Lund University International Master's Programme in Environmental Science (LUMES)

Energy Use and Energy Management in Tyre Manufacturing: the Trelleborg 1 Case

Master's thesis

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Chapter 1

INTRODUCTION

1.1 Background

The conservation of energy is an essential step we can all take towards overcoming the mounting problems of the world-wide energy crisis, and is a necessary contribution to the sustainability transition *(30).*

The rubber industry has a history of more than a hundred and ten years, and it has especially grown remarkably fast in its last half. At the same time, the energy consumption has increased rapidly with its growth *(30).* Reducing energy use will not only lower the costs, it will improve competitiveness and increase profits. At the same time if the rubber processing industry embraces this policy of reducing energy demand, it will make a contribution towards lowering the emissions of carbon dioxide. Reducing energy does more than save money, it reduces a company's effect on the environment by consuming fewer finite resources and reducing the generation of harmful greenhouse gases *(8).*

Demonstrating good environmental credentials will not only be increasingly required by law in the future, but will have a beneficial effect on a company's public image and on customers *(8).*

In this context, an industrial rubber company is chosen to investigate the existing energy flows and management of energy so as to suggest ways of improving energy performance in the tyre manufacturing processes. Suggestions will be made for reducing the energy losses related to the generation of scrap, waste and rework in the tyre manufacturing processes and improving the energy management in the company.

1.2 The Trelleborg 1 company

Trelleborg Wheel Systems develops, manufactures and markets complete wheel systems for forest and farm machines, trucks and other material-handling equipment.

The business area consists of four business units:

- **Forest & Farm Tyres** and **Agricultural Radial Tyres** develop, manufacture and market a wide range of tyres and wheels for forest and farm machines.
- **Industrial Tyres** develops, manufactures and markets solid and pneumatic industrial tyre systems for forklift trucks and other material-handling equipment.
- **Technical Materials** develops and manufactures polymer compounds, among other products *(27).*

Production plants are located in Belgium, Denmark, the Netherlands, Sri Lanka, Sweden and the US *(27).*

In the home city of Trelleborg in Sweden, the factory named Trelleborg 1 manufactures TWIN tyres for agricultural, forestry, grassland and industrial uses along with the tyres for light transportation, and special tyres for motorcycles *(28)*. The plant has a total of 900 employees (excluding management group) and sales of 670 MSEK (1999). Along with the production of different tyres, hoses, carpets and linings, etc., are also manufactured in this company *(32)*.

Energy within the factory is used for heating, ventilation, cooling, processes and transport and it makes up around 6 % of the total factory costs. The total energy consumption of Trelleborg 1 in 1999 (not including transport) amounted to 120,123 MWh, of which electricity accounted for 71,532 MWh and natural gas 48,590 MWh *(22)*. "Although energy is not the largest cost faced by the rubber processors, it is certainly one, which they can bring under control and reduce, through no-cost and low-cost measures" *(8)*.

The two departments for manufacturing tyres in the Trelleborg 1 factory are analysed in this paper: the mixing and compounding department and the tyre manufacturing department. The mixing and compounding department makes the compounds for other products than tyres as well, the compounds for tyres account for 20 % of the total production in this department *(21)*.

1.3 Objective

The objective of this paper is to identify and analyse the present use and management of energy in the tyre manufacturing processes in Trelleborg 1, and to name possible measures to improve the energy performance in the tyre manufacturing processes of the plant.

Additionally, the work analyses the energy costs of the generated scrap, waste product, and rework in the processes of tyre production. This is done while focusing on the major energy using processes in the departments of mixing and compounding, and tyre manufacturing.

1.4 Methodology

First, a literature study to develop a better understanding of rubber production, particularly tyre manufacturing, was undertaken. To complement the theoretical background regarding the manufacturing processes with practical experience, a number of site visits at Trelleborg 1 were conducted. Energy performance and management was investigated by means of telephone and personal interviews with industry leaders and employees, and more site visits followed along with desktop research (university and industry libraries, internet sources).

After examining the relevant literature, a multi-disciplinary approach towards energy conservation was utilised. Causal loop diagrams were used in order to better understand the interaction of different parameters within a system. Additionally, calculations along with different figures were developed and performed to justify the proposed suggestions towards better energy performance and energy management in the company.

1.5 Scope and limitations

Trelleborg 1 company has no explicit investigation of the energy consumption of its tyre manufacturing processes. Thus, the scope in first place is allocated to the study of the energy use in the tyre manufacturing processes. In fact, the phase of reading relevant literature and collecting and analysing data from the company revealed a lack of energy consumption monitoring, accounting and management in the company. For that reason the study was narrowed considerably. The analysis was focussed on identification of the major energy using processes and the amount of energy that is lost when generating scrap, waste and rework.

However, in order to successfully implement future energy conservation activities in the company, the introduction of a systematic energy management to the company is of great importance. This issue is as well investigated in this study.

Limitations of this paper are such:

- the sub-departments of heavy and light tyres are assumed to be one sub-department since the major energy source -steam- in these buildings is measured jointly for the two departments.
- the sub-department of hot stretch, where the process of pre-treatment of tyre cords is performed, is excluded from the content of this paper.

1.6 Paper outline

The paper is presented in seven chapters. In the first chapter a brief introduction, background on the plant followed by the objectives of the study is given. The methodology used in the study, scope, and limitations are also presented in this chapter.

Chapter two presents the importance of energy efficiency in the world, the significance for its conservation and explains why energy efficiency projects should be initiated.

Chapter three gives a short description on the manufacturing of tyres, presents the energy use in the whole plant and the tyre manufacturing departments alone. It also identifies the major energy using processes to produce the tyres.

