord. Steel wire is first drilled and than manufactured into steel cord. For weight reduction purposes not only steel wire, but high performing synthetics (e.g. Aramid) are used as well.

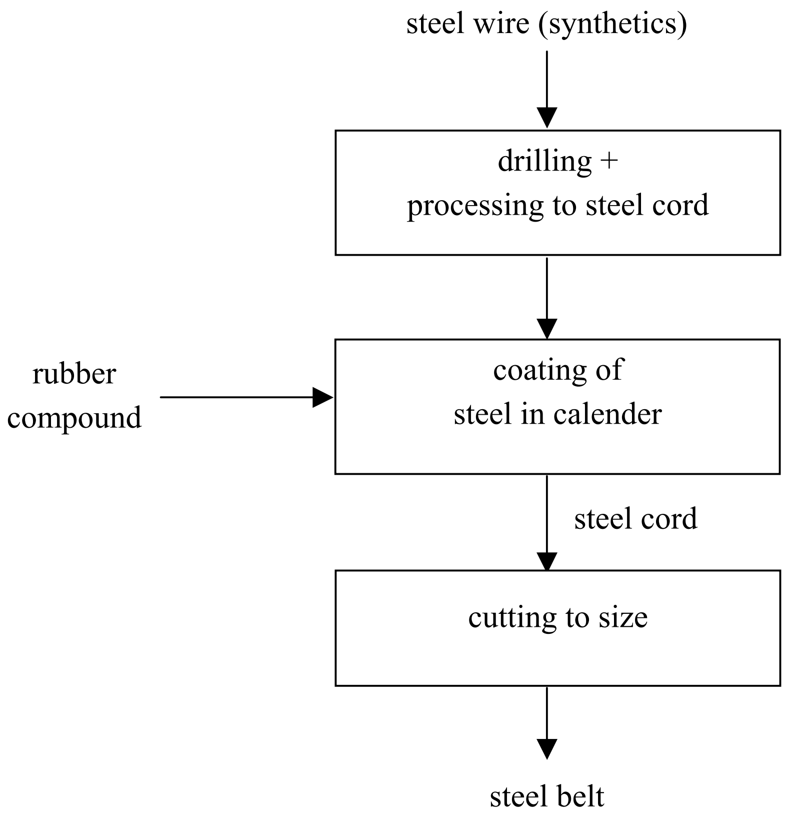

Figure 4-5 Manufacturing of steel belt

Steel cord as well as textile cord is coated in a calender with a rubber compound and cut to the desired size. On a coiling drum two layers of steel belt are crossed and are joined to one steel belt.

Production of the bead coil

The bead coil fix the tyre firmly to the wheel rim.

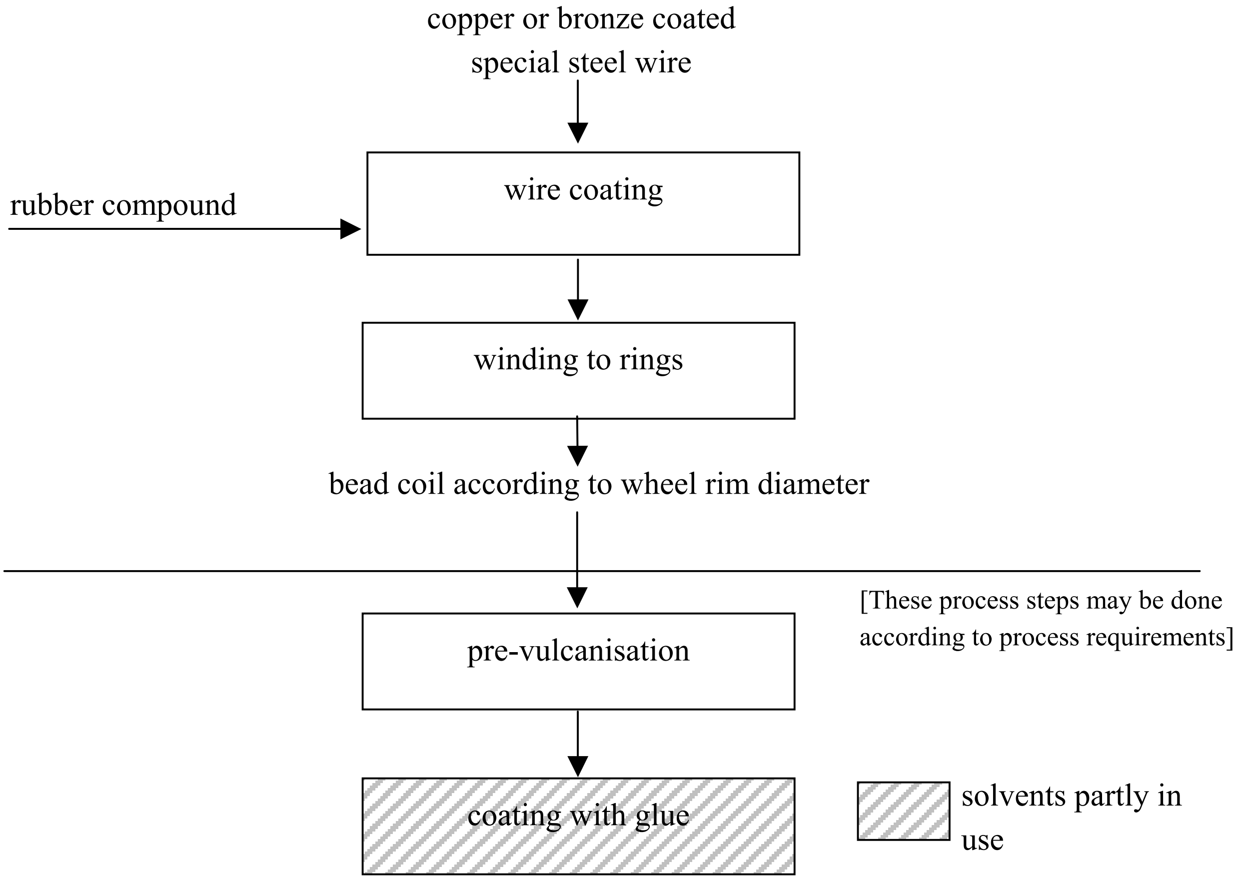

Figure 4-6 Production process of bead coil

To produce bead coil, a special steel wire, which is coated with copper or bronze, is coated in a single or in several lines with a rubber compound. Subsequently, it is winded to rings according to the wheel rim diameter.

Depending on the processing, pre-vulcanisation or coating with glue may follow. The coating process may be solvent relevant depending on the process used.

Production of tyre tread, sidewalls and other components

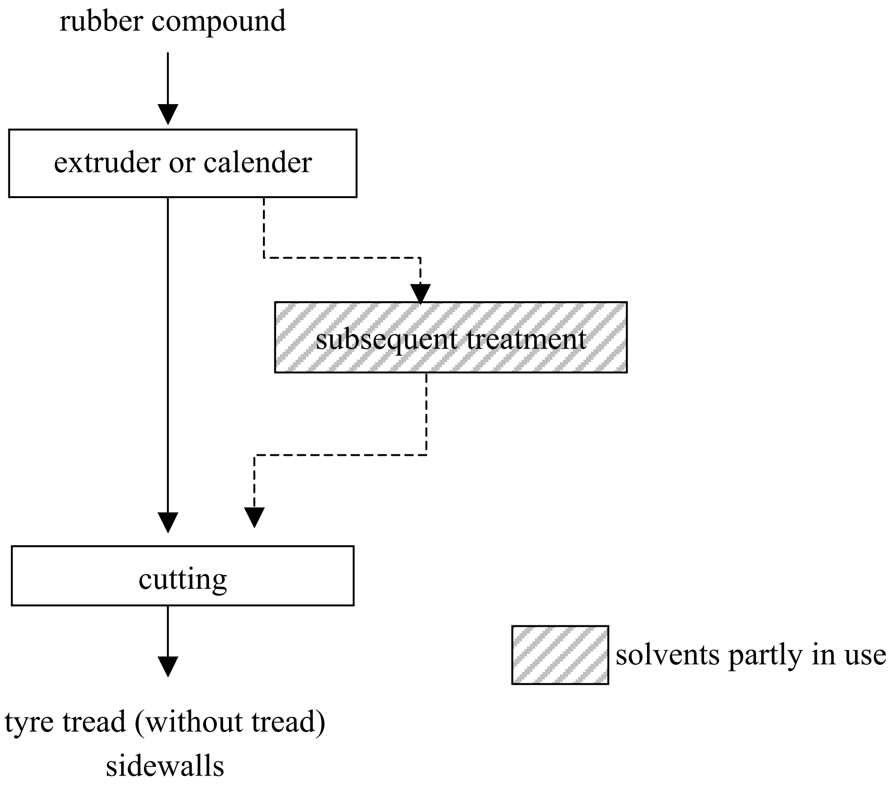

Figure 4-7 Production process of tread of tyre and sidewalls

Very tenacious compounds of synthetic rubber are used to produce the tread and sidewalls. This mixture is worked either in an extruder or a calender into cover or sidewalls.

The subsequent treatment with solvents may be necessary after the extrusion, depending on the demands of the process.

In the next step, the tyre tread - yet without tread- are cut to the demanded length.

Finishing of the tyre

The parts of tyre, the production of which is described above, are assembled together in a so-called lay-up machine to basic tyres.

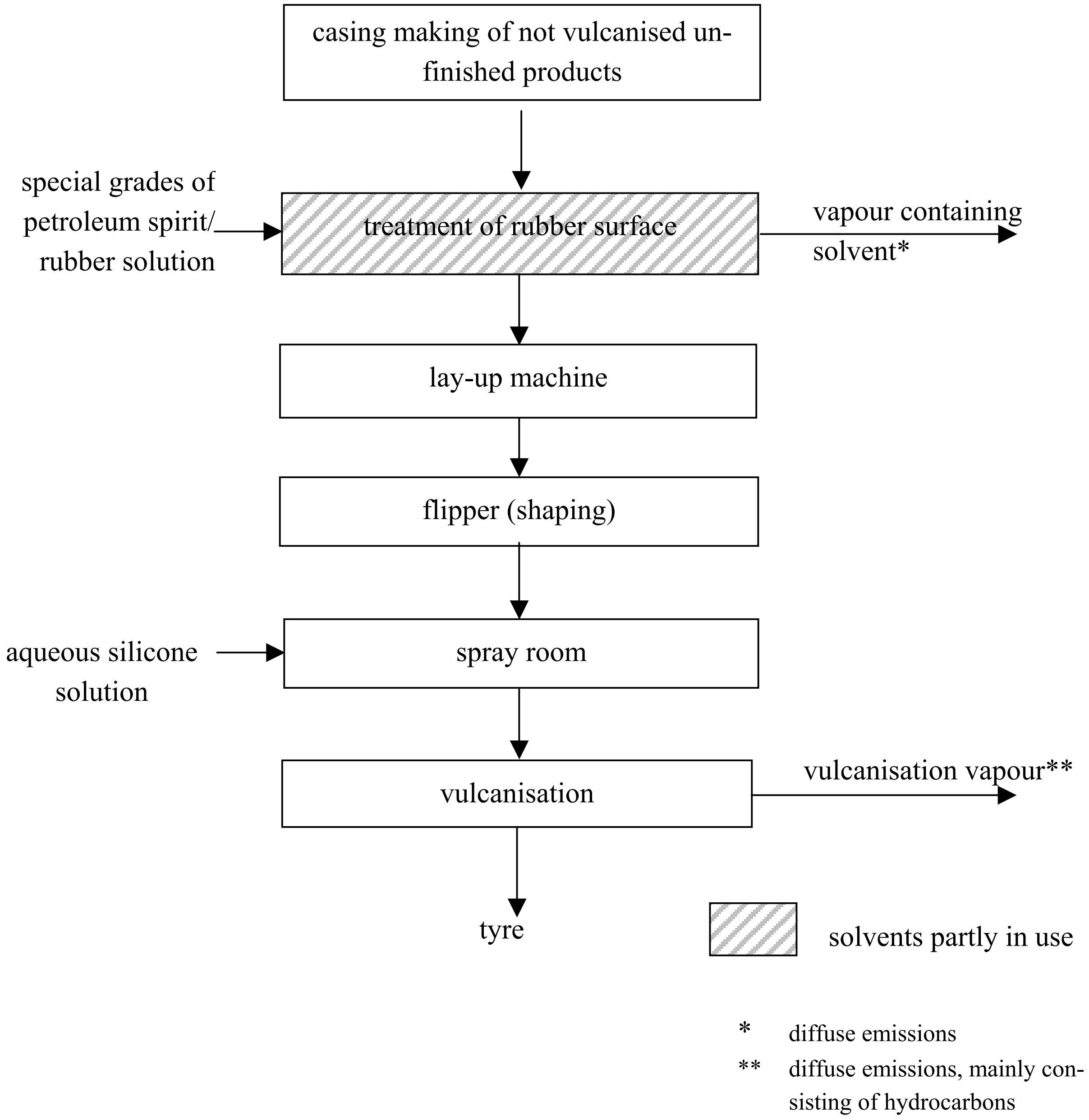

Figure 4-8 Finishing of tyre (scheme)

Since it is almost impossible to produce all components at the same time, the rubber surface is etched by special grades of petroleum spirit or rubber solutions just before the components are joined. This is done in order to improve the bonding during vulcanisation.

Organic solvents are released as diffuse emissions to the environment.

The components are placed around an inflatable, but not yet inflated rubber expansion joint in the lay-up machine. In the next step, the so-called flipper (shaping), the rubber expansion joint is inflated by compressed air. Thus the carcass is arching just to the point where it is rechucked by the steel belt, which was before only loose attached. After that, the tyre tread is put on the tyre.

After the shaping (flipper), the green tyres are vulcanised and are automatically pressed with heated plates. This is where they get their final shape and tread. In the heating press a steam heated membrane is pressed from inside against the tyre. At a temperature of 180°C the long-chained rubber molecules react with the vulcanisation agent (in most cases sulphur). This results in an inseparable bonding of the various rubber parts and layers and thus the parts of the tyre. During this process vulcanisation vapour arises as diffuse emission.

In order to prevent the membrane of the rubber expansion joint from sticking to the tyre and to improve the gliding ability the tyres may be drizzled with a aqueous silicon solution before vulcanisation.

Finally, the tyres undergo a quality control including X-ray testing.

Subsequent treatment

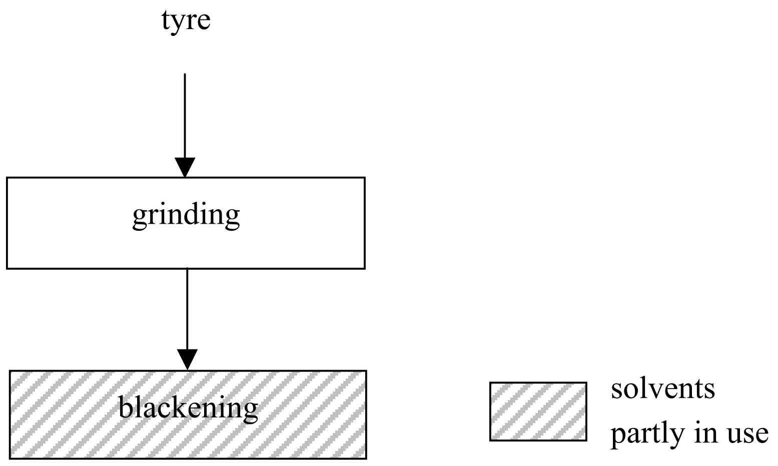

Figure 4-9 Subsequent treatment

Subsequent treatment might be necessary from case to case to meet the demanded product quality. Grinding can be necessary to reach the demanded roundness. After grinding the tyre must be blackened, a procedure where solvents may be used.

4.2.3. Impact of organic solvents

Organic solvents are used in different process steps during manufacturing of new tyres. Mainly important are special grades of special benzine (boiling point between 80 – 160 °C), which may be used pure or as a rubber solution.

4.2.4. Components of installations and required differentiation

A plant existing of the following components typically accomplishes the described processes. It is important to notice, however, that single components may be produced as well externally.

Storage of raw materials

Typically, the various raw materials are stored and available in different storages or a central storage with different storage sectors. For example the rubber, the chemical, the sulphur, the benzine or solvents, the plasticizer storage sector and the carbon black silo works [Lit. 6].