Chapter four analyses the energy costs of generated scrap, waste and rework in the tyre manufacturing departments based on the biggest energy consuming processes. Along with the calculated energy losses, the chapter shows other costs encountered and overlooked in the company when generating scrap, waste and rework in the processes with the help of causal loop diagrams.

Chapter five analyses the existing energy management in the company along with the energy efficiency measures that have been implemented earlier.

Suggestions drawn from chapter four and five towards improving the energy efficiency in the plant are presented in chapter six. This chapter also presents the performance indicators for benchmarking the energy efficiency between tyre manufacturing plants.

In the last chapter of the paper, a general conclusion of the study is given.

Chapter 2
UNDERSTANDING THE IMPORTANCE OF ENERGY CONSERVATION

2.1 The importance of energy efficiency

> "Energy is essential to economic and social development and improved quality of life. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption, and on growing reliance on environmentally sound energy systems, particularly new and renewable sources of energy. All energy sources will need to be used in ways that respect the atmosphere, human health and the environment as a whole" *(31).*

Our world has been shaped by energy. Energy is inseparable from all material phenomena and is an essential condition for the mere existence of life *(7).* One of the main problems of this century has been the provision of sufficient energy. Accordingly, energy concerns and energy policies have been driven by one simple preoccupation: increasing the supply of energy, and have been committed almost exclusively to the energy production sector.

In this process, the appetite for energy often exceeds the capacity of local sources of supply. The energy supplies of some 'modern' countries has to be brought half the way round the globe *(7).* At the same time, there is evidence that the general extracted energy 'output/input ratio'[1] is gradually deteriorating. With oil, for example, a ratio of about 100-1 was obtained in the 1940's. By the 1970's the ratio had fallen to 23-1. The ratio for newly discovered oil reserves is now about 8-1. The average extracted energy ratio, taken across all non-oil energy sources, is about 5-1 today *(5).* Energy security has become one of the major issues all along this century, shaping national policies in foreign affairs, economy, science and technology.

Meanwhile, the sheer intensity of energy production and use began to result increasingly in deleterious impacts on the environment. These strategic and environmental consequences of the pattern of energy consumption were virtually neglected for a long time. More recently, there has been a broad understanding on the fact that energy related human activities account for the most important part of the accumulation of greenhouse gases in the atmosphere *(17).* Based on scientific data and quantitative reports, the international community has focused attention on the threat of climate change and a range of disastrous consequences such as change in rainfall patterns, melting of polar caps, causing flooding and harming air quality. Additionally, changing regional climates could alter forests, crop yields, and water supplies. It could also threaten human health, harm birds and fish, and many types of ecosystems *(13).*

The climate change has been discussed for decades in the scientific community, but only in this last decade of the second millennium, it became officially

[1] The amount of energy available as output from a given input of energy for exploration, extracting and processing is termed the energy output/input ratio.

a major issue on the global agenda. There is now overwhelming evidence that CO_2 emissions from the energy sector account for more than 50 % of the human contribution to the greenhouse effect, which means that reforms in the area of energy will be crucial in the effort to meet the challenge of climate change *(12).*

Apparently, energy is now understood as being related to a new series of conflicts that have arisen between energy on the one hand, human health and the future of the planet on the other. Awareness of these issues, although still partial and imperfect, has become a worldwide fact as we are arriving at the turn of the century. Directly linked to this rising awareness, it becomes clear that energy policy issues should no longer rely exclusively on the responsibility of the energy production and supply sector. It should be enlarged to the level of responsibility of the civil society.

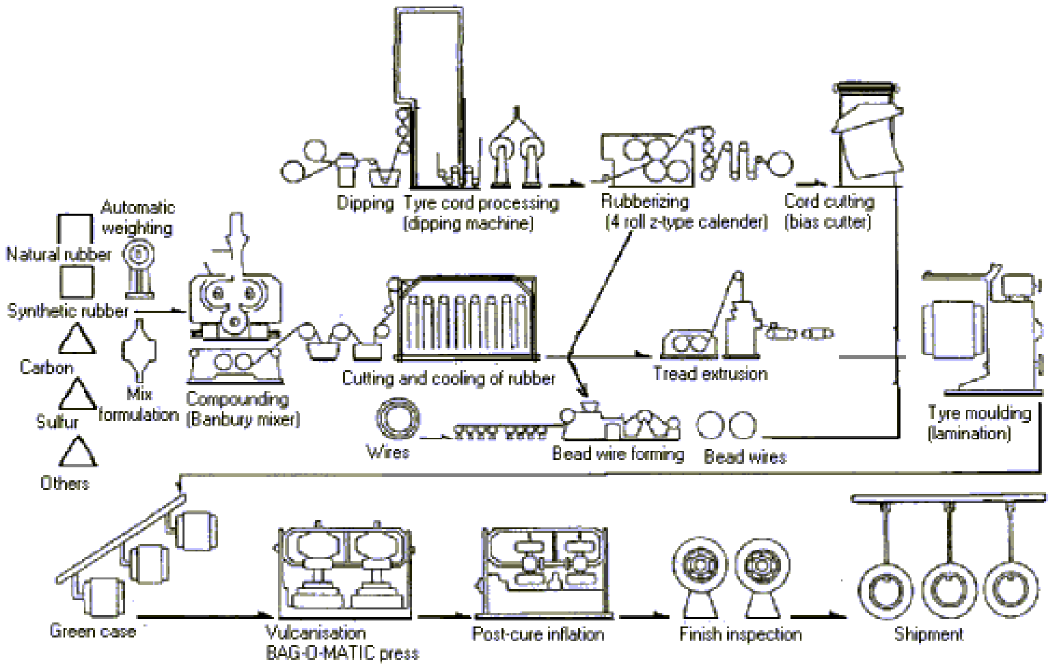
A number of studies of energy and the environment have concluded that environmental degradation can be reduced by switching to cleaner fuels and reducing the energy intensity of economic activity by using best practices and best technology in both energy production and consumption *(33).*

In this context, an industrial rubber company is chosen to investigate the existing energy flows and management of energy so as to suggest ways of improving energy performance in the tyre manufacturing processes.

Chapter 3
ENERGY USE IN THE PLANT AND IDENTIFICATION OF MAJOR ENERGY USING PROCESSES

3.1 Tyre manufacturing processes

In order to understand the production chain for tyre manufacturing I will briefly outline the latter's general processes. The process flow diagram (Figure 1) represents the general tyre manufacturing processes engaged by Trelleborg 1. Figure 1 gives the flow of work ranging from the preparation of intermediate products (members) from various raw materials to the completion of tyres by a combination of those members, along with the outlines of all the equipment used for respective processes. The processes mainly consist of mix formulation, compounding, moulding, vulcanisation, and finishing, accompanied by the processes of manufacturing tyre cords and bead wires. *(See glossary – appendix 3 for the explanation of terms)*



Source: United Nations Industrial Development Organisation (UNIDO), 1998.

Figure 1. Tyre manufacturing process flow diagram

The following paragraphs briefly explain the processes more specifically.

At the Trelleborg 1 factory the raw materials are first made into rubber compounds and glues. The raw materials are fed into a mixing machine according to precise recipes, which are determined by the properties desired for the rubber compound. During mixing the temperature of the mixing machine rises as high as 180 degrees Celsius *(4).*

A single tyre generally requires 10-30 different components. The components are rubberised using closely specified compounds and then built up into a tyre on the drum of a tyre building machine. Then, an operator places the components in position while the control system of the machine runs the assembly process. This produces a 'green tyre' *(4).*

At this stage the green tyres are still soft. They are hardened and made elastic by vulcanisation, that is by curing at the correct temperature and pressure. The hardening is achieved by the vulcanisers in the rubber compound. Vulcanisation is carried out in a curing press, which moulds the tyre to its final form and tread pattern. Light tyres are vulcanised at temperature of 170 degrees Celsius under a pressure of 15 bars for 10-15 minutes. For heavy tyres the vulcanisation times are as long as 5 hours *(4).*

A more detailed description of the processes is found in the appendix 1. The structure and names of the tyre parts is found in the appendix 2.

3.2 Energy system for the plant

To analyse and to capture the energy consumption in Trelleborg 1, energy inputs to the plant and the tyre manufacturing departments must be identified. Figures 2 and 3 illustrate the energy inputs to Trelleborg 1 plant. It is important to account for the total consumption, cost, and how the energy is used for each commodity such as steam, compressed air, and natural gas.

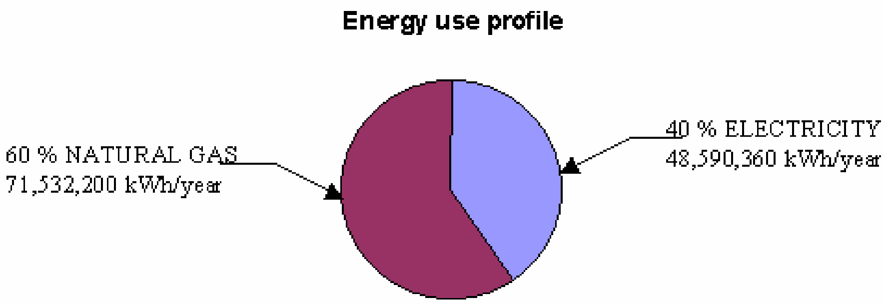


Figure 2. Energy type and its relative percentage use

However, the prices for the purchased energy could not be established, because of the changing prices of oil and the agreements that have been set between both sides: Trelleborg 1 and SYDGAS (Natural gas suppliers), and ELBOLAGET (Electricity suppliers). In 1999, the internal price for the electricity in the plant was 0.23 SEK/kWh, and most of the natural gas is used to produce steam with an internal price of 187 SEK/t or 0.297 SEK/kWh *(22).*

According to the energy accounting data in the plant an approximate figure 3 was developed showing how much energy was used for the functions such as lighting, process, and buildings' heating and ventilation in the year of 1999 *(22).*

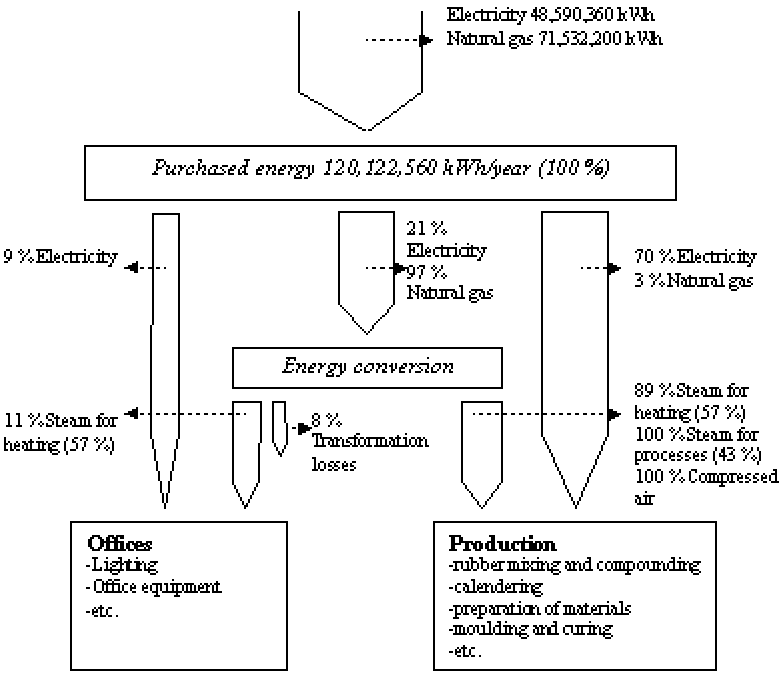


Figure 3. Energy supplies and flows in the plant

The diagram above is divided into three sections: offices, energy conversion and production. In the energy conversion section, 21 % of the electricity and 97 % of the natural gas are used to produce steam and compressed air. Until they reach the stage of useful energy, they have to undergo various "conversion or transformation losses" because the transformation process is not 100 % efficient.