Working the raw material, production of the rubber compound

The following important processing components are needed:

- balance
- kneader
- extruder/calender

Production of textile cord and steel cord

The following important processing components are needed:

- impregnating machines
- drilling machines
- calender
- cutting machines

Manufacturing of beads, tread, sidewalls finishing

The following important processing components are needed:

- extruder/ calender
- coating machine
- vulcanisation press
- spray machines
- cutting machines
- reeling machine
- tyre lay up machine
- grinding machine

4.3. Current consumption and emission values

This plant, which is described in the following, produces passenger car tyres, truck tyres and semi-finished products and materials for tyre production. The data are given as specific values related to 10.000 t passenger car tyres per year. The capacity of the actual plant is about 50.000 t passenger car tyres per year.

Total balance

Input		**Output**	
Raw materials			
synthetic and natural rubber	6.970 t/a	passenger car tyres	10.000 t/a
filler and chemicals	5.467 t/a	tyres for utility vehicles	2.374 t/a
steel cord	1.342 t/a	semi-finished products for other plants	2.303 t/a
steel und textiles	1.738 t/a	rubber compound	1.718 t/a
rubber compound	2.293 t/a	retreading material	388 t/a
foils	208 t/a	foils	125 t/a
		rubber parts	83 t/a
		sealing agent (IMS)	20 t/a
		waste	1.254 t/a
		hazardous waste	71 t/a
solvents			
benzine and solutions	40 t/a	emissions	36 t/a
processing materials			
packing material	265 t/a		
water	45.573 m^3/a	waste water and off steam	45.573 m^3/a
Energy [MWh/a]			
Energy	54.840		

Table 4-2 Total balance – tyre production plant

The difference of 49 t (higher output) is due to variations in storage of unfinished products and rubber compounds.

Important waste volumes and waste treatment

waste type	amount [t/a]	treatment/disposal
tyres	427	processing; additive/energy carrier in cement industry
scrap	1.037	additive in metal foundry
rubber and textile waste	1.039	material processing
steel cord	861	additive/energy carrier in cement industry
foils	520	synthetic recycling
hazardous waste	**amount [t/a]**	**treatment/disposal**
emulsions	77,6	separation and material processing/thermal treatment
waste oil	75,9	recycling of waste oil
packaging material, contaminated with chemicals	57,4	processing by REPA, RIGK/thermal treatment
oil contaminated process materials	8,7	material/ thermal processing after pre-treatment
other	5,3	material processing/thermal processing

Table 4-3 Waste volumes and waste treatment – tyre production plant

Important emissions during production

emissions	freight [kg/a]	concentration [mg/m^3][1]
solvents (VOC)	20.679	56 – 1.315
vulcanisation vapour[2]	14.530	0,9 - 24
dust	648	0,5 - 34
N-Nitrosamine	0,26	max. 0,0007

Table 4-4 Important emissions – tyre production plant

Note: The energy demand depends to a large degree on the manufactured product range. This has to be considered when transferring the values to plants manufacturing other product ranges.

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[1] half hour median value

[2] without solvents, mainly consisting of hydrocarbons

The following balance has been provided by the association of the German rubber processing industry (wdk). It contains the input-output values from 9 German tyre production sites at a higher level of aggregation. These data represent approximately 2/3 of the German tyre production.

Input		Output	
raw materials and processing materials			
raw and processing mat.[3]	847.111 t	passenger car and truck tyres	354.611 t
drinking and process water	3.491.656 m^3	truck tyres	92.514 t
		retreated tyres	40.503 t
		Co-products[4]	266.638 t
energy [MWh]		emissions	
electricity	535.825 MWh	exhaust gas[5]	1.996 t
fuel oil (light and heavy)	8.223 MWh	dust[6]	31 t
crude gas	875.333 MWh	waste water[7] and steam[8]	3.491.656 m^3
		waste[9]	31.673 t

Table 4-5 Input-output situation of the German tyre industry

Note: Differences between input and output volumes is due to variations in storage. For data collection the whole production sites have been taken into consideration. Thus the raw material storage facilities and the product storage facilities are integrated

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[3] includes solvents, separating agents and foils but no operation agents such as hydraulic oils

[4] e.g. failed compounds (sold), unfinished products, compounds for other plants

[5] organic substances from compounding, vulcanisation, (also from rolling or extruding etc.) and use of solvents

[6] exclusive from production process (compounding, spraying, grinding [for retreating])

[7] directly or indirectly via public water treatment plant

[8] condensed

[9] waste from processing such as rejects, cords, heating membranes, chemicals, emulsions, foils (no packaging)

4.4. Determination of BAT-candidates

The following technologies or measures can be considered as BAT candidates:

4.4.1. Emissions to air

- charging and discharging of silos (e.g. for carbon black) via encapsulated transport equipment. Exhaust gas treatment with filters
- For balancing and filling stations installation of suction equipment and air cleaning with filters.
- Filter dusts are recycled as additives within the production process.
- Effective suction installations for all arising vapours during vulcanisation.
- Substitution of organic solvents by aqueous solvents in various process steps. A more detailed differentiation is not possible due to discretion required from the tyre producers.
- Application of vulcanisation systems that comply with the nitrosamin limit values of 1,5 mg/m^3.

In Germany, the exhaust gas treating installations are currently not applied to a degree as prescribed by the VOC Directive for new installations. The emission of organic solvents arises from both, diffuse and collected emissions.

The German tyre manufacturing industry intends to comply with the legal prescriptions to develop reduction plans.

4.4.2. Emissions to water

In tyre production water is only applied for cooling purposes. No polluted waste water arises.

4.4.3. Waste

The processes can be realised in a way that a reasonable treatment of the following waste types is possible

- (rejected) tyres
- scrap
- rubber and textiles
- steel cord

- foils
- emulsions
- waste oil
- chemically polluted packaging materials
- oil contaminated process materials

4.4.4. Energy

- closed cooling agent cycles
- use of heat recovery systems in vulcanisation

4.4.5. Risk

- Separated storage according to risk classes
- Appropriate capacities to hold back water from fire fighting
- All devices for storage, filling or handling of water endangering chemicals and filling stations are equipped with liquid proof ground, collecting basin and rooms, barriers and double walls
- Plasticizers are generally stored in installations with leakage detectors
- Fire extinguishing installations (e.g. for sprinkling)
- Storage of rubber solutions with explosion protection in order to minimize the risk of fire.

4.5. Selection and recommendation of best available techniques

Table 4-6 shows a rough evaluation of the BAT-candidates. The symbols “↓“ and “↑“ stand for decreasing and increasing environmental pollution respectively. Numbers in brackets ”(1)“ indicate the need for further differentiation which is given in a corresponding comment below the table. "ok" expresses that a technology is „available“ in the sense of the IPPC-Directive.

Technology	A	W	WA	E	R	noise	risk	cost/ benefit
encapsulated transport equipment for charging and discharging of silos; exhaust gas treatment with filters	↓							ok
dust filters and recycling within the production process	↓	↑					↓	ok
effective suction installations for vapours from vulcanisation	↓							ok
substitution of organic solvents by aqueous solvents	↓							(1)
cleaning of solvent containing exhaust gas in order to minimise emission of vulcanisation vapour and VOC	↓							(2)
vulcanisation systems with emission values below 1,5 mg/m^3	↓							ok
closed cooling agent cycles			↓	↓				ok
heat recovery systems				↓				ok
separated storage according to risk classes							↓	ok
appropriate capacities to hold back water from fire fighting							↓	ok
appropriate fire extinguishing installations; storage of gum solutions with explosion protection							↓	ok
storage of softeners with leakage detectors and collecting basins							↓	ok

A = Air, W = Waste, WA = Water, E = Energy, R = Resources

Table 4-6 Evaluation of BAT-candidates – production of tyres

Comments

(1) Individual solutions are currently not available at industrial scale; reliable statement at present not possible

(2) Cleaning of solvent containing exhaust gas is currently not state of the art

Consequently all selected BAT-candidates can be considered as BAT with the exception of “substitution of organic solvents by aqueous solvents” and “cleaning of solvent containing exhaust gas”. Considering the use of aqueous solvents it turns out, that this is at the present state not possible throughout Germany. The cleaning of solvent containing exhaust gas can be requested if comparable installations exist in Europe. According to the present knowledge, in Germany no appropriate exhaust cleaning installations are operated.

4.6. New advanced processes

There is no information available from the tyre manufacturing industry. It can be assumed that the efforts to substitute organic solvents will continue (Reduction plans in order to comply with the prescriptions from the VOC-Directive). However, detailed information is not available to competition reasons.

5. Production of enamelled winding wires

5.1. General information

Depending on the size of the installation for the production of enamelled wires IPPC-relevant quantities of solvents are used.

Application fields

The main application fields of enamelled wires are magnet wires in windings and coils. These are used in a wide range of applications such as miniature coils for medical devices (hearing aids, pacemakers, etc.), various devices for entertainment electronics (microphones, audio and video heads, etc.), ultra-fine wires used in watches, windings for electrical motors, relays and power transformers. The use of winding wires is essential in modern industrial applications such as environmental technologies (e. g. wind driven power stations or electrical motors and transformers with low energy consumption) is absolutely indispensable and shows up promising aspects for future use.

Production and sales

The German Federal Statistical Agency stated a production of 82.506 t of coated and enamelled wires in Germany in 1999 from 8 producers . The ratio of coated wires to the total insulated wire and cable production in Germany is approximately 11%.

The German share of global production of enamelled wires is approximately 5%.

Table 5-1 shows the development of production amounts of enamelled wires and correlated consumption of organic solvents from 1990 to 1999.

	production [t]	organic solvents [t]
1990	80.600	5.400
1993	76.500	5.100
1996	77.200	5.100
1999	82.500	5.200

Table 5-1 Development of production of enamelled wires and correlated consumption of organic solvents

For the interpretation of the data the following additional information has to be kept in mind:

- The share of lubricants without organic solvents has increased from 0% in 1990 to approx. 20% in 1999.
- The amount of organic solvents consumed has been lowered by using high solid varnishes
- The share of enamelled wires grade 2 has increased. Those wires have a thicker varnish layer (approx. 50%) and are thus correlated to higher use of organic solvents
- The market share of fine wires has increased. Fine wires use proportionally larger amounts of solvents in the coating.

To conclude it can be stated that measures to reduce the use of organic solvents have been offset by changes in final product design and customer demands.

The share of coated wires on the German wire market is shown in Figure 5-1 (German Federal Statistical Agency, 1999).

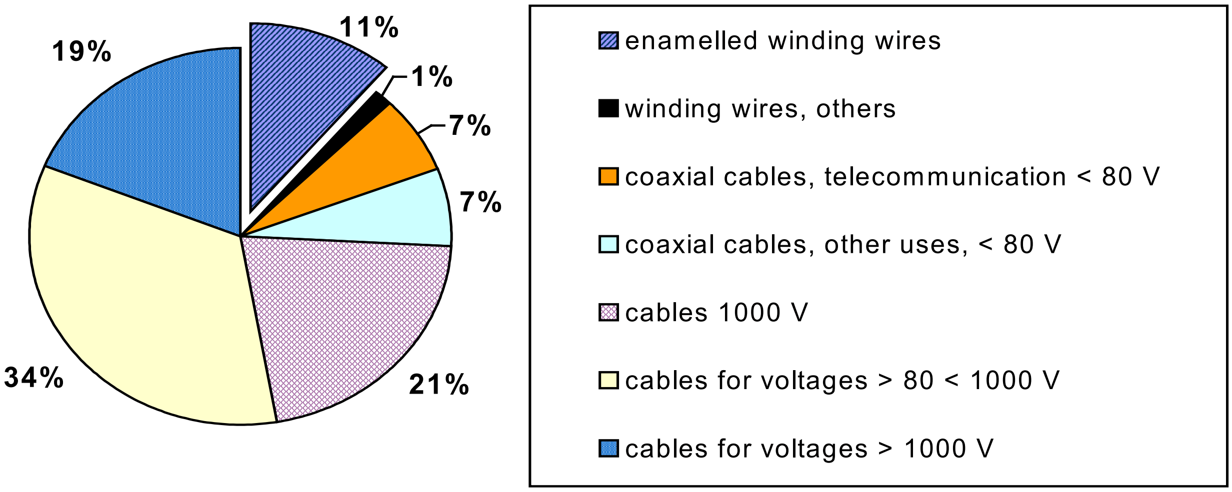

Figure 5-1 Percentage of cables and wires in the German marketplace, 1999 (Data: German Federal Statistic Agency)

Product characterisation and quality requirements

The main types are enamelled copper wires with a round cross-section and diameters from 0.01-6.0 mm (mainly from 0.3-0,65 mm) and flat enamelled copper conductors with typical thickness to width dimensions of 0.8-5 mm to 2.0-25 mm.

The share (by weight) of fine wires (< 0,1 mm) is approximately 3,5% of the total production.

Insulating materials are classified in the technical terms of delivery in the DIN EN 60317 Standard, sections 1 to 54 (corresponding to IEC 60317), testing methods are defined in DIN EN 60851 and packaging of enamelled wires in DIN EN 60264.

The main property of enamelled wire is the very thin, high specification insulating film allowing close packed and energy efficient windings to be produced which can operate at high temperatures. Thermal stability of the wire coating materials is characterised by a temperature index. Other specific requirements for insulating coating systems for wires are mechanical strength, chemical resistance and overload current stability as well as electric and dielectric strength. Contemporary electrical insulating systems already meet these requirements within thin layers (see above mentioned standards for details).

5.2. Processes and technologies in manufacturing

5.2.1. Process overview

The manufacturing process for enamelled wires is generally linear and can be described as follows:

Process Step	Solvent Use
Wire production process (drawing or rolling)	None
Thermal cleaning /annealing process	None
Coating process	Yes
Curing process	None
Lubricant application	Depends on specific process

Table 5-2 Solvent use in process steps of wire coating

Both main wire manufacturing processes - drawing or rolling - are solvent free.

The following coating or enamelling process covers the wires with insulating, protective and in some cases colour differentiation layers.

5.2.2. Detailed Process Steps

Figure 5-2 shows the process steps in production of enamelled wires in detail.

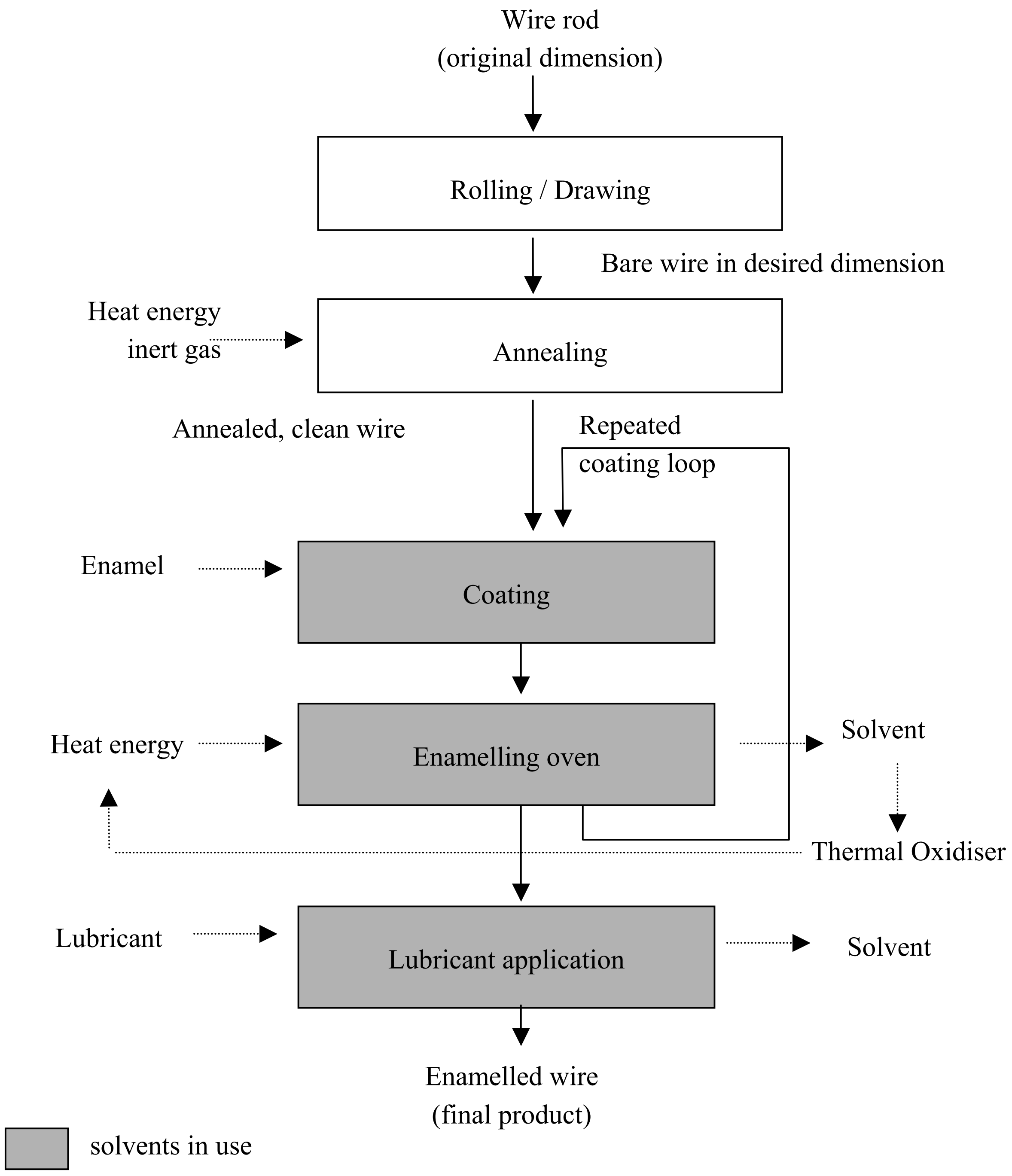

Figure 5-2 Manufacturing process for enamelled wires in detail

Rolling and drawing are deformation processes. Rolling is a continuous or stepwise forming process under compressive conditions. The involved material can be rolled at ambient or elevated temperatures. Wires for enamelled and other insulated winding wires are preferably manufactured by a drawing process. The wire is drawn through dies reducing its size and extending its length. Fine wires require several drawing stages to reach the desired dimension. The drawing process applies tractive and pressure stress to the drawn material.