The remaining 70 % of the supplied electricity go to the production units and 9 % is received by offices for lighting, equipment, etc. Only 3 % of the natural gas are used directly in the manufacturing processes.

57 % of the produced steam is used to heat the buildings, of which offices receive 11 % and production areas receive 89 % of the steam for heating. The remaining 43 % of the produced steam are allocated to manufacturing processes. Compressed air is only used for the processes.

The figures above generally explain the use of energy in the Trelleborg 1 plant. Although heating of the buildings is one of major energy consuming components in the plant, it is excluded from the analysis since the paper focuses on the manufacturing processes themselves. The tyre manufacturing in the mixing and compounding and tyre manufacturing departments accounts for 29 % of the total energy consumption in the plant. The following paragraphs and figures show the energy consumption in the tyre manufacturing sector; mixing and compounding department and tyre manufacturing department, and its relative costs for each department based on internal factory price. The figure below helps the reader to understand the production flow for tyres in Trelleborg 1 according to which the paper is followed.

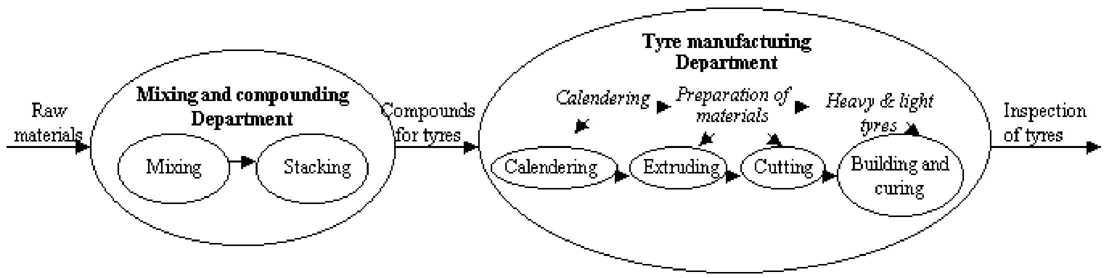
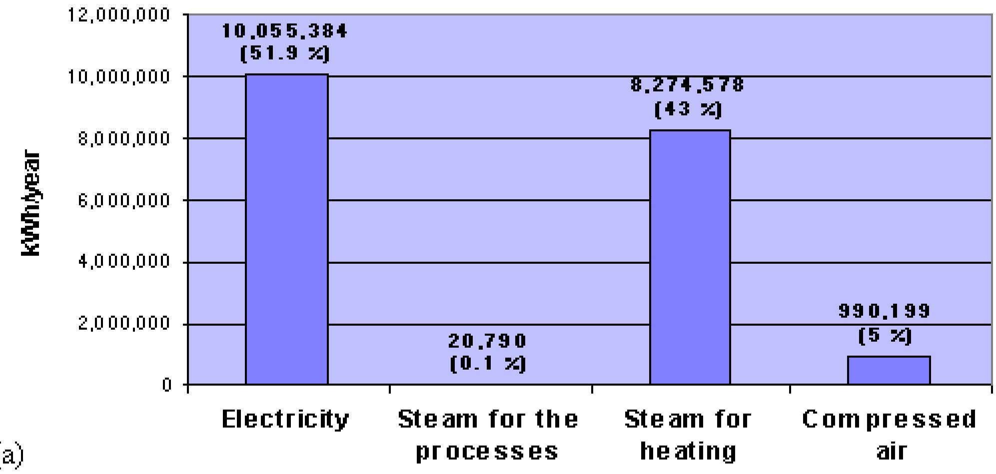


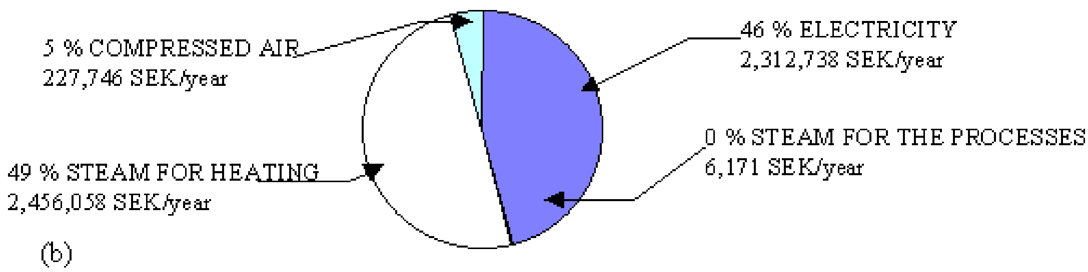
Figure 4. Production flow for tyres in Trelleborg 1 factory (departments and sub-departments) (see glossary – appendix 3 for the terms)

See description of the processes Chapter 3, section 3.1 and appendix 1.

3.3 Energy supply to the mixing and compounding department



(a)



(b)

Figure 5. Energy use (a) and cost profile (b) for the mixing and compounding department (1999) (21).

It can be seen from figure 5 that to run the machinery in the mixing and compounding department electricity is needed the most. Therefore, the consumption of steam and compressed air for the processes is excluded from the analysis and the focus is allocated to electricity consuming machinery. In order to identify the electrical energy consumed just for the production of tyre compounds among other compounds in this department, it is important to list major tyre compounding energy consuming processes and to show their actual use of electricity among the total use of it in the department.