The wire drawing process is followed by an annealing where the wire passes through heated tubes containing an inert atmosphere to prevent oxidation and leading to re-crystallisation and softening of the wire.

The next process step is enamel application followed by the drying and curing of the enamel film. The coating is normally applied by passing the wire continuously through a bath of enamel and metering the amount by an accurately sized die or metered by felt application. The coated wire passes into a heated chamber (horizontally or vertically arranged) where the solvent is evaporated before moving into a higher temperature zone (400 - 700ºC) where the film is cured.. In this continuous coating process up to 30 applications of enamel are applied until the desired layer thickness is obtained.

Recirculated air flow ovens are in use for contemporary wire coating processes. The direction of the recirculating air flow can be with or against the direction of the moving wire . The recirculating air flow has the advantage that the vented volumes can be decreased. The solvent evaporation process leads to evaporation of the solvent and the air/solvent mix is usually treated in a (catalytic) thermal oxidiser which ensures that residual solvent concentrations are below legal threshold limits (typically 20 mg organic C/Nm^3). The process heat from the thermal oxidiser can be used in the drying process respectively for the heat up of the circulating air flow (loop).

Contemporary ovens in use for very fine enamelled wires work with radiation or a combined radiation and circulating air flow. The uptake of organic solvents in the circulating air flow leads to a higher solvent concentration. The treatment in a catalytic thermal oxidiser with heat recycling works analogous the above described way.

Depending on the final product requirements the enamelled wire are lubricated before being wound onto a reel. Several lubricants contain different volatile organic solvents.

Typically paraffin is applied from an organic solvent with a solvent content from 98 to 99,9%. Lubricants as concentrated emulsions with a solvent content between 50-95%, water-borne emulsions or even solvent free hot melts are used with limited success. With respect to the use of solvent free alternatives, customers quality requirements with respect to thickness and evenness of the lubricant film have to be respected. The lubricant is generally specified by customers. Generally it can be stated that high quality requirements and thin wires are less appropriate for solvent free lubricants.

Alternative to solvent application may be application of a molten lubricant to the wire surface by a lubricant wetted felt or by feeding the finished enamelled wire with a lubricant filament that melts due to the residual heat of the wire. The later technique applies the lubricant by looping the filament 2-3 times around the enamelled wire and moving it in the same direction as the wire, although with lower velocity. Both techniques are not suitable for applying lubricants to very fine wires with diameters less than 0.1 mm yet.

5.2.3. Impact of organic solvents

The main process steps involving volatile organic solvents are during enamel coating and the application of solvent borne lubricant. During the drying process the complete solvent is evaporated, took up by the circular air flow system and treated in the thermal oxidiser.

The emission of solvent is more significant from the lubrication stage rather than the enamelling stage as the evaporating solvent is not always completely taken up by the vent air system but is partially released untreated and therefore leads to fugitive emission of solvents. In the case of very fine wires sometimes vent air systems can not be applied due to product quality requirements.

According to the customers requirements different types of coating systems are applied to winding wires (in agreement with the DIN EN 50317 (section 1-54) Standard. One main characteristic is the adhesion on the metallic wire. The classification of winding wires and the corresponding shares to total production in Germany are shown in Table 5-3 (1999).

Product	Insulating coating system	Share of total production [%]	Average solvent content [%]
Solderable wires (round cross-section)	Polyurethane base	11	50 – 75
Thermo stable wires (round cross-section)	THEIC polyesterimid or polyamidimid (partially*)	23	50 – 75
Selfbonding wires (round cross-section)	THEIC polyester(imid) with additional polyamidimid layer(*)	49	50 – 75
Other round cross-section wires	As above with an additional backing layer of aliphatic or aromatic polyamid base (partially*)	11	50 – 75
Rectangular wires	Dependent on temperature class: polyvinylacetal, THEIC polyesterimid	6	50 – 75
Total		100	50 – 75

Table 5-3 Main winding wire types in Germany, 1999.

The insulating coating systems that are marked with an asterisk (*) contain n-Methylpyrrolidone as volatile organic compound.

The solid content of wire coatings usually varies between 25 and 50%. The main components of the organic solvents (content from 50-75%) are cresols, aliphatic and aromatic hydrocarbons. The solvent for the coating application depends on the coating type as well as the wire diameter. For very fine wires (with diameters in the ten micron range) high solvent contents up to 75% are necessary, whereas with increasing diameters of the wire less solvent is needed in the coating application (e.g. solvent content around 50%). Higher environmental standards have enforced the development of medium and high solid coatings.

At present a handful of possible alternative coating techniques are developed: hot melts, high solids, cresol-free and water-borne coatings, electrophoretic applicable coatings, 2-K coating systems, powder polyester coatings, UV-Curing coating systems and extrusion coating with thermoplastic materials. For many reasons, i.e. lack of performance (quality), as well as economical, technological or safety aspects these alternatives have not yet succeeded against the classical winding wire coatings.

5.2.4. Components of installations and required differentiation

Figure 5-3 gives an overview on the components of an installation for manufacturing enamelled wires. The processes are typically realised in installation with the following components:

Component	**Established technologies**
drawing process	
drawing machine	Wet drawing machines with blocks or cones working with slippage
annealing	electrical resistance annealing with vapour/inert atmosphere and wire cooling and drying by the means of drawing emulsion and compressed air
emulsion cleaning	paper filter, hydrocyclone separator
emulsion treatment	demineralised water
raw wire cleaning prior to annealing	sponges + demineralised water with filter circuit, paper filter (dry)
coating process	
annealing	indirect heated ducts or shaft annealing with inert gas atmosphere (vapour or inert gas)
enamel application	recirculating enamel with filtration, dosed varnish supply with felt application
enamelling oven	Hot air recirculating system with or without radiation; energy recovery by usage of heat from catalytic or thermal oxidation of volatile organic compounds
wire cooling	with room air or outside air
exhaust gas treatment	secondary catalytic or thermal (electrical or gas flame) oxidation of volatile organic compounds

Component	Established technologies
lubricant application	
application equipment	dosage and application of lubricant via organic solvents and felts; for selected processes also application without organic solvents possible by the means of lubrication filaments or felts possible. Lubricants usually consist of waxes containing organic solvents; in certain cases organic solvent free waxes and water dispersions (restricted to special cases, currently not state of the art).
exhaust gas treatment	none

Table 5-4 Installation components in enamelled wire manufacturing

Usually an installation consists of several machines or production lines where wires with different diameters and product quality can be manufactured.

Production of coated wires (schematic)

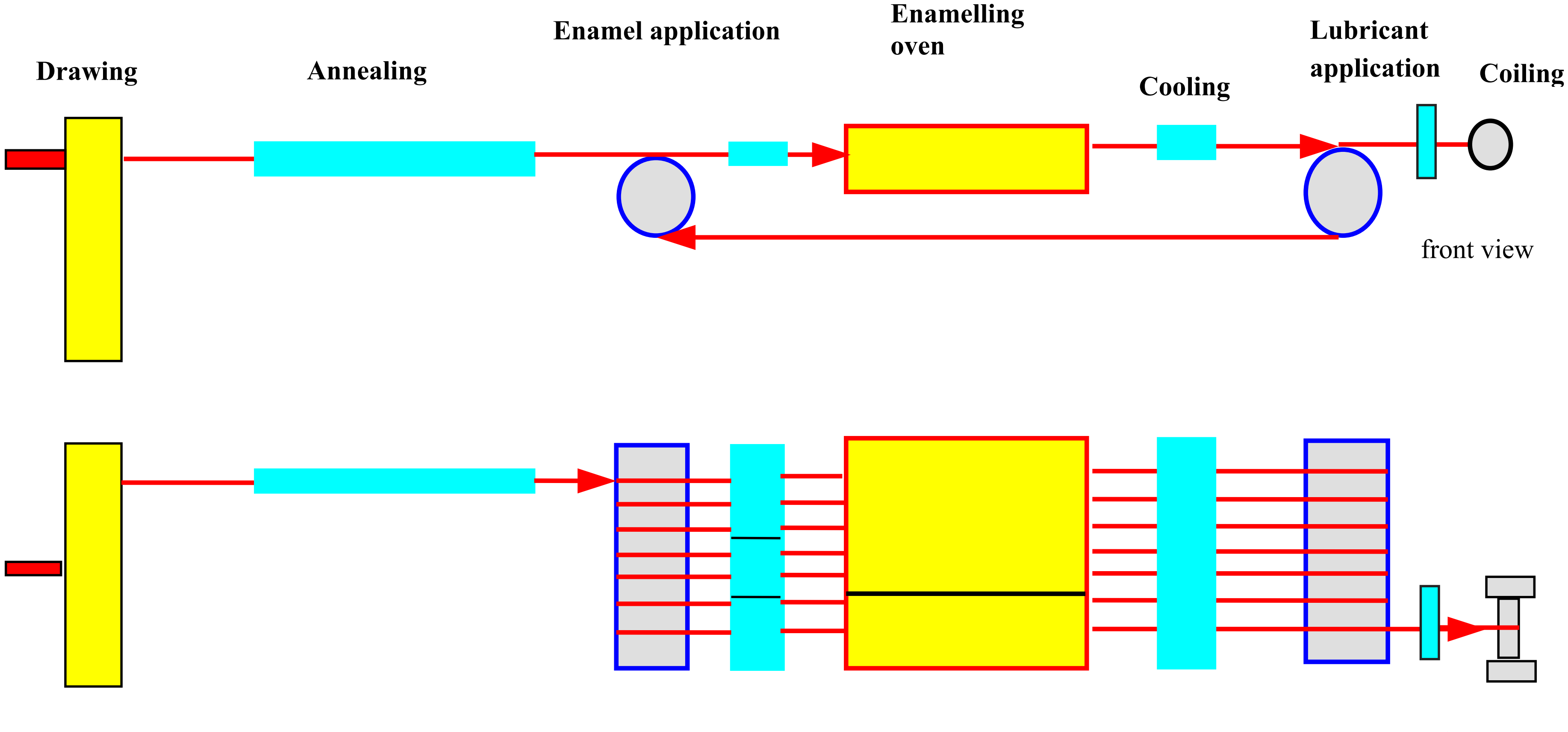

Figure 5-3 Components of an installation for the manufacturing of enamelled wires

Required differentiation of installations

The range of diameters (0,01 – 6,0 mm) results in a large variation between production quantity (tonnes wire) and product surface (m^2)coated. As a consequence, the technologies and varnishes applied for fine wires are different from those for larger diameter wires.

For the description of BAT Candidates this is considered by differentiating two types of installations. These are separately characterised with respect to their ecological key figures. The two types can shortly be described by the following parameters:

Installation M:	medium wires, predominant diameter 0,6 mm, 3 shift operation at 320 to 340 days per year, typical capacity 90 t wire per line/year
Installation F:	fine wires, predominant diameter 0,08 mm, 3 shift operation at 320 to 340 days per year, typical capacity 30 t wire per line/year

As mentioned above, an installation is composed from several machine. Usually the machines of an existing plant correspond to different technical status that may have an influence on the overall emission from the installation.

Important parameters in this context are:

- the technology applied at each single machine
- the wire diameter that is produced
- the quality that is produced

Generally thin wires are related to higher specific VOC emissions (calculated as g volatile organic compound per kg product) compared to thicker wires. This is due to the relation product weight / product surface and to the achievable share of VOC in varnishes and lubricants. Both effects have to be added. To give an example: a wire with a diameter of 0,02 mm results in 4 times VOC emission compared to a wire with 0,1 mm diameter.

Current consumption and emission values (see chapter 5.3) refer to existing installations. Thus the different technological status of the installation components influences the overall emissions of the whole installation. This explains why all important German plant operators can assure compliance with the limit values as specified in the SE-Directive until the year 2007 even if the limit values can not be achieved at present. It has to be noted that the major share of the VOC emissions is due lubricant application.

5.3. Current consumption and emission values

Installation M
(medium wires, predominant diameter 0,6 mm, typical capacity 90 t per year and line)

The following data refer to an installation with predominant wire diameter 0,6 mm grade 2. They are given as specific values related to 1000 kg final product. Depending on the technological status of the single machines of the installation variations can be observed for the individual values. A transfer of the values to other diameters has to consider an increase in specific VOC emissions for wires with decreasing diameter.

Input		Output	
raw materials			
Cu-wire (8 mm)	1070 kg	product (Cu-wire 0,6 mm)	970 kg
		wire residues (bare and coated)	100 kg
varnishes and solvents			
polymer in varnish	38 kg	varnish on product	30 kg
		polymer losses	8 kg
solvents	71,5 kg	solvents in waste	4,7 kg
		catalytic oxidation of VOCs 1)	58,6 kg
		emitted VOCs	8,2 kg
		NO_x, CO CO_2	2)
process materials			
water	~ 1.000 kg	water	~ 1.000 kg
wax	0,1 kg	wax	0,1 kg
drawing compound	0,3 kg	drawing compound waste, wet	3,5 kg
energy			
energy	2,1 MWh 3)		

1) This value is not an emission amount but the share of VOC-input that is used for energy recovery by thermal or catalytic oxidation.

2) No representative emission values are available that allow the calculation of specific emission factors. Single measurements have shown that concentrations up to several thousand mg/m³ are obtained. NO_x- and CO-values are highly related to the increasing input of Nitrogen compounds from the varnish systems (NMP).

3) The value depends strong on the product (isolation) system

Table 5-5 Overall balance of a plant for the production of medium wires

Installation F
(fine wires, predominant diameter 0,08 mm, typical capacity 30 t per year and line)

The following data refer to an installation with predominant wire diameter 0,08 mm. They are given as specific values related to 1000 kg final product. Depending on the technological status of the single machines of the installation variations can be observed for the individual values. A transfer of the values to other diameters has to consider an increase in specific VOC emissions for wires with decreasing diameter.

Input		Output	
raw materials			
Cu-wire (8 mm)	1100 kg	product (Cu-wire 0,08 mm)	962 kg
		wire residues (bareand coated)	138 kg
varnishes and solvents			
polymer in varnish	58 kg	varnish on product	38 kg
		polymer losses	20 kg
solvents	186 kg	solvents in waste	6 kg
		catalytic oxidation of VOCs 1)	165 kg
		emitted VOCs	15 kg
		NO_{x}, CO CO_2	2)
process materials			
water	~ 1.000 kg	water	~ 1.000 kg
wax	0,1 kg	wax	0,1 kg
drawing compound	0,3 kg	drawing compound waste, wet	6,5 kg
energy			
energy	4,5 MWh		

1) This value is not an emission amount but the share of VOC-input that is used for energy recovery by thermal or catalytic oxidation.
2) No representative emission values are available that allow the calculation of specific emission factors. Single measurements have shown that concentrations up to several thousand mg/m³ are obtained. NO_x- and CO-values are highly related to the increasing input of Nitrogen compounds from the varnish systems (NMP).

Table 5-6 Overall balance of a plant for the production of fine wires

5.4. Determination of BAT-candidates

The following technologies or measures can be considered as BAT candidates:

5.4.1. Emissions to air

- Varnish application:
  Encapsulation and suction of the VOC vapours above the enamelling oven
- Exhaust gas treatment:
  Treatment of VOCs by catalytic or thermal (electrical or gas flame) oxidation
- Lubricant application
  Dosage and application of lubricant wax via organic solvents and felts; for selected processes also application without organic solvents possible by the means of lubrication filaments or felts possible
- Application of low solvent or solvent free substances
  The use of solvent free waxes and dispersion is currently only applicable in selected cases

5.4.2. Emissions to water

Emissions to water are not relevant during manufacturing of enamelled wires.

5.4.3. Waste

- Emulsion treatment
  In order to reduce waste amounts, emulsion treatment with demineralised water; water is evaporated and thus waste amounts are minimised
- Cleaning of emulsions with paper filter and hydrocyclone separator
- Varnish application
  In order to reduce varnish losses the application is realised in varnish baths and die stripping with varnish circuit or dosed varnish supply felt application

5.4.4. Energy

- Annealing
  indirect heated ducts or shaft annealing with inert gas atmosphere (water vapour or inert gas)

- enamelling oven
  Hot air circulating system with or without radiation; energy recovery by usage of heat from catalytic or thermal oxidation of volatile organic compounds
- Wire cooling with room air or outside air

5.5. Selection and recommendation of best available technologies

For the definition of best available technologies several coherences have to be considered:

The emission of untreated VOCs depends highly from the produced wire diameter. According to industry statements in the case of manufacturing small wire diameters (below 0,08 mm for fine wires and below 0,3 mm for medium wires) the limit values as foreseen in the SE-Directive can at present not be achieved – even if BAT candidates are applied.

Furthermore client's and quality requirements with respect to thickness and evenness of the lubricant film have to be respected. As a consequence for the majority of product qualities the BAT-candidates are not realistically applicable.

Table 5-7 shows a rough evaluation of the BAT-candidates. The symbols "↓" and "↑" stand for decreasing and increasing environmental pollution respectively. Numbers in brackets "(1)" in the column „cost/benefit" relation indicate the need for further differentiation which is given in a corresponding comment below the table. "ok" expresses that a technology is „available" in the sense of the IPPC-Directive.

Technology	A	W	WA	E	R	noise	risk	cost/ benefit
Encapsulation and suction of the VOC vapours above the enamelling oven	↓							ok
Treatment of VOCs by catalytic or thermal (electrical or gas flame) oxidation	↓			↓				ok
Solvent free application of lubricants by the means of lubrication filaments or felts	↓				↓			(1)
Cleaning of emulsions with paper filter and hydrocyclone separator		↓			↓			ok
varnish application in varnish baths with die stripping and varnish circuit or dosed varnish supply felt application					↓			ok
indirect heated ducts or shaft annealing with inert gas atmosphere (water vapour or inert gas)							↓	ok
Hot air circulating system with or without radiation; energy recovery by usage of heat from catalytic or thermal oxidation of volatile organic compounds				↓				ok

A = Air, W = Waste, WA = Water, E = Energy, R = Resources

Table 5-7 Evaluation of BAT-Candidates – production of enamelled wires

(1) The application of lubricants without organic solvents by the means of lubrication filaments or felts is currently only possible in selected cases. Considerable additional costs for the technical system and service has to be taken into account.

The technologies and BAT candidates that are currently used in Germany are appropriate to achieve a considerable reduction in environmental pollution. The should be included in the establishment of a BAT-Document.

Installations for the manufacturing of enamelled wires as they are currently operated in Germany – including new installations – can only comply with the prescriptions of the SE-Directive if they are furnished with special lubricant application equipment. During the negotiations for the establishment of a BAT-document it is recommended to take the prescriptions of the SE-Directive as a basis but also to take into account the manufactured wire diameter and the correlated variation of the VOC Emissions.

5.6. New advanced processes

Component	**Established technologies**	**Future developments and visions**
drawing process		
drawing machine	Wet drawing machine with blocks or cones working with slippage	Medium diameter and Inline drawing machines working without slippage
annealing	electrical resistance annealing with vapour/inert atmosphere and wire cooling and drying by the means of drawing emulsion and compressed air	Annealing in plasma stream with inert gas atmosphere; Cooling and drying as before
emulsion cleaning	paper filter, hydrocyclone separator	/
emulsion treatment	demineralised water	/
raw wire cleaning prior to annealing	sponges + demineralised water with filter circuit, paper filter (dry)	plasma stream; ultrasonic with filter circuit
coating process		
annealing	indirect heated ducts or shaft annealing with inert gas atmosphere (vapour or inert gas)	plasma stream
varnish application	varnish bath with die application and varnish circuit, dosed varnish supply with felt application	Extruder system, 2k-application
enamelling oven	Hot air circulating system with or without radiation; energy recovery by usage of heat from catalytic or thermal oxidation of volatile organic compounds	can be dropped or replaced by UV-radiation (UV-hardening varnishes) as soon as extruder systems are applied
wire cooling	with room air or outside air	compressed air, fluid cooling agents with drier
exhaust gas treatment	catalytic or thermal (electrical or gas flame) oxidation of volatile organic compounds	can be dropped as soon as no exhaust gases emerge

lubricant application		
application	dosage and application of lubricant via organic solvents and felts; for selected processes also application without organic solvents possible by the means of lubrication filaments or felts possible	Application of lubricant containing varnish with felts or dies; to be enamelled in enamelling oven
exhaust gas treatment		
exhaust gas treatment	none	in case of application of lubricant containing varnishes: catalytic or thermal oxidation of eventually included VOCs; energy recovery
production materials	**established technologies**	**future developments and visions**
emulsion	mineral oil, synthetic oils, soaps	waterborne drawing emulsion
varnishes	resins, dissolved in organic solvents	isolating resins or synthetics that are solvent free or do not set free organic solvents
lubricants	solvent borne waxes; in limited cases solvent free waxes and water borne dispersions (at present not state of the art)	isolating lubricant containing varnishes

Table 5-8 Possible future developments and visions

6. Production of friction lining

6.1. General information

Organic solvents are used in IPPC-relevant quantities in plants for the production of friction lining with adhesives and rubber varnish and in the production of wet mixtures.

Areas of application

Friction lining is used as brake lining or clutch facing for all types of vehicles and for machines and other industrial appliances. All friction linings can be produced by dry or wet processing.

Production and sales

Less than ten companies are manufacturing friction linings in Germany. The total amount of production amounts to

- approximately 45 million drum brake linings for passenger cars
- approximately 20 million drum brake linings for lorrys
- approximately 140 million disk brake linings for motor vehicles
- approximately 20 million industry friction linings
- approximately 10 million clutch facings for all motor vehicles

The turnover of the friction lining industry is about 670 million €/a. Approximately half of the European production of brake linings and about 30 % of the clutch facings are manufactured in Germany.

All raw materials for the production of friction linings using phenol formaldehyde resins and other synthetic resins and solvents are bought from suppliers.

Characterisation of the product "friction lining" and its quality demands

Friction linings are safety product and have to meet precise quality requirements. The most important client is the car producing industry which needs friction linings for drum and disk brakes and clutch facings. In addition industrial friction linings are manufactured.

Drum and disk brake linings consist of up to 30 components depending on the specific needs in their range of application. Most important components are organic and inorganic fibres, metals, rubber, lubricants and bonding agents. The bonding agent "resin" is almost exclusively used as phenolic resin. The proportion of resin usually ranges between 5 and 10% and reaches in particular cases up to 35%.

Depending on the bonding agent type two manufacturing processes for friction linings for brakes can be differentiated: dry and wet processing. Powdered resin is used in the dry process while liquid resin or resin solutions are used in the wet process. According to resin suppliers, 80 % of all drum and disk brakes are produced using the dry process. This leaves 20 %, which may be IPPC-relevant dependant on production volumes. The most common solvent used in the wet processing is ethanol.

Following standards apply to the friction lining production:

- VDA 6.1
- QS 9000
- ECE R90
- ISO 14001
- ISO/TS 16949

The requirements of quality are to a large extent influenced by the automobile industry (quality agreements, technical specifications, enterprise specific standards).

In this context it is noteworthy that in many cases the production process has to be considered as “part of the product”. Alterations of the production process have to be coordinated with the corresponding client. Any change of processing is usually only possible with the client’s approval.

6.2. Processes and technologies in manufacturing

6.2.1. Processes overview

Friction linings are basically produced according to the following routes:

Brake linings:

Production process	Potential of VOC Emissions
Coating of lining carrier	yes
Production of mixtures	partly
Moulding/pressing	partly
Curing	partly
Mechanical processing	no
Scorching	partly
Lacquer coating	partly
Marking	partly

Table 6-1 Processing of friction linings for brakes

Clutch lining:

Production process	Potential for VOC Emissions
Mixture production	yes
Thread impregnating and drying	yes
Moulding/pressing	partly
Curing	partly
Mechanical processing	no
Marking	no

Table 6-2 Processing of friction linings for clutches

In the following single process steps and process flow-charts are described for drum and disk brake linings and clutch linings these being the most important process in manufacturing friction linings.

6.2.2. Detailed process steps

Drum brake linings for passenger cars

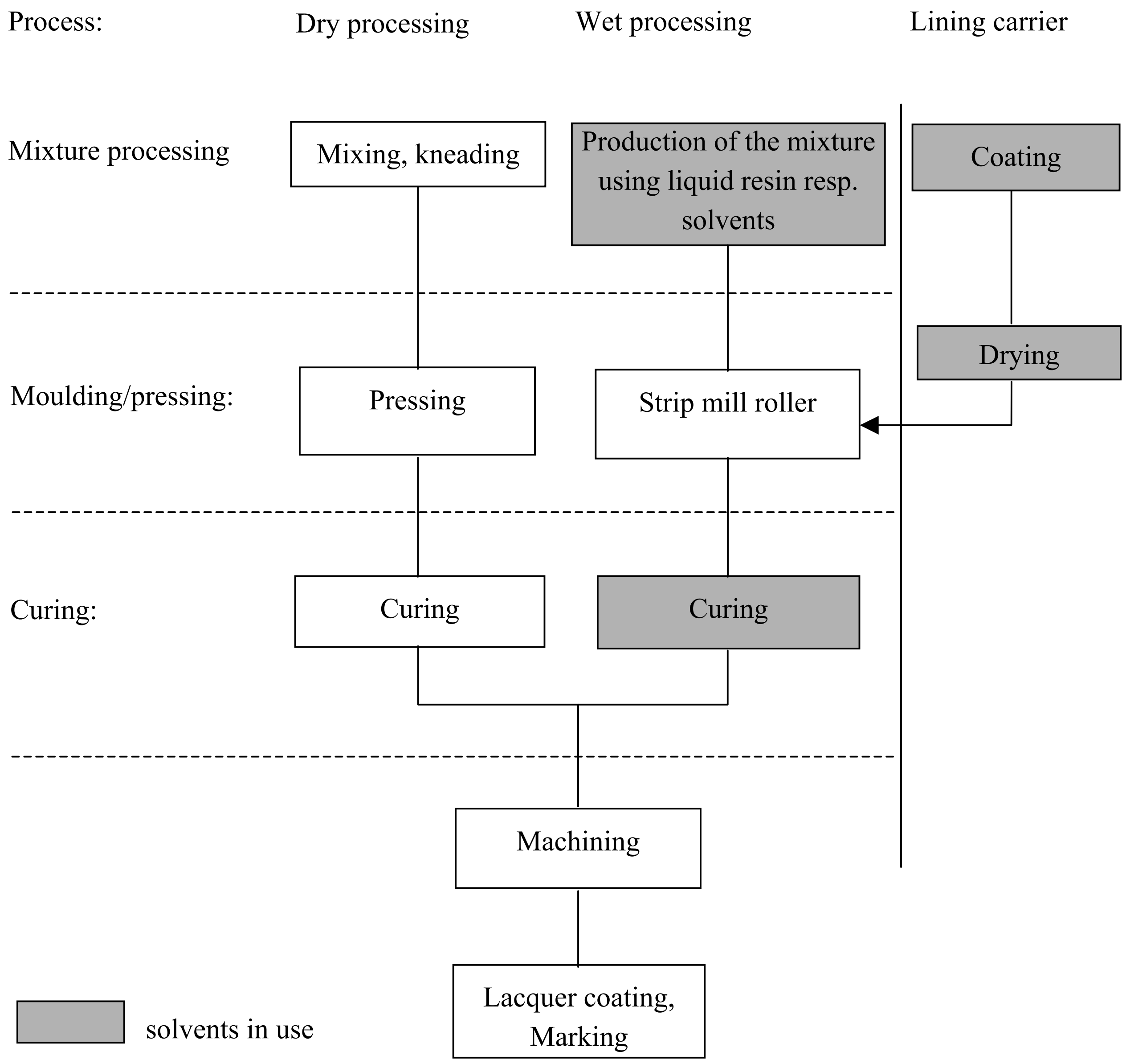

Figure6-1 Production of drum brake linings

During wet processing the mixture for brake linings is manufactured by using liquid resins which may include organic solvents. This mix may be rolled onto a carrier by a strip rolling mill. If a carrier is used this may be pretreated by coating with an organic solvent based coating. After curing products are machined to size. Finally the product may be lacquered and marked.

Disk brake linings

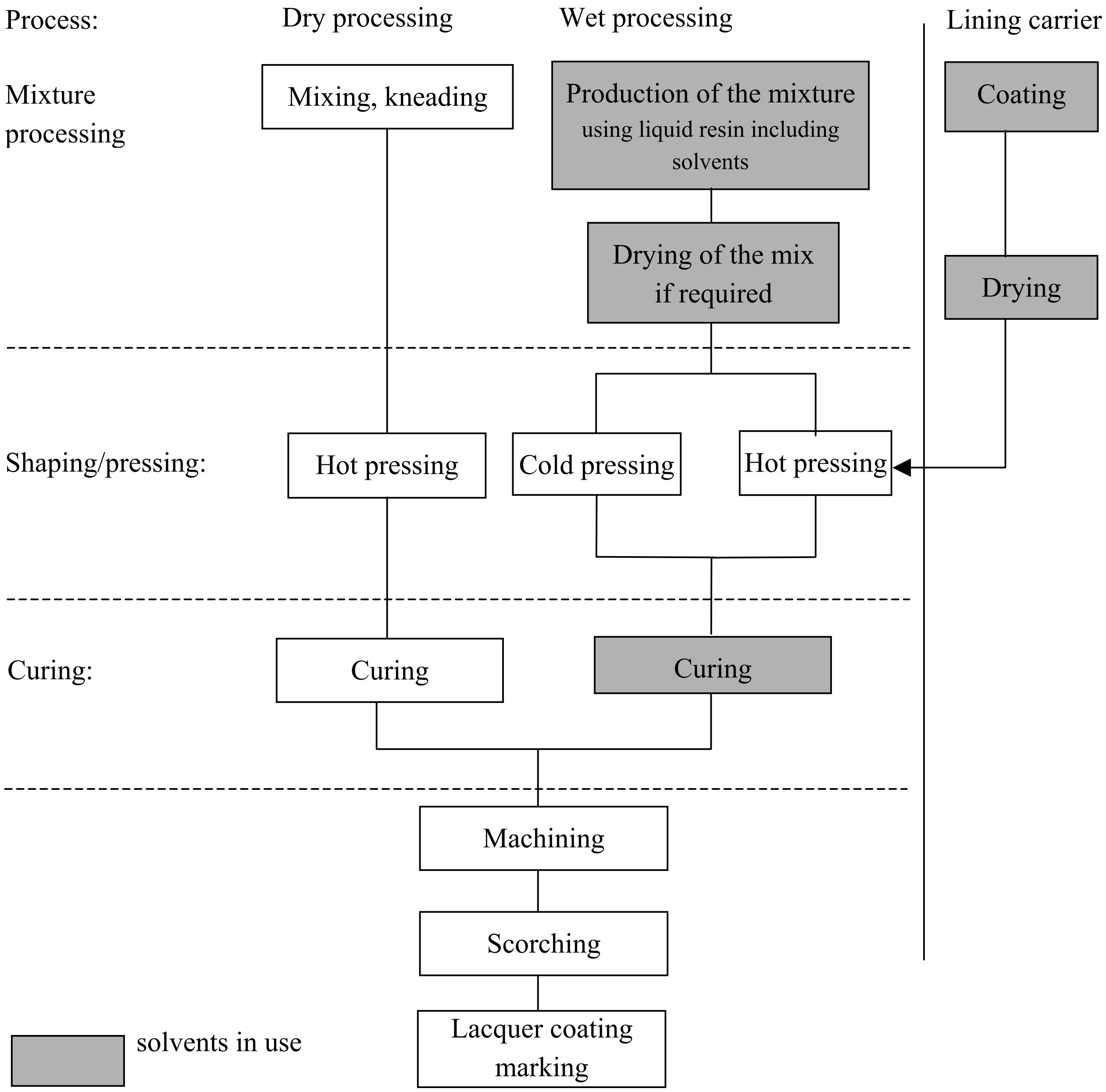

Figure 6-2 Production of disk brake linings

The process is similar to that of the manufacturing of drum brake linings. The principal difference is that during disk brake lining production the mixture is not applied to the carrier by strip mill rolling but by hot or cold pressing during moulding. As an alternative to rubber varnishes so called “anti-noise-foils” can be applied or bonded later.