Table 1. Electricity consumption of major consuming processes for the compounds of tyres and its respective use among the total electricity use in the department (April 2000).

Process no.	Machinery	Measured use of electricity kWh/month (April, 2000)	Total use of electricity in the department kWh/month (April, 2000)
1.	Mixer 1 Extruder	465,120 54,080	
2.	Mixer 2 Two mills	126,000 155,360	
Total		**800,560** **40.0 %**	**2,004,020** **100 %**

Source: list of measuring devices and their consumption in the mixing and compounding department for April 2000.

To produce the compounds for tyres, the Trelleborg 1 factory engages a dual stage mixing process, where the masterbatch is mixed in the mixer 1, dropped into the extruder, and cooled on a cooling rack prior to stacking. After aging of the masterbatch, the masterbatch is re-introduced to the mixer 2, where it is re-mixed along with curatives and various other chemicals. It is then transferred to the mills and further proceeds the same way as the masterbatch. (See glossary – appendix 3 for the terms)

As can be seen from table 1, the major processes for producing the compounds for tyres, which account for 20 % in the department among other products, consume 40.0 % of the total electricity in the whole department, at 184,128 SEK/month

The total production of tyres for the same month was 466,000 kg *(16).* Thus, referencing table 1, we can calculate the electricity needed to produce 1 kg of tyre compound per one month based on the major electricity consuming processes:

800,560 kWh/month ÷ 466,000 kg/month = 1.718 kWh/kg

The figure has importance for the energy performance, particularly for the production of tyre compounds and based just on the electricity use of the major consuming processes, when comparing historical consumption data with the current data in the plant, or outside the plant when comparing it with the other tyre producing factories. (Further mentioned in Chapter 6, section 6.3).

Both mixers are used for around 35 years, thus the figure identified could help in the evaluation of past and present energy efficiency of the equipment and induce an action towards improving energy use in this machinery.

3.4 Energy supply to the tyre manufacturing department

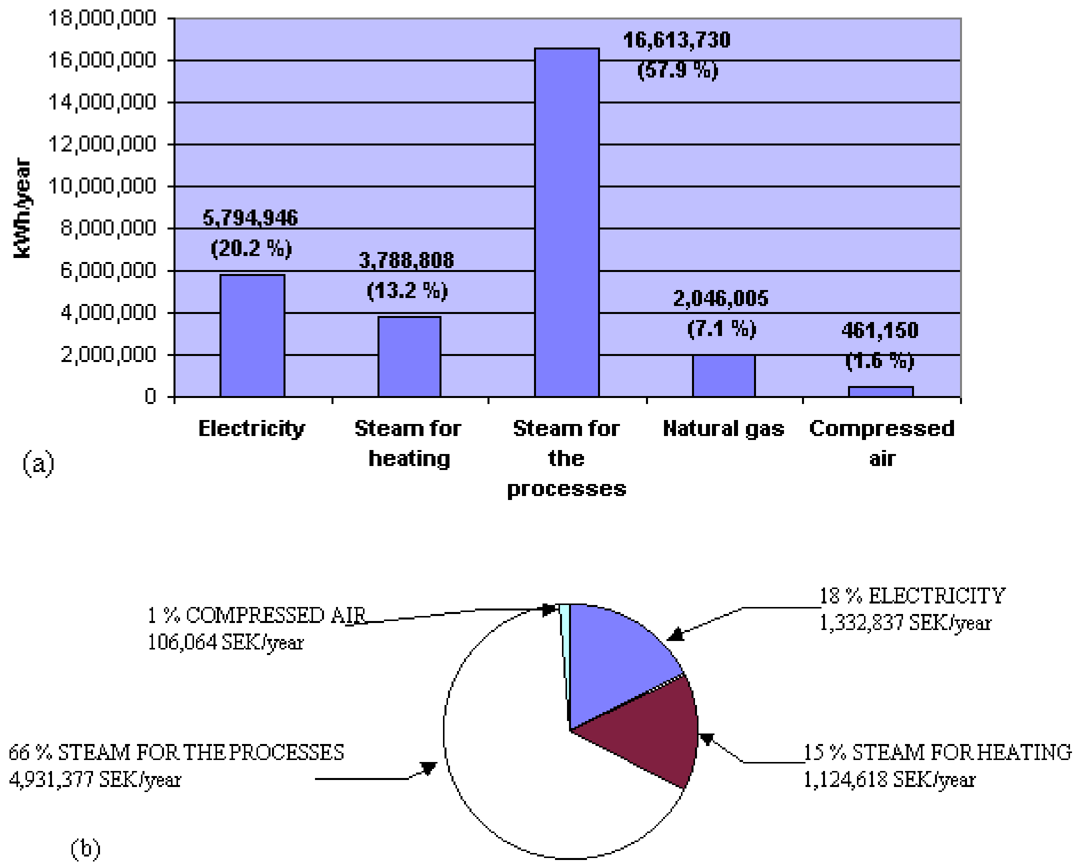


Figure 6. Energy use (a) and cost profile (b) for the tyre manufacturing department (1999). The cost for the natural gas is not included because of the conditions described in Chapter 3, section 3.2. (22)

The department of tyre manufacturing receives the tyre compounds from mixing and compounding department and further processes them till ready made tyres. In this department only tyres are produced.

Figure 6 shows that the major energy source for the processes in the tyre manufacturing department is steam, which is used for the vulcanisation processes. Even though, the consumption of steam is three times bigger than the electricity use in the same department, the quite big use of electrical energy should not be rejected when finding ways to control and reduce the energy consumption. This states that it is important to identify and list the major electricity and steam users in the department and to show their proportion among the total energy of the department.