Clutch linings for gear boxes

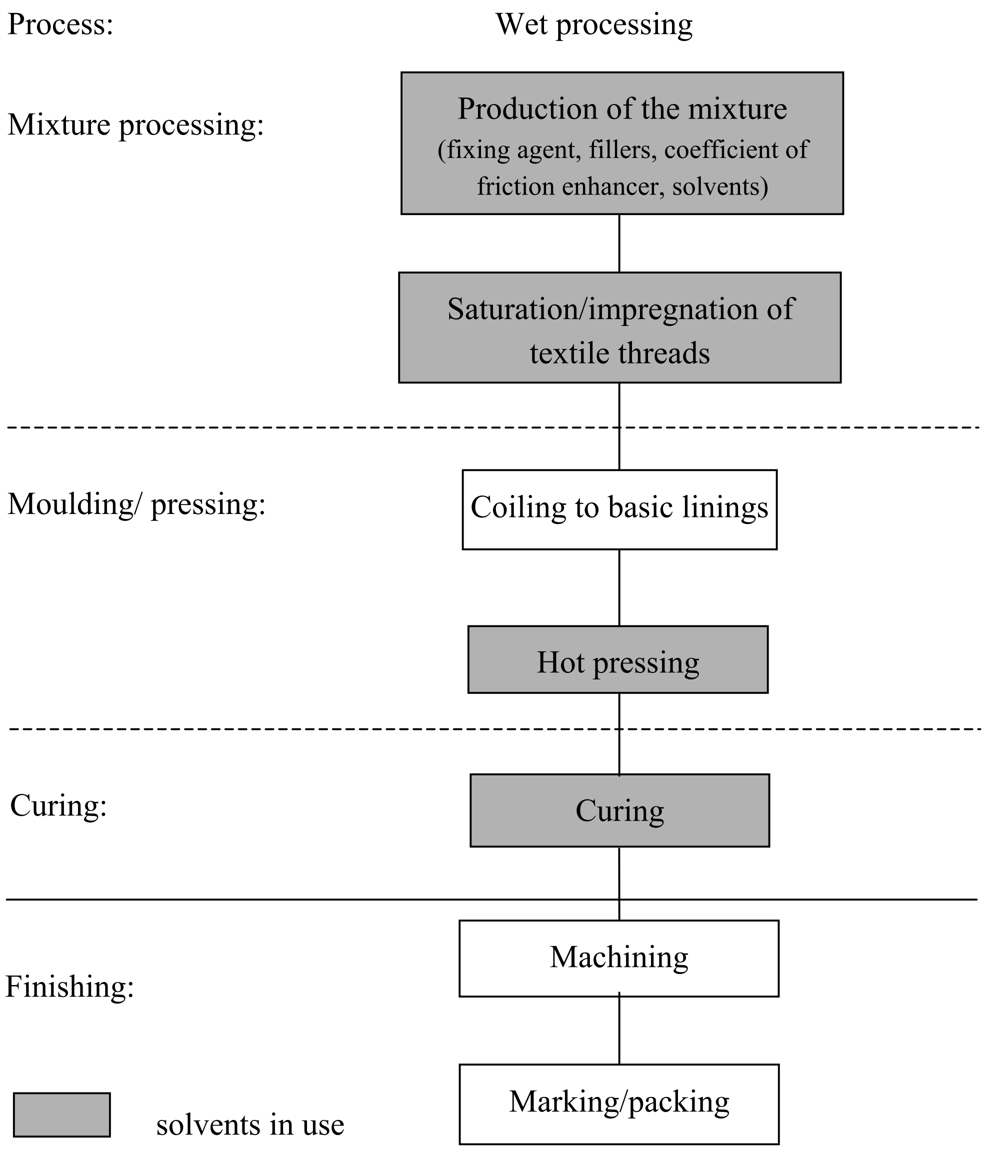

Figure 6-3 Production of dry clutch lining

In the wet preparation of clutch linings for cars with manual gear boxes, threads are impregnated with a pasty resin-rubber solution, then dried and coiled to blanks. These blanks are pressed, cured, machined and then riveted to the clutch disk.

Clutch linings for automatic transmission (=friction disks)

During this production process special kinds of paper are soaked in a resin solution (solvent content 40-70 %). Afterwards they are dried and bonded to the carrier.

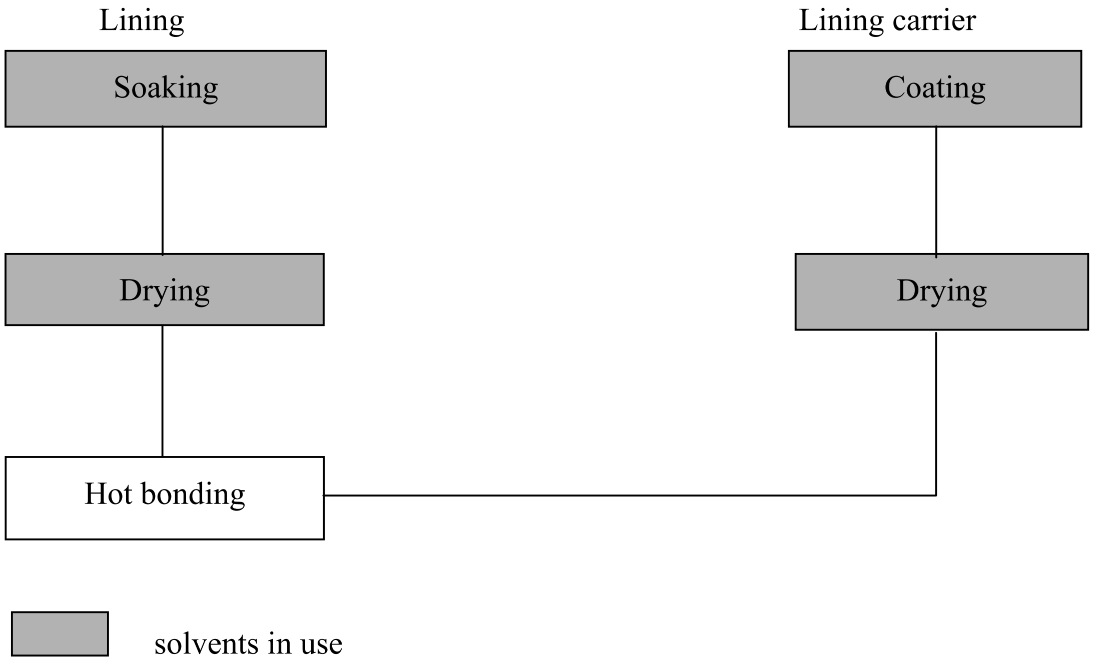

Figure 6-4 Production of clutch lining for automatic transmission

6.2.3. Impact of organic solvents

The following solvents are used during manufacturing of friction linings:

ethanol, toluene, 2-butanone, butanol compounds, acetone

6.2.4. Components of installations and required differentiation

Typically, the processes are realised in installations using the following processes:

Brake lining

Mixer/kneader, drier, carrier coating, press/rolling, curing oven, machining (grinding, drilling), scorching machine, lacquer coating, marking machine (see figure)

Clutch facing

Kneader, mixing machine, thread impregnation, drying, spooling machine, press, hardening oven, grinding machine, drilling machine, surface impregnation machine, marking machine (see figure)

Plant components for the production of brake lining

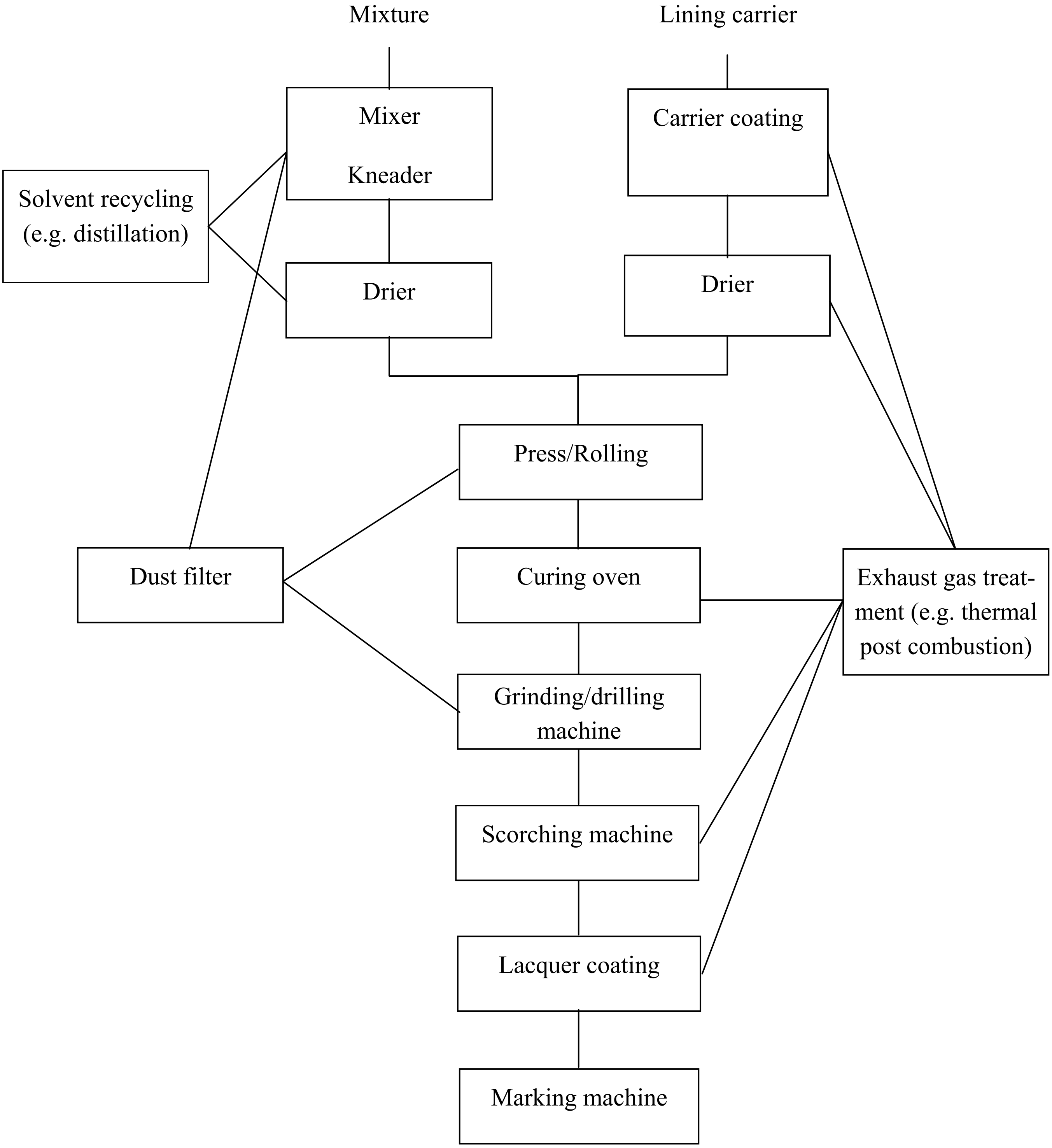

Figure6-5 Components of an installation for the production of friction linings

Plant components for the production for clutch lining (wet processing)

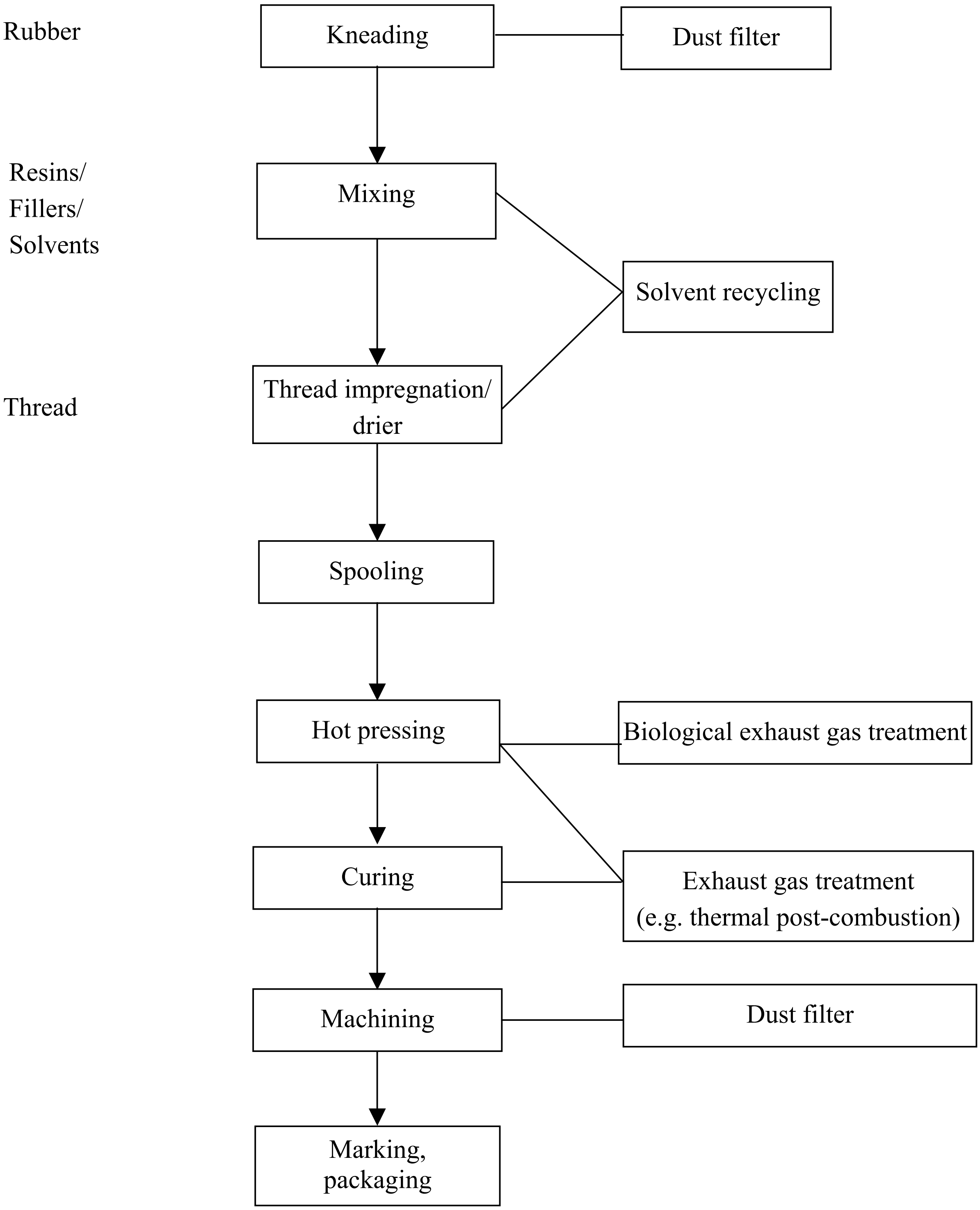

Figure6-6 Plant components for the production of clutch lining

6.3. Current consumption and emission values

Plant 1: **Plant 1 is an installation for the production of disk brake linings for motor vehicles in the wet processing method. The production volume is 10 million pieces.**

Input		Output	
raw material			
binding agent	140 t/a	product	3.345,5 t/a
fibres	280 t/a		
fillers	214 t/a		
friction support	346 t/a		
metals	420 t/a	waste	354 t/a
carrier	2.300 t/a	dust	0,5 t/a*
organic solvents			
wet mixture	45 t/a	low diffuse emission (< 5%)	
glue/lacquer	8 t/a		
energy			
re-heating		emission (total C)	5 t/a**
energy	16,1 Mio. KWh/a		

* corresponds to 0,08 kg dust/h at 200.000 m^3/h

** corresponds to 1 kg total C/h at 130.000 m^3/h

Table6-3 Total balance plant 1 – production of disk brake linings

Plant 2: Plant 2 is an installation for the production of drum brake linings for motor lorries. The production volume is about 10 million pieces.

With the application of appropriate technologies a solvent free operation of the installation is possible.

Input		Output	
raw material			
binding agent	2.931 t/a	product	13.635 t/a
fibres	4.299 t/a		
fillers	3.713 t/a		
friction support	4.495 t/a	waste	5.902 t/a
metals	4.105 t/a	dust	6 t/a*
solvents			
wet mixture	0 t/a		
glue/lacquer	0 t/a		
energy			
re-heating		emission (total C)	5,6 t/a**
energy	16,1 mio. kWh/a		

Table 6-4 Total balance plant 2 – production of drum brake linings

Plant 3 : Plant 3 is an installation for the production of friction linings for clutches. The production volume is about 10 million pieces.

The plant is equipped with dust filters, solvent recovery, biological exhaust gas treatment and thermal post-combustion.

Input		Output	
raw material			
binding agent	790 t/a	product	1.820 t/a
filler	925 t/a		
friction modifier	250 t/a		
threads	1.000 t/a		
organic solvents			
Toluene	2.660 t/a	emission/consumption	130 t/a
		internal recovery	2.530 t/a
ethanol	550 t/a	emission/consumption	110 t/a*
		internal recovery	440 t/a
		waste for further treatment	56 to/a
		waste for disposal	1093 to/a
energy			
heating oil	1.150 t/a		
electric current	13 mio. kWh		

* corresponds to 20 mg total C/Nm^3

Table6-5 Total balance plant 3 – production of friction linings for clutches

The position “emission/consumption” includes as well collected emissions before thermal post-combustion as well as comparatively low diffuse emissions (< 5%) of organic solvents and product components.

6.4. Determination of BAT-candidates

The following technologies or measures can be considered as BAT candidates:

6.4.1. Emissions to air

- Use of solvent free processes
- water based lacquers
- application of anti-noise-foils instead of rubber varnishes
- phenolic resins with low content of free phenols
- application of exhaust treatment processes (thermal, regenerative or catalytical post-combustion; biological exhaust gas treatment)
- organic solvent recovery plants (e.g. condensation, distillation, adsorption, pervaporation)
- use of dust filters (e.g. tube filters, sinter filters, filter mats, cassette filters)

6.4.2. Emissions to water

Emissions to water are not relevant in manufacturing of friction linings

6.4.3. Waste

Internal recycling of waste within the plant depends on specific formulations and desired quality criteria. General BAT-candidates are not available.

6.4.4. Risk

- appropriate fire extinguishing installations (e.g. sprinklers)
- If required machines equipped with explosion protection devices
- gas extinguishing installations
- retention/storage facilities for fire extinguishing water

6.5. Selection and recommendation of best available technologies

Table 6-6 shows a rough evaluation of the BAT-candidates. The symbols “↓“ and “↑“ stand for decreasing and increasing environmental pollution respectively. Numbers in brackets ”(1)“ indicate the need for further differentiation which is given in a corresponding comment below the table. "ok" expresses that a technology is „available“ in the sense of the IPPC-Directive.

Technology	A	W	WA	E	R	noise	risk	cost/ benefit
Use of solvent free processes	↓						↓	ok*
Use of water based lacquers	↓			↑			↓	ok
Application of anti-noise-foils	↓					↓	↓	ok
Noise avoiding production procedures						↓		ok
Phenolic resins with low content of free phenols	↓							ok
Degreasing without use of chlorinated hydrocarbons	↓							ok
Appropriate exhaust gas treatment	↓			↓				ok
Solvent recovery	↓				↓			ok
Appropriate fire extinguishing equipment		↓	↓				↓	ok

A = Air, W = Waste, WA = Water, E = Energy, R = Resources

* see chapter 6.3, technical requirements corresponding to plant 2

Table 6-6 Evaluation of BAT-Candidates – production of friction lining

The production of friction linings is a process which is carried out by comparatively few enterprises. If no appropriate technologies are applied this production may, particularly in the field of emissions to air, contribute to environmental pollution. The technologies and measures as they are applied within Germany as BAT-candidates show at reasonable cost/benefit with a comparatively high environmental standard. The application of processes without organic solvents is already established in the case of friction linings for drum brakes whereas in the case of other friction linings this is currently not possible due to quality requirements.

To conclude it can be recommended to consider the technologies as they are proposed as BAT-candidates for the Seville process.

6.6. New advanced processes

Due to competitive reasons no information was available from the friction lining industry. It can be assumed that components as well as production procedures will be developed further.

7. Production of magnetic tape

7.1. General information

Magnetic tapes are currently used as a storage for analogue and digital audio data (tapes of music, DAT) video data (VHS-tapes, DVC, Digital Beta cam, D-VHS) and for digital data storing (floppy disks, computer tapes).

Organic solvents are in use for the application of the magnetic film on the carrier material. To this end about 200 t organic solvents are consumed per year (e.g. ether and ketones).

Production and sales

About 2,5 milliard m² of magnetic tapes are annually produced in Germany in two different production sites of the same enterprise. This production volume represents about 2/3 of the magnetic tape production in Europe.

Characterisation of the product "magnetic tape"

The thickness of magnetic tapes products varies between 9 µm (compact music tape) and 75 µm (3,5" floppy disk). Magnetic tape products are composed of the following layers:

- carrier (foil)
- magnetic film
- (back side coating)

At present in most cases PET-foil (PET: polyethylenterephthalat) in different thickness (6 µm to 70 µm) is used as carrier. The magnetic film, which is used as storage medium for magnetic signals, is applicated as dispersion on the carrier foil by different coating processes. Magnetic dispersion for the magnetic film usually contain the following components:

- Magnetic pigments (iron oxide, cobalt-doped iron oxide, chrome dioxide, pure iron)
- Binding agents (e.g. polyvinylchlorid, polyurethane)
- Organic solvents (e.g. cyclic ether, ketones)
- Dispersion agents
- Lubricants
- Supporting pigments

7.2. Processes and techniques in manufacturing

7.2.1. Process overview

The production of magnetic tapes is done according to the following table:

Production process	Use of solvents
dispersion	yes
coating	yes
drying	yes

Table7-1 Processes for production of magnetic tapes

Homogeneous dispersions are produced by different grinding processes. After a particular filtration these dispersions are coated to the carrier foils. From the preparation until the application to the carrier foil the manufacturing is done in closed systems. Therefore, during dispersion only very few emissions of organic solvents occur.

In coating machines in driers the solvents evaporate from the dispersions. On the carrier foil remains a solid magnetic layer with a very low share of resting organic solvents. The evaporated solvents are recovered. After a recycling treatment they are repeatedly used for the preparation of dispersions.

7.2.2. Detailed process steps

The following illustration shows the process steps of the total procedure

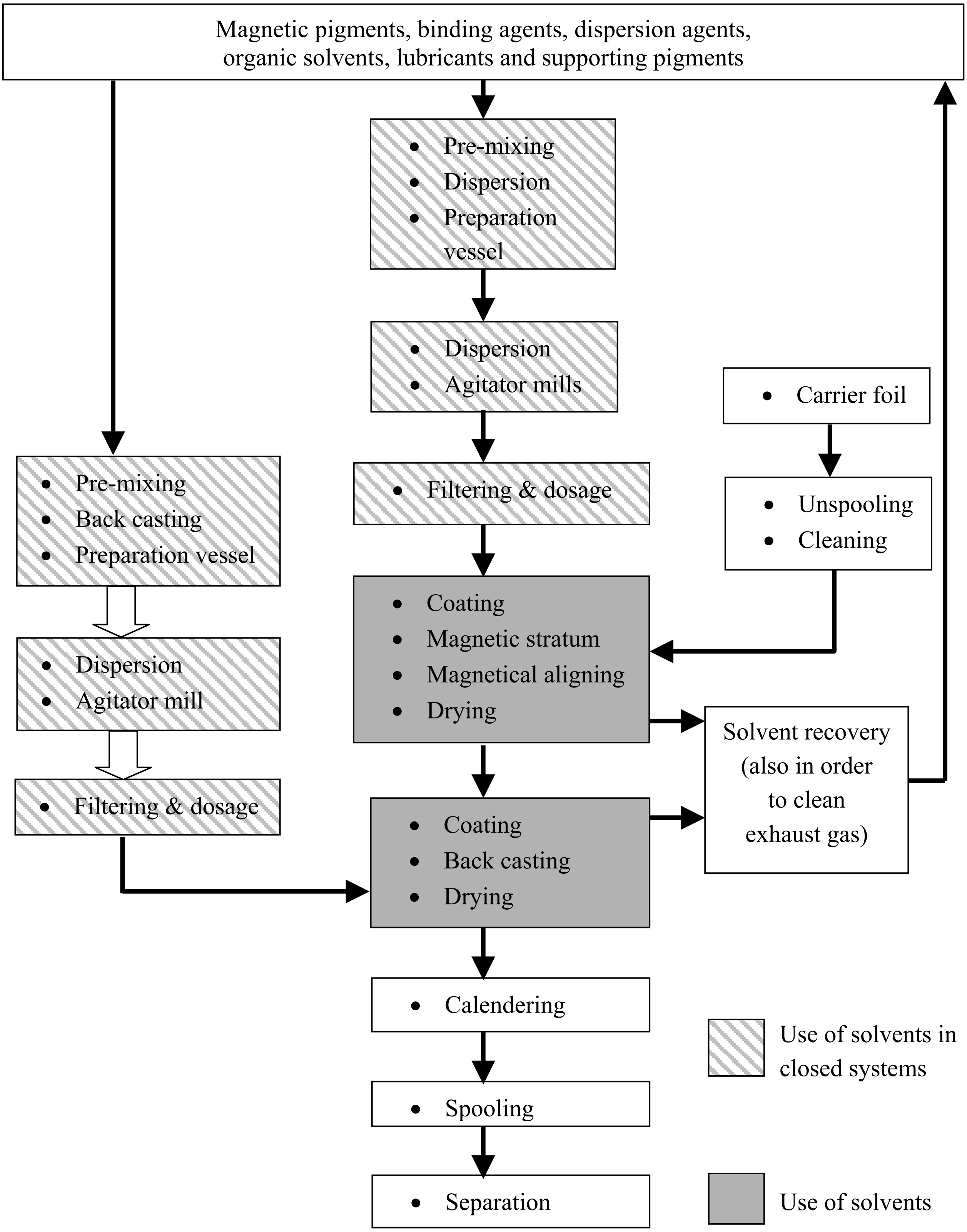

Figure 7-1 Production process during manufacturing of magnetic tape

An important step in the production of magnetic tape is the manufacturing of the magnetic dispersion. First the components (magnetic pigments, binding agents, dispersion agents, organic solvents, lubricants and supporting pigments) are put together according to the given recipe in a preparation vessel. Here a pre-mixing takes place with the help of an agitator. Afterwards the mixture is converted to a homogeneous dispersion in the closed system with agitator ball mills.

After grinding the dispersion is supplied to the coating machines via gradual filter systems and dosage equipment. In the coating plants the dispersion is applicated to the carrier foils by means of different application processes (depending on layer thickness, viscosity of the dispersion and product purpose). Immediately after the “caster” the individual pigment needles are aligned with the help of magnets. Already during alignment the drying process starts.

The solvents from the dispersion are recovered by two different methods:

a) Coating machines with inert gas driers (condensation)

The driers of the coating machines are supplied with heated inert gas. Due to the composition of the inert gas there is no risk for explosions. Thus the concentration of the solvents in the inert gas is not limited. The solvent is recovered by condensation at low temperatures. The remaining content of water in the recovered solvent can be removed by means of molecular filters. The solvent can be re-used for the preparation of new dispersions.

b) Coating machines with air driers (adsorption)

The driers of the coating machines are supplied with heated air. The concentration of the solvents in the exhaust gas of the coating machines must never amount above 50% of the lower explosion boundary. As a consequence the concentration of organic solvents in the gas is considerably lower compared to that in inert gas driers. The solvent is separated from the exhaust gas of the driers by adsorption to activated carbon. The desorption is carried out with the help of water vapour or nitrogen. The solvent has to be regenerated before the re-use by means of complex distillation steps.

When the magnetic layer is dried, the tape is transported to a calender (rolling mill). Here the surface is smoothed and the layer is compressed at high pressure and temperature.

Hereafter the magnetic tape is spooled up to large rolls. These rolls are again unspoiled and are cut to the desired width and length.

During manufacturing of magnetic tapes with back side coating analogous to the production of the magnet dispersion a dispersion for the back side is prepared, pre-mixed, ground and filtered. The back side coating can be applied in the coating machine before or after the application of the magnetic layer via a second application unit. After this in a separate back casting drier the solvent is evaporated and recovered in the solvent recovery.

The magnetic tape manufacturing requires high precision, since even small unevenness in the magnetic stratum or small breaks lead to errors during data storage and impair thus the quality of the product. Therefore the coating and the following process steps are carried out in dust free rooms.

A process-integrated continuous operation control system allows a constant monitoring and control of the process parameters during the entire manufacturing process.

7.2.3. Impact of organic solvents

Most common solvents in magnetic tape manufacturing are:

- cyclic ethers
- ketones

a) Solvent delivery, dispersion

The delivery of the solvents is effected in fuel-trucks. For the evacuation the gas pendulum procedure is applied. With these measures potential emissions are reduced to a minimum amount.

The solvents are stored in tanks and are pumped via pipings in closed systems directly to the preparation vessels for the dispersions.

The processing of the dispersions after preparation – pre-mixing, grinding, filtering – is also effected in closed systems. Limited emissions of solvents occur during dispersion when the tube filters are changed. In order to keep the solvent losses as small as possible the tube filters are evacuated before the change. Additionally in the case of most of the filters that are contaminated with dispersion or lacquer solutions the solvent in the vacuum is sucked off and condensed for recycling. The used tube filters cannot be recycled; they are disposed off.

All pumps are equipped with double working floating ring seals. The air that is displaced out of the tanks during filling procedures is directly supplied to the adsorption plant. For explosion protection reasons all tanks are under pressure of 25 mbar of nitrogen. Suction plants close to the soil and objects ascertain that worker's protection rules are obtained.

b) Coating plants with air driers

After the coating process the share of solvents from the dispersion (50% to 80%) and the from the back side coating (approx. 90%) are evaporated in the downstream driers with hot air. The loaded air is transported via pipings to the adsorption system with activated carbon. Here the solvent in the drier exhaust gas (solvent content 10-30 g/m^3) is adsorbed to the activated carbon. The cleaned air is released to the environment. Such adsorption systems achieve emission values below 50 mg C/Nm^3. The filled adsorbers are desorbed with water vapour or nitrogen. The desorbed solvent is condensed in a first step before further distillation. After desorption with steam the solvent must be separated from the water in a subsequent several step procedure.

The coating machines are operated with a small partial vacuum. Thus solvents are not emitted from the driers except during maintenance work. For occupational health and safety reasons the driers are operated with the room exhaust air from the coating boxes as input air for the driers.

c) Coating plants with inert gas driers

In such systems the solvent proportion of the dispersions is evaporated in the driers with hot inert gas and supplied via pipings to a condensation plant. Here in a multi step procedure the temperature of the gas mixture is lowered until the solvent is almost completely condensed. The cleaned inert gas is re-heated and re-supplied to the drier. The small share of remaining in the condensed solvent is removed by means of molecular filters.

A small quantity of surplus inert gas still contains organic solvents is supplied to the inert gas production system. Also this method for solvent recovering allows to achieve emission values below 50 mg C/Nm^3.

d) Solvent reprocessing

For the reprocessing of solvents recovered by activated carbon adsorption significantly higher investment costs are required compared to the reprocessing by condensation. The recovering rate for the solvents is in both procedures above 99%. Reprocessing via distillation after adsorption results in almost water free organic solvents (approx. 0,01%) whereas in molecular filtering system after a condensation residual water contents are about 0,3%.