However, not all the equipment in Trelleborg 1 factory are measured alone, but in lines with one or two other equipment. The table below lists the electricity and steam major using processes in the tyre manufacturing department.

Table 2. Major electricity and steam using processes in the tyre manufacturing department (April, 2000)

Sub-department	**Machinery**	**Measured use of electricity kWh/month (April, 2000)**	**Total use of electricity in sub-departments kWh/month (April, 2000)**
Preparation of materials	2 mills for the extruder 1 Extruder 1	322,700 3,630	
	Total:	326,330 (76.2 %)	428,347 (100 %)
Calendering	Calender 3 mills for the calender	23,300 46,600	69,900
	Total:	69,900 (100 %)	69,900 (100 %)
Sub-department	**Machinery**	**Use of steam kWh/month (April, 2000)**	**Total use of steam in the department kWh/month (April, 2000)**
Light and heavy tyres	33 presses	1,099,980	
	Total:	1,099,980 (100 %)	1,099,980 (100 %)
Total use of electricity and steam by major energy consuming processes (April, 2000)		1,492,210 (93 %)	
Total use of electricity and steam in the department (April, 2000)		1,598,227 (100 %)	

Source: list of measuring devices and their consumption in tyre manufacturing department for April 2000.

From table 2 can be seen that the identified biggest energy using processes consume 93 % of the total electricity and steam used in the department. The remaining 7 % are allocated to other running equipment in the department.

Knowing the output production for the same month we can calculate how much energy was needed to produce 1 kg of tyre in the tyre manufacturing department based on the major energy consuming processes (see table 2): *(20)*

Table 3. Energy needed to produce 1 kg of tyre based on the major energy using processes identified

Sub-department	Output (kg/month)	Energy consumption (kWh/kg)
Preparation of materials	499,309	0.65
Calendering	90,746 (m)	0.77 (kWh/m)
Light (77,417) and Heavy tyres (355,707)	433,124	2.54

Note: the production output of calendering department is measured only in meters, the data showing the amount in kilograms could not be established.

The purpose of identifying the major energy using processes for the manufacture of tyres in both departments is to direct the attention of leaders of departments and energy responsible people towards possible optimisation or other action, which could lead to the reduction of energy consumption in these processes since the machinery of the processes identified consumes large amounts of energy when comparing it with the total energy usage in the departments.

Chapter 4
REVIEW OF GENERATION OF SCRAP, WASTE AND REWORK AND IDENTIFICATION OF ENERGY LOSSES WHEN GENERATING THEM

4.1 Energy losses of scrap, waste and rework

One aspect of energy usage that is often overlooked is the amount of energy that is spent in the generation of scrap and waste product and in the reworking of sub-standard or surplus in-process materials such as compounds, extrudates and calendered materials *(3).*

- Scrap in this paper is identified as the compound, which has certain defects in its structure and can not be used in the tyre manufacturing processes, but can serve as a suitable compound in the manufacturing line of other products, such as hoses, carpets, etc.
- Waste is defined as material, which is not suitable for any further manufacturing processes and has to be disposed off.
- Rework is defined as compound, which has minor defects in its structure, therefore is still suitable for the tyre manufacturing processes, but has to be re-mixed.

In most of the rubber industry, waste and rework is a significant cost penalty and any reductions will not only save energy but also will result in a reduction in material and labour costs.

In many rubber industries there is a belief that, because uncured rubber compounds can be re-worked, there is no wasted cost as they can be added back into some part of the process to rework material rather than to scrap the material. The concept is far from the truth.

The causal loop diagram in figure 7 below explains the traditional view in the rubber industries when generating scrap, waste or rework.

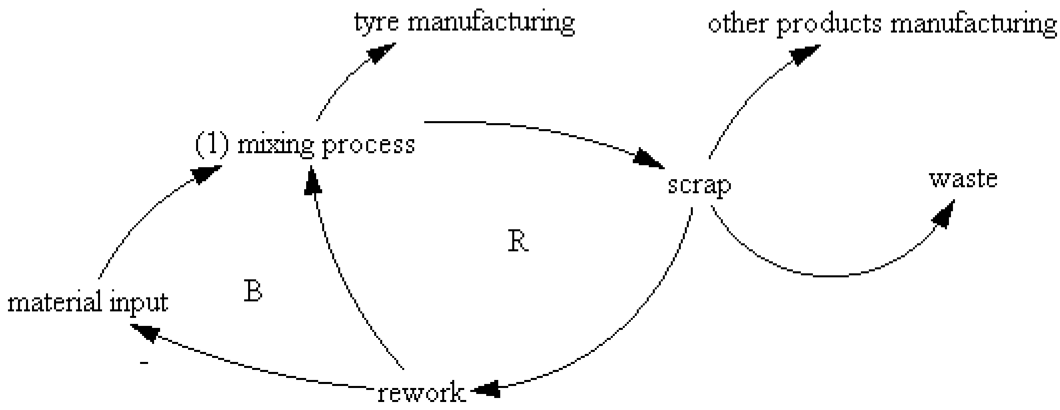


Figure 7. CLD - Traditional view on scrap, wastes or rework

Figure 7 shows that once the compounds for the tyres are mixed, the outputs are the products suitable for further tyre manufacturing. But the output also includes waste, which could be either deposited or sold cheaply, and scrap, which can still be re-mixed for the tyre compounds or transferred to another application but the manufacturing line for tyres. This applies to the mixing and compounding department. The tyre manufacturing department has only waste, for which they pay to another company in order to get rid of it.

However, traditional view of rubber manufacturing could be added some of the following additional costs that are involved in reworking materials:

- The cost of producing the material in the first place;
- The segregation, identification, trucking and storage of the rework material;
- The use of valuable floor space;
- The additional laboratory tests and quality control;
- The extra handling involved when reworking material into the process;
- The quality degradation due to the incorporation of the rework;
- The additional energy needed to convert rework into a suitable form (3).

Some manufacturers in the rubber manufacturing industry sector are wasting in excess of more than 5 % of their total energy spending on the generation of scrap, waste and rework *(3).* The important points mentioned above are showed in the following revised causal loop diagram in Figure 8 to better see how different parameters interacts within the system.

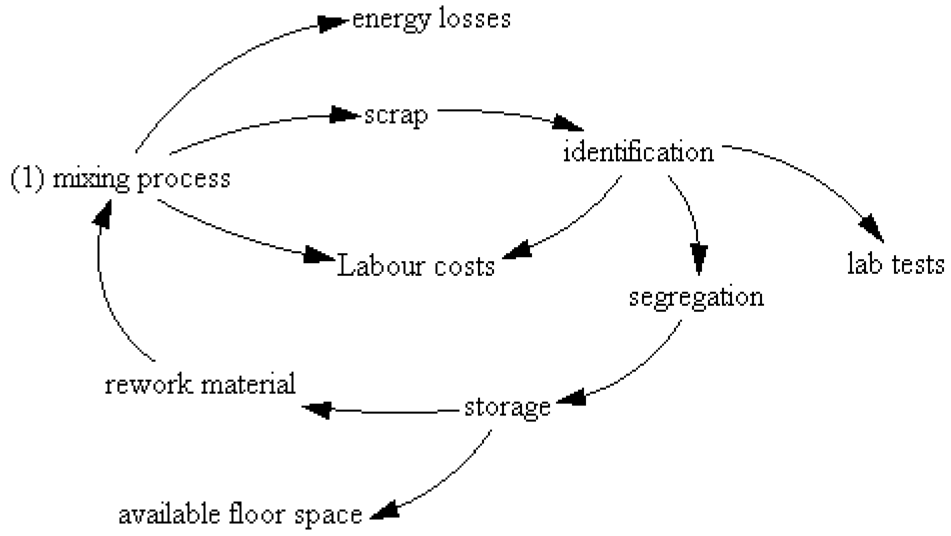


Figure 8. CLD - Revised view on generated scrap, wastes and rework

The following paragraphs focus on the estimation of energy losses when generating scrap, waste and rework based on the biggest energy consuming processes identified in Chapter 3 for the production of tyres in the Trelleborg 1 factory.

4.1.1 Mixing and compounding department

The philosophy of modern quality assurance is to control the process of manufacture to such an extent that product testing is virtually eliminated *(4).* For the raw materials this would also mean the supplier's process being in total control and so on down the line. Although the rubber industry has moved a long way towards this state, it presupposes a total understanding of the process involved. When raw materials are chosen and mixed to form a tyre compound, there is still a need to confirm that the compound possesses the expected properties, that allow further manufacturing, and that the product will perform according to the customer's expectations.

The moulding operator needs to be confident that the compound he is getting from the mixing department will have reasonably consistent flow behaviour, each time a batch is mixed. The extruder and calender personnel also need consistent smooth processing. The time lag between application of heat to a compound and the beginning of cure (scorch time) is often essential to its success in curing process. Attention must also be focused on characteristics of the cross-linking process itself. *(See glossary – appendix 3 for the terms).* There are lots of instruments available to measure all of these essential properties, all of which come under the heading of rheology *(1).* For the output quality purposes tests engaged in Trelleborg 1 factory include testing of raw material before the mixing and testing of the sample compound after the mixing. When the tyre is ready, it additionally has to experience a 100 % inspection. Numerous tests that are performed in the laboratory often show non-favourable results.

The following table presents the total amount of generated scrap, waste and rework in kg in the processes (see CHAPTER 3 section 3.3.) in April, 2000 when comparing with the total output of production in the same processes *(6).*

Table 4. Scrap, waste and rework in mixing and compounding department

Scrap, waste and rework (kg) 4/2/00-4/29/00	What was done with it? (kg)	Total production (kg) 4/2/00-4/29/00
14,449 (3.1 %)	-Re-mixed: 12,450 (86.2%) -Transferred to another application: 852 (5.9%) -Sold for 1 SEK or deposited into landfills: 1,147 (7.9 %)	466,000 (100 %)

Knowing the energy consumption per kg of tyre compound, which we identified based on the major energy consuming processes for the tyre compounds and found to be equal to 1.72 kWh/kg (see Chapter 3, section 3.3), we can calculate the primary energy losses of generated scrap, waste and re-work.

Primary energy losses: 1.72 kWh/kg × 14,449 kg= 24,823 kWh/month or 3.1 %

We can see that 3.1 % of total energy used in the major energy consuming equipment are wasted when generating scrap, waste and re-work.

Uncured rubber compounds with little defects can still be re-worked, this way reducing material loss, but bringing up energy consumption. Additionally, in the same way we can calculate the energy use that is experienced when re-working the compounds.

Re-work energy use: 1.72 kWh/kg × 12,450 kg= 21,414 kWh/month or 2.67 %

Total energy use = primary energy losses + rework energy use

24,823 kWh/month + 21,414 kWh/month = 46,237 kWh/month or 5.77 %.

We can see that almost 6 % of total energy used in the major energy consuming equipment are spent for the production if scrap, waste and re-work occur.

If considering just the energy cost when generating scrap, waste and re-work in the mixing and compounding department, then it could be calculated based on the internal electricity price and the kWh spent on waste, scrap and re-work/month.

Energy costs of production in case of scrap, waste and re-work:
46,237 kWh/month × 0.23 SEK = 10,635 SEK/month.