Reprocessing of organic solvents via distillation is carried out in 3 steps

step 1: Azeotropic distillation leading to solvents with about 15% of water content (the desorbed solvents contain about 50% water)

step 2: Extraction with soda lye

step 3: Residual water separation

From reprocessing rests used soda lye. The soda lye is used in circuits. However it has to be replaced from time to time. This waste-lye is treated externally.

7.3. Current consumption and emission values

The total balance of a coating unit shows the following input-output-scheme for the product with the largest production volume. The values are based on a standardized volume of 100 mio m²/a:

Input		Output	
Raw materials			
Magnetic pigments	360 t	Product	100 Mio.m^2/a
Binding agents	80 t	Waste for further treatment	
Supporting pigments			
Aluminium oxide	6 t		
Organic solvents			
Cyclic ethers	1.100 t/a	Recovered solvent	1.099 t/a
		Emissions	1,2 t/a
Process materials			
Cross-linking agents	36 t		
Lubricants	4 t		
Energy			
Electric current	8.000 MWh/a	Waste water	10.000 t/a
Steam	10.000 t/a		
Cooling water	440.000 m³/a		

Table7-2 Total Balance – plant for the production of magnetic tape

Important waste types and their further treatment

Waste type	Amount [t/a]	Treatment
Waste from tapes	150	Thermal recycling
Used filters	34	Thermal recycling
Soda lye	14	Material recycling

Table 7-3 Waste treatment – plant for the production of magnetic tape

Important emissions from production processes:

Emissions	Freight [kg/a]	Concentration in exhaust gas [mg/m^3]
Cyclic ethers	1.200	20

Table 7-4 Important emissions – plant for the production of magnetic tape

7.4. Determination of BAT-candidates

The following techniques or measures can be considered as BAT-candidates:

7.4.1. Emissions to air

At the present state of knowledge for exhaust gas purification in magnetic tape manufacturing only two processes have to be considered. This is due to economic and ecological reasons. The two processes are activated carbon adsorption and condensation. Only with these procedures allow on the one hand to achieve legally established emission limit values and on the other hand high recovery quota (which is economically very important). All procedure where the used solvents cannot be reused within the production processes are for economical reasons not relevant. Thus only the share of organic solvents that cannot be recovered due to the process engineering conditions is emitted. Alternative procedures to adsorption to active carbon and water vapour desorption are not important due to the high energy consumption.

7.4.2. Emissions to water

Water in the magnetic tape production is mostly needed for cooling. The repeated use of cooling water allows a better efficiency with respect to water resources. In order to avoid emissions into the cooling water system the water pressure is kept higher than the product pressure.

When recovering solvents with adsorption and following distillation the water-ether-mixture has to be separated quantitatively as far as possible through distillation. The wastewater, which does not contain organic solvents is released in batches by means of a process gas chromatograph.

From the process materials a small quantity of fatty acids is emitted via process wastewater. These emissions are degraded in a biological sewage plant.

7.4.3. Waste

The largest amount of waste is tape that can not be sold, the so-called “edge-tapes“. For coating PET-foils with 664mm width are used. The coating width is 654mm. In the cutting unit the foil is cut into 51 tapes with a width of 1/2“. Thus 2 tapes at the edges result that are only partly coated. These tapes cannot be sold and have to be disposed (as well as not usable material due to coating errors).

Further waste materials are plastic filters and cleaning rags that are soaked with dispersion. These materials are be combusted because a recycling is not possible.

7.4.4. Energy

The manufacturing of magnetic tape requires energy in the form of electric current, steam and cooling water for the described process steps. Commonly the electrical energy is supplied from the public network and is brought via transformers to the process machines in the required voltage level.

The production of steam takes place near the manufacturing location in order to avoid losses during long transport. Due to gas combustion for steam production the emissions are max. 40 mg/m^3 Carbon monoxide and 200 mg/m^3 nitrogen oxides. The total emission is thus approx. 1.200 kg/a Carbon monoxide or 15.000 kg/a nitrogen oxides. In order to reduce the energy input the flue gases pass a heat exchanger to pre-heat the air for the burner.

Usually the cooling water is pumped out of wells and supplied to the process plant and afterwards it is led into the surface water. In order to avoid pollution of the water, measurements of temperature, pH-value, conductibility and content of organic materials are required. A variable share of cooling water is re-used in circuits. Thus an optimised efficiency of the cooling waster can be achieved and the maximum temperature before releasing can be controlled. Furthermore it is possible to take or add or use energy from the cooling water by heat pumps or cooling machines in order to provide warm or cold water. To avoid that substances from processing enter the cooling water there is no connection between cooling water system and product lines and furthermore the pressure in the cooling water system is always higher than the pressure in the product lines.

7.4.5. Risk

In the production of magnetic tapes large amounts of high inflammable solvents are used. Therefore extensive fire protection measures are necessary.

All process components where solvents are used have to be protected according to the explosion protection guidelines. There are special requirements for electrical equipment and measures for discharge of electrostatic charge. If this is technically not possible a development of atmosphere, which is likely to explode, has to be avoided by inerting. Nitrogen is used for that purpose.

Because of the fast spreading of organic solvent fires an early warning and fire fighting system is necessary to avoid larger damage to humans and machines. Fire warning systems are in use and a working alarm centre operates 24 hours per day and all necessary information is processed.

7.5. Selection and recommendation of best available techniques

Table 7-5 shows a rough evaluation of the BAT-candidates. The symbols "↓" and "↑" stand for decreasing and increasing environmental pollution respectively. "ok" expresses that a technique is „available“ in the sense of the IPPC-Directive.

Technique	A	W	WA	E	R	noise	risk	cost/ benefit
Solvent recovery (condensation or adsorption)	↓				↓			ok
Closed systems in dispersion (gas pendulum system)	↓				↓		↓	ok
Re-use of cooling water			↓			↓		ok
Heat recovery in steam production				↓				ok
Inertisation of tanks that contain organic solvents							↓	ok
Fire warning systems							↓	ok
Noise reduction cabins for all ventilators						↓		ok

A = Air, W = Waste, WA = Water, E = Energy, R = Resources

Table 7-5 Evaluation of BAT-candidates – production of magnetic tape

Only a small amount of enterprises within the EU are manufacturing magnetic tapes.

In Germany there is only one producer which uses techniques that are appropriate to avoid emissions to air to a very large degree. As a consequence the plant concerned is not relevant in the sense of the IPPC directive as the consumption of organic solvents is by far below the corresponding threshold amount.

In the sense of the prevention and reduction of environmental pollution it would be recommendable to investigate whether other EU productions sites are relevant in the sense of the IPPC directive. If so it would be recommendable to consider the BAT-candidates for the establishment of corresponding BAT documents.

It can be assumed that the world-wide most important producers from Asia show much higher emissions. Such differences might be subject to international contacts.

7.6. New advanced processes

Possible and to a small extent available are solvent free procedures for the manufacturing of magnetic tapes:

a) Ferrous magnetic layers on carrier foils can be manufactured by means of vacuum evaporation or sputtering techniques. Both procedures do not require any use of organic solvents and there are no corresponding emissions. The disadvantages of both procedures are the high energy demand and low yield concerning the applied metals and also the low tape yields. The prices for such tapes are much higher than for conventional tapes. Therefore they cannot compete on the market for standard products.

b) The use of dispersions with water as solvent was tried in experiments between 1979 and 1990. Theoretically a use of the common magnetic pigments (Chrome dioxide, iron oxide, Cobalt-doped iron oxide) is possible with water as solvent. The binding agents would have to be adapted. The problems start when the water has to be evaporated in the driers instead of organic solvents. The energy input would increase because of the much higher evaporation enthalpy of water. Common driers are not sufficient. The machines would have to be changed. For new magnetic tape applications only pure iron pigments are in use. These pigments would spontaneously corrode when using water as solvent and therefore would be unusable. In the near future water as solvent seems for these reasons not to be a realistic alternative to organic solvents.

8. Coating of paper

8.1. General information

The field of paper coating is very heterogeneous. There is a differentiation between “coating through printing” and “other coating processes”. The part of printing is not described in this section; it is treated within another part of the study. This section deals with the other coating processes including the soaking or impregnation of papers.

Areas of application

„Other coating“ of papers is used for example for:

- Use as packing material (coating e.g. with paraffin)
- Photochemical use (coating with photoactive substances)
- Use as isolation material (coating with insulating materials)
- Use as filter material (coating with filter materials)
- Use as abrasive paper (coating with abrasive grain; see chapter 3)
- Use for sticking purposes (coating with glue; see report DFIU)

Coated, soaked and impregnated papers are produced directly in the paper production („in-line“) as well as in a separate process („off-line“).

The general production processes for manufacturing of paper and cardboard operate mostly with use of aqueous process materials. If organic solvents are in use at the primary production or “in-line” the corresponding processes are not described here. These processes are part of the BAT-document „Pulp and Paper“ because plants for the production of paper and cardboard, with more than 20 t per day production capacity are IPPC-relevant plants in the sense of annex I point 6.1 letter b) of the IPPC-directive.

Production and sales

According to figures of the Federal Statistical Office the production of coated, covered, soaked, tarred, bituminised, asphalted, gummed or with glue layer coated papers and cardboards (Güterklasseabteilungen 2112 56 and 57) and parchment and artificial parchment (Güterklasseabteilungen 2112 40 100 and 300) was in 1999 altogether 563.000 t, which means a weight-related proportion of around 3 percent of the entire paper production in Germany. The annual production of impregnated paper in Germany is approximately 150.000 t [Lit. 10]. About 80 companies in Germany produce this amount.

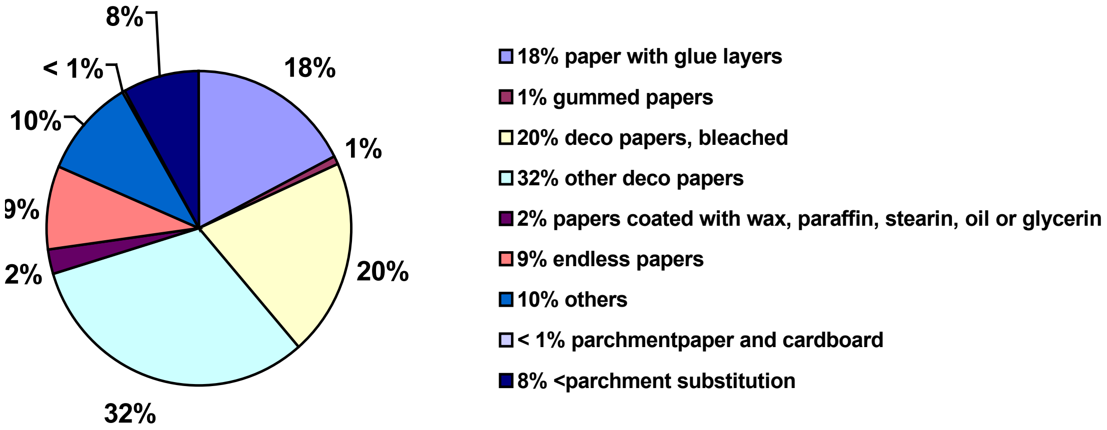

Figure 8-1 Weight-related meaning of Special papers in Germany in 1999 (Source: Federal Statistical Office)

Technical and special papers are on the average twice expensive than graphical papers. Therefore their economic importance is much higher compared to their weight share in production volumes.

Characterisation of the product paper and quality requirements

The term „special papers“ means coated papers with special properties. This group consists of a large number of different kinds of papers. Therefore it is difficult to characterise this group. Special properties are for example:

- Aroma-impermeability
- Gas-impermeability
- Odourless and tasteless

- Chemical resistance
- Resistance against bacteria and mould fungus
- Heat sealing
- Corrosion prevention
- Protection against certain light wave lengths
- Barrier properties against water vapours
- Hygrostability and water proof property
- Hydrophobic property
- Separation properties
- Low temperature stability and heat proof property
- Electrical insulation
- Photochemical properties
- Resistance against humidity and air pressure

To fulfil the manifold requirements for coated, impregnated and soaked papers and cardboards the recipes for the corresponding coating-, impregnation- and soaking materials are very different. Therefore it is not possible to define characteristic values for components.

8.2. Used processes and techniques

The term „coating“ means in praxis often also „soaking“ and „impregnating“ and therefore all three techniques are mentioned in this chapter.

Coating in its real sense means a one or both side application of liquid or gaseous substances on the paper surface without use of a bonding agent. The objective of coating is to change the properties of the paper. The film of coating material should be as thin as possible and only infiltrate the paper structure to a limited extent. The characteristic of the carrier paper should not be changed.

Coating materials for papers may be gases or vapours (e.g. for metallizing with aluminium; solvent free), solutions (e.g. silicon solutions for silicon coating; partly with organic solvents), dispersions (e.g. coating with aqueous pigment dispersions; partly with a small content of organic solvents) or melting (e.g. for polyethylene coating of photographic papers; solvent free). Due to ecological reasons coating materials with organic compounds are more and more replaced through aqueous systems (e.g. emulsions polymers for the coating with latex, solvent free).

Contrary to coating of paper in its real sense – where the coating material is applied only on the surface as a coherent layer – the impregnation and soaking material distributes evenly in the entire paper structure and fills the pore volume partly or full. A distinct separation between impregnation and coating is difficult. Certain materials are used for both techniques. Between „impregnation“ and „soaking“ of paper there is no principal difference. The term „sizing“ as it is used in the paper industry can be seen as impregnation. The used materials are named sizing or varnish for impregnation.

The impregnation changes certain physical and chemical properties of the paper (as described above). According to the required properties there is a large variation of impregnation materials. In use are different natural and synthetic supplying materials like mineral oil products (e.g. paraffin or bitumen melting), synthetic dispersions, resin dispersions (for the paper sizing), mixtures of synthetic resins and polymer dispersions (e.g. as pre-impregnation for furniture), hydrocarbon derivates or other chemicals (e.g. sulphuric acid → real parchment, zinc chloride → vulcan fibre), partly with insecticide, fungicide or bactericide effect.

8.2.1. Process overview

The following processes are carried out for coating papers:

- Supplying of paper as raw material via rolls to the application unit
- Application of coating materials by means of
  - Bathes
  - Rolls
  - Spraying units
  - Extruders
  - Gravure printing units
- drying, rolling up and if necessary cutting and assembling

The following figure gives an overview of the important process steps for the coating of paper.

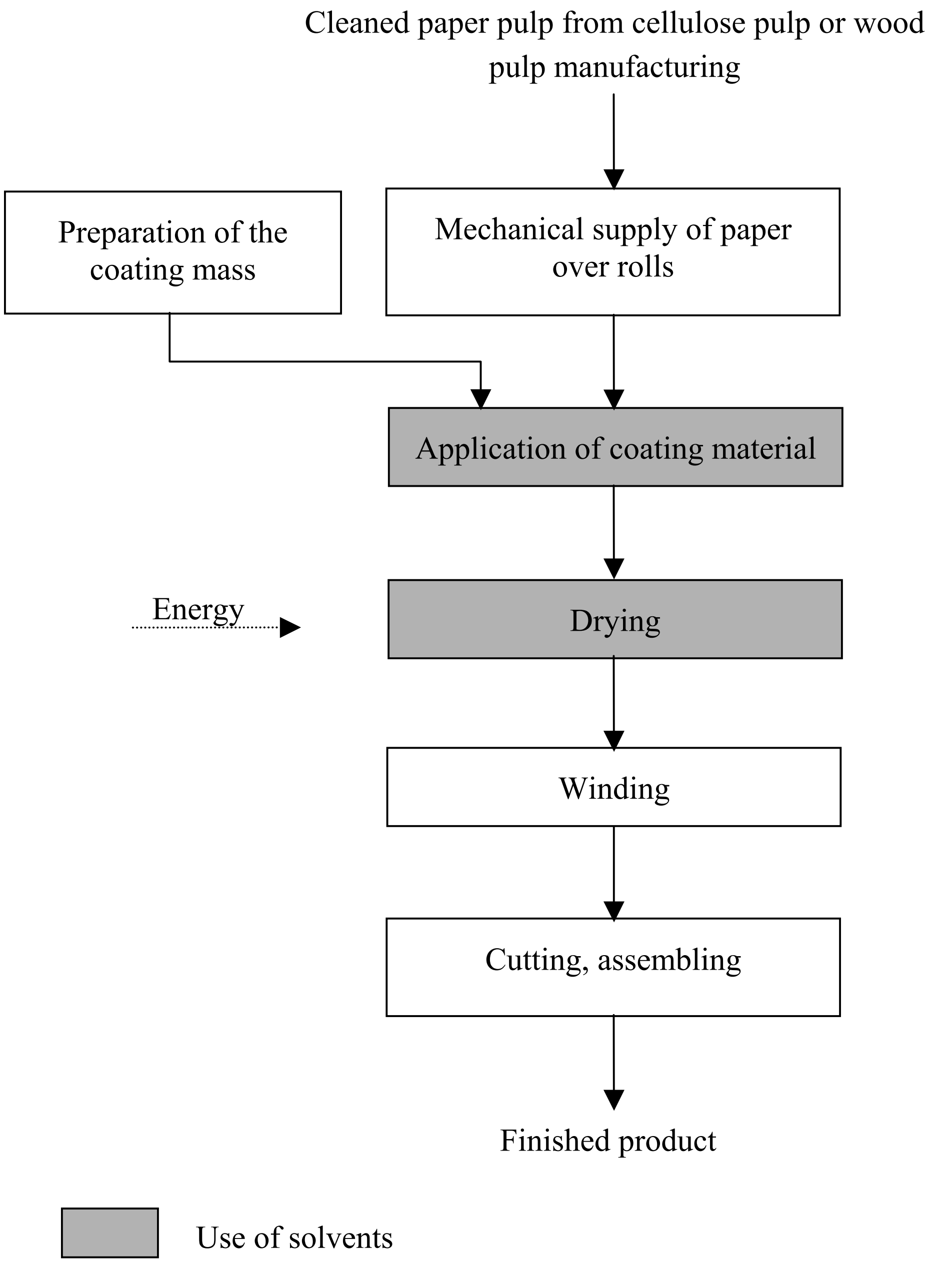

Figure 8-2 Process flow - paper coating

8.2.2. Detailed process steps

Coating of paper with synthetics and silicon

In this procedure the paper webs (also foils or fleeces) are coated on both sides with a polyolefin layer and afterwards with a silicon layer solved in white spirit. These papers are mostly used as separation papers for adhesive labels.

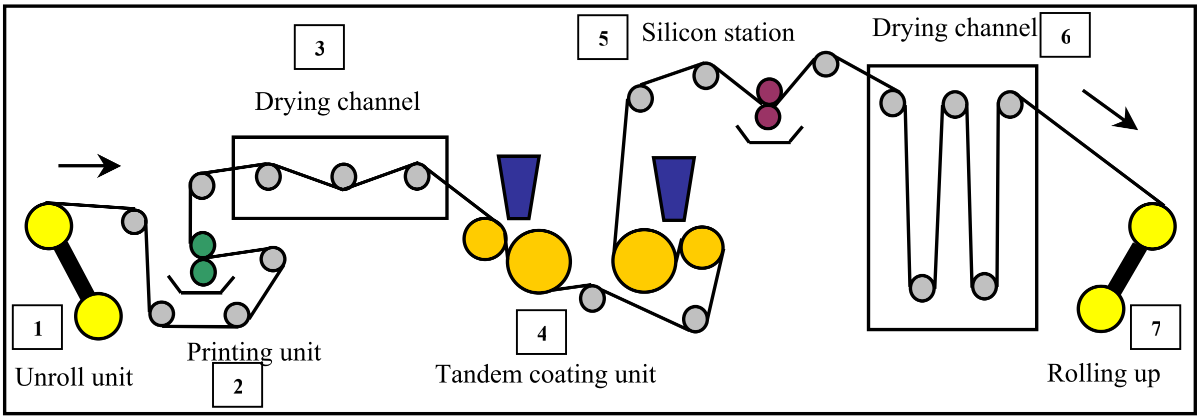

Figure 8-3 Process flow plastics and silicon coating

The most important process steps are shortly described below:

1: The raw material roll is hanged on the unroll unit and uncoiled.

2: In the gravure printing the paper is printed with the required labels. In use are only water-soluble colours.

3: The water is evaporated and dried in the drying channel.

4: In the tandem coating unit both sides of the paper are coated with polyolefin (PE/PP) through a slit die extrusion.

5: The complete silicon application is made by a grid roll application unit (gravure printing like procedure). All used silicones are diluted with solvents (solvent relevant process step).

6: The silicon is cured in the drying channel. The solvent containing exhaust gas is sucked off and cleaned (thermal post-combustion or adsorption unit; solvent relevant process step).

7: The finished product is rolled up and packed.

Paper impregnation

Paper impregnation is a common procedure for manufacturing air-, fuel- and oil filters, indoor air filters for utility vehicles and dust bags for vacuum cleaners.

For the impregnation commonly synthetic resins (phenolic or epoxy resins) dissolved in methanol are used.

The following figure shows the most important process steps:

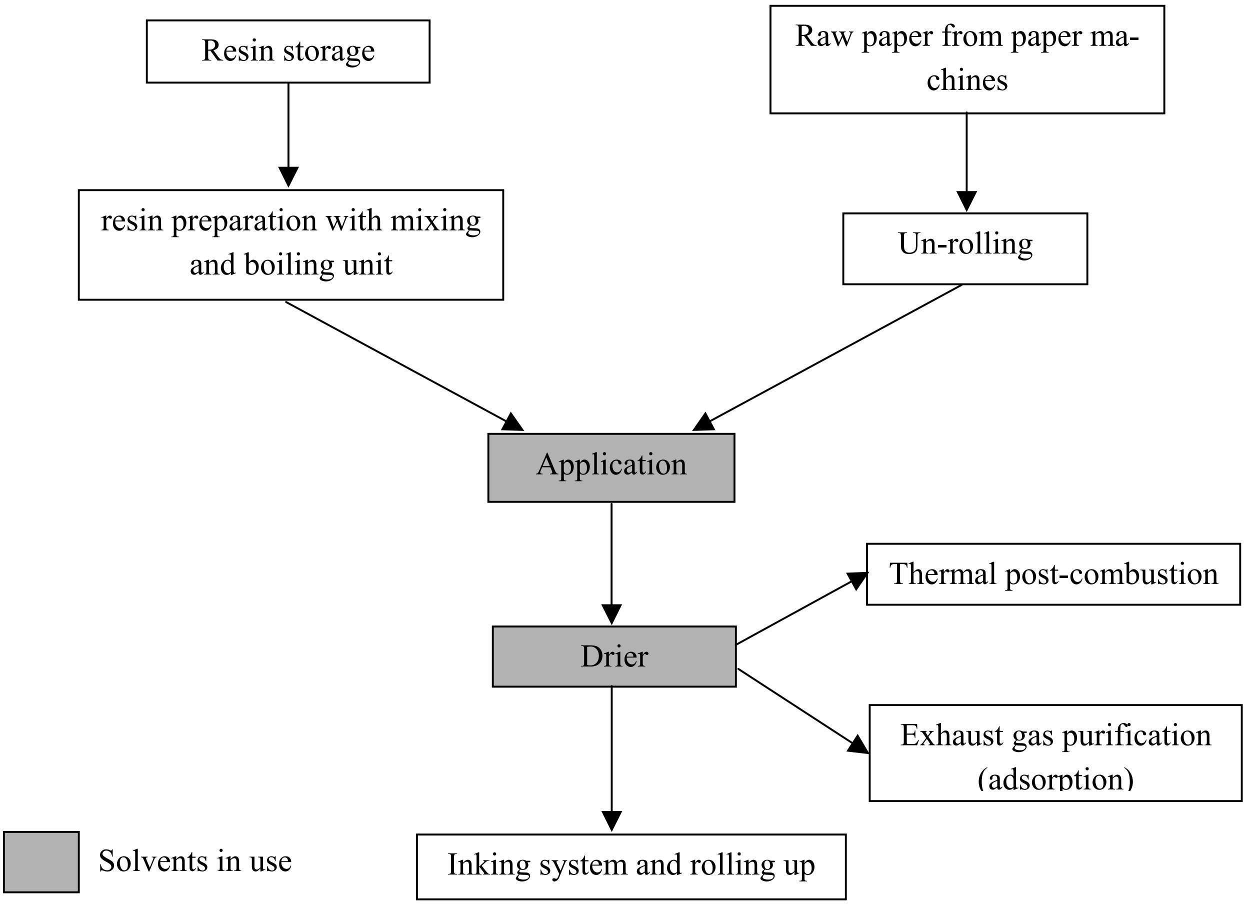

Figure 8-4 Process flow paper impregnation

In the applying unit the raw paper is impregnated with an artificial resin mixture and afterwards it is dried in the drying channel to cure the coating. A suction plant supplies the solvent containing air flows to an exhaust air purification plant (adsorption) or a thermal post combustion.

The exhaust gas treatment unit consists of a scrubber through which the methanol containing exhaust gas flows and a distillation column for the recovering of methanol.

A partial vacuum in the whole impregnation plant assures that all exhaust gas is supplied to the abatement units.

Solvent relevance

Typically the following organic solvents are in use:

- Ethyl acetate
- Isopropanol
- Ethanol
- Methanol
- White spirit
- Toluol, Xylene
- Methyl ether ketone

8.2.3. Equipment components and necessary system differentiation

The described processes are implemented typically by a system with the following components:

- Storage for raw materials
- Preparation unit / mixer for coating material
- Un- and up roll units
- Coating plant / applying unit (extruder; gravure printing unit; grid roll application unit)
- Drier
- Suction plant
- Solvent recovery unit
- Exhaust gas purification
- Assembling and cutting unit
- Storage for finished products

8.3. Current consumption and emission values

Plant 1 (coating of paper with synthetics and silicone)

Plant 1 is a plant for coating of paper with synthetics and silicone. The paper in use is bought from extern producers. The plant is equipped with a thermal post-combustion with energy recovery. The lost heat is used to produce saturated steam and is provided to the steam supplying system for heating the drying units and the halls.

Total balance plant 1

Input		Output	
Raw materials			
Paper	12.000 t	Finished material / End product	15.500 t
Synthetics (PE / PP)	5.000 t		
Silicon (usually supplied solvent diluted; different solid contents not considered)	200 t		
White spirit	1.000 t		
Printing ink / Lacquer	300 t		
Process materials	450 t		
Waste			
		Waste of composite materials	2.200 t
		Plastic waste (recycling possible)	500 t
		Paper waste (recycling possible)	100 t
		Hazardous waste	50 t

Energy			
Electric current	10.000 MWh		
Gas	9.500 MWh		
Steam*	16.000 MWh		
		Steam (heat recovery – thermal post-combustion) **	6.500 MWh
		Total C in collected emissions	2.600 kg/a [+]
		Nitrogen oxide NO_x	30.300 kg/a [++]
		Carbon monoxide CO	20.500 kg/a [+++]

* Total amount of steam needed for the heating of the drying channels and the production halls

** Share of steam that is supplied from the heat recovery to the steam supplying system: Since November 2000 the heat recovering produces the whole amount of required vapour.

[+] corresponds to 0,53 kg/h total-C

[++] corresponds to 6,31 kg/h nitrogen oxide

[+++] corresponds to 4,28 kg/h carbon monoxide

Table 8-1 Total balance plant 1 – coating of paper with synthetics and silicone

Important emissions from the production process:

Emissions	Freight [kg/a]	Concentration [mg/m^3]
Total C in collected emissions	2.600	5
Nitrogen oxide NO_x	30.300	60
Carbon monoxide CO	20.500	40

Table 8-2 Important emissions plant 1

Important waste amounts and waste treatment

Waste type	Amount [t/a]	Treatment
Waste of composite materials	2.200 t	secondary combustion (cement industry)
Plastic waste (recycling possible)	500 t	Recycling (Re-granulation) in the plastic industry
Paper waste (recycling possible)	100 t	Recycling in the paper industry
Hazardous waste	50 t	Combustion

Table8-3 Waste and waste treatment plant 1

Plant 2 (impregnation of paper)

Plant 2 is a plant for the impregnation of paper. The manufactured paper is usually produced in the same factory. The paper impregnation is an off-line process. The impregnation plant consists of two impregnation units for paper (paper width 1.580 mm, speed 100 m/s). The plant has a solvent recovering as well as a thermal post-combustion of exhaust gas.

Total balance Plant 2

Input (2000)		Output	
Raw materials			
Raw paper	13.715,7 t	Impregnated paper	17.329,9 t
Solvents			
Methanol	9.030 t	Methanol from recovery	8.833 t
		Diffuse emissions	see "*" **Table8-5**
		Total C in collected emissions	6.825 kg/a max. 45 mg/m3 + 2169 kg/a from thermal post-combustion
		NO_x	NO_2 9550 kg/a max. 60 mg/m3
Process materials			
Epoxy resin	658 t	Hazardous waste	
Phenolic resin	1.658 t	Resin residues	32 t
Flame protection materials on nitrogen-phosphor basis	370 t	Regeneration methanol	14 t
		Rest of paper colour	40 t
		Activated carbon ABR	0,2 t
Energy (2001)			
Thermal post-combustion	9.516.672 kwh		
Impregnation unit			

Table8-4 Total balance plant 2 – impregnation of paper

Important emissions from the production processes

Emissions	Freight [kg/a]	Concentration [mg/m^3]
Phenol *	2.321	4,9
Methanol *	8.054	23,6
Formaldehyde *	3.891	11,4
Diethyl amine *	3	0,01
Total C	6.825	20
Total C thermal post-combustion	2.169	13,63

* see Table8-4

Table8-5 Important emissions plant 2 – impregnation of paper

Important amounts of waste and waste treatment/recycling

Other waste	Amount [t/a]	Waste treatment/recycling
Impregnated paper waste	2.300 t	Energetic utilization

Methanol recovery by means of exhaust gas purification in 2000

Methanol recovery by means of distillation column	8.833 t
Internal use	8.644 t
External sell	189 t

Table8-6 Important amounts of waste and waste treatment/recycling plant 2 – impregnation of paper

8.4. Determination of BAT-candidates

8.4.1. Emissions to air

By means of suitable purification techniques for exhaust gas with solvent content (thermal post-combustion with heat recovery) the emissions are below legal limit values.

Basically also a solvent recovery unit can be considered as BAT-candidate having in mind the reduction of resource consumption. However it has to be taken into account that a solvent recovery is not available under economic acceptable conditions for the process of silicone coating of paper. As a consequence this technique is not generally appropriate as BAT-candidate.

8.4.2. Emissions to water

Water emissions are not important with respect to coating and impregnation of paper.

8.4.3. Waste

The selection of raw materials and a consequent separation of the residues during processing allows an appropriate and recycling of important waste flows. Due to the heterogenity of the processes no specific BAT-candidates can be defined.

8.4.4. Energy

The lost heat that is generated during combustion is used for the production of saturated steam (BAT-candidate: heat recovery systems). The steam is provided to the steam supplying system for heating the drying units and the halls.

8.4.5. Risk

BAT-candidates are

- Suitable fire protection measures are necessary. (e.g. CO2 for fire fighting, Ex-protection)
- Retention facilities for water from fire fighting

8.5. Selection and recommendation of best available techniques

Table 6-6 shows a rough evaluation of the BAT-candidates. The symbols “↓“ and “↑“ stand for decreasing and increasing environmental pollution respectively. Numbers in brackets ”(1)“ indicate the need for further differentiation which is given in a corresponding comment below the table. "ok" expresses that a technique is „available“ in the sense of the IPPC-Directive.

Technique	A	W	WA	E	R	noise	risk	cost/ benefit
thermal post-combustion with heat recovery	↓							ok
organic solvent recovery unit (not generally applicable)	↓				↓			ok
heat recovery systems				↓	↓			ok
fire protection measures							↓	ok
retention facilities for water from fire fighting							↓	ok

A = Air, W = Waste, WA = Water, E = Energy, R = Resources

Table 8-7 Evaluation of BAT-candidates – paper coating

Having in mind the heterogenity of the various paper coating procedures and the limited amount of enterprises that exceed the threshold amount as specified in the IPPC-directive it should be discussed weather it would be appropriate to establish a particular BAT document for paper coating.

If the negotiations during the Seville process require the establishment of BATs for paper coating in a BAT-document the use of a post-combustion unit and of heat recovery systems would be recommendable. As BAT for specific applications the use of a solvent recovery plant may be taken into consideration.

8.6. New advanced procedures

Due to the small number of enterprises and the heterogenety of the various paper coatings there is no appropriate information available.

Directory of figures

Directory of tables

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