In the cost calculated above, the following monetary value is lost on wasted energy:
24,823 kWh/month × 0.23 SEK = 5,709 SEK/month.

The amount identified is not big, but when including the factors showed in the figure 8, the cost for generation of scrap, waste and rework increases considerably.

Some of the waste compounds are sold for 1 SEK/kg to the companies for different purposes when there is a need for them. When the market is not available, at least 1 t/month of rubber materials travels to Trelleborg landfill. In this case, landfilling becomes the most reasonable and cost efficient management option. Nevertheless, land disposal of waste rubber materials should be considered a last resort solution because of the following reasons:

- Many disease-carrying pests flourish in waste rubber piles. Chief culprits are many kinds of mosquitoes that prefer to breed in the quiet, stagnant water that collects on rubber materials. In addition to being the normal pests that all mosquitoes are, several of these varieties can carry deadly diseases, including encephalitis and dengue fever. Control and eradication programs, short of removing the pile, are difficult *(25).*

- Rubber materials represent a unique problem to landfills because they tend to rise and even pop through groundcover as other landfill materials compact around them. Rubber is a slowly degradable material *(25).*

4.1.1.1 Identified reasons for the generation of scrap, waste and re-work

Reasons for generation of scrap, waste and rework should be well known in the department in order to constantly monitor the mistakes and think of reduction measures for them to cut down the energy consumption along with other costly aspects.

The top six reasons are listed below:

- Differences in the structure of raw materials (56 %);
- Breakdown of the equipment (8.8 %);
- Operators mistakes (7.9 %);
- Wrong amount of the material weighting (7.4 %);

- Impurities (7.0 %);
- Others (13 %) *(16).*

The first differences in the structure of raw material, which is the biggest reason for the generation of scrap, waste and rework is the hardest one to influence and requires more research and development done in this field. Strict requirements for the suppliers of raw materials should be identified, but this requires further analysis.

The rest of the reasons could be managed if implementing a proper energy management in the company, which is introduced in Chapter 6, section 6.2.

4.1.2 Tyre manufacturing department

The tyre manufacturing department is divided into five sub-departments, which are hot stretch, calendering, preparation of materials, heavy tyres and light tyres. Waste is generated in these sub-departments: lowest rate in the sub-department of light tyres (0.27 %), followed by preparation of materials (0.65 %), and the highest rate in the department of heavy tyres (1.23 %) *(20).* The following paragraphs evaluate the energy losses when generating waste in each of these sub-departments for the month of April, 2000 based on the major energy using processes in each sub-department (see Chapter 3, section 2.)

The table below presents the total number of generated waste in kg in the processes (see CHAPTER 3 section 3.4) in April, 2000 when comparing with the total output of production in the same processes *(20).*

Table 5. Waste tyres in tyre manufacturing department

Sub-department	Waste (kg/month)	What was done with it?	Production output (kg/month)
Light tyres	209 (0.27 %)	Paid 400 SEK/t to sell to company in Malmö	77,417 (100 %)
Preparation of materials	3,246 (0.65 %)	Paid 400 SEK/t to sell to company in Malmö	499,309 (100 %)
Heavy tyres	4,375 (1.23 %)	Paid 400 SEK/t to sell to company in Malmö	355,707 (100 %)
Total:	**7,830 (0.84 %)**	**3,132 SEK/month**	**932,433 (100 %)**

Knowing the energy consumption per kg of the material for the tyre (see table 3) we can calculate the energy losses when generating waste in each sub-department based on the major energy using processes.

Sub-department of preparation of materials:

- 0.65 kWh/kg × 3,246 kg/month = 2,110 kWh/month or 0.65 %

Note: It is not possible to divide the two following sub-departments because the consumption of steam is measured like for one department.

Sub-department of light tyres and heavy tyres:

- 2.54 kWh/kg × 4584 kg/month = 11,643 kWh/month or 1.06 %

Total energy losses experienced when generating waste in tyre manufacturing department:

- 2,110 kWh/month + 11,643 kWh/month = 13,753 kWh/month or 0.92 %

Now we can calculate the energy costs for the generated waste for each sub-department based on the internal electricity (0.23 SEK /kWh) and steam price (0.297 SEK/kWh) (see chapter 3, section 3.2).

Energy costs for the waste generation in sub-department of preparation of materials:

- 2,110 kWh/month × 0.23 SEK/kWh = 485.3 SEK/month;

Energy costs for the waste generation in sub-department of heavy and light tyres:

- 11,643 kWh/month × 0.297 SEK/kWh = 3,458 SEK/month

Total energy costs for the generation of waste in tyre manufacturing department:

- 485.3 + 3,458 = 3943.3 SEK/month

These are the calculated losses on energy, which are based on the major energy consuming processes in the tyre manufacturing department.

Along with the energy losses when generating waste in this department costs for getting rid of it are encountered, which amounted to 3,132 SEK/month (see table 5). All the waste that was generated up to this month went to the energy producing company in Malmö for burning those tyres and producing energy. From this month the waste is given to the companies in Sweden to produce rubber tracks in fields, etc. To give the waste tyres to the companies, tyre manufacturing department has to pay 400 SEK/t of waste tyre for them to accept it.

Based on the major energy consuming processes identified in both departments; mixing and compounding and tyre manufacturing, it can be concluded that for the production of tyres Trelleborg 1 is wasting in excess 4 % of the energy when generating scrap, waste and rework.

4.1.2.1 Identified reasons for the generation of waste tyres in the tyre manufacturing department

When the tyre is identified as a waste tyre, department then performs a good accounting of reasons why it was rejected. But the specific reasons for generating the waste tyre are not known to the management of the department.

According to the people interviewed in the department the following reasons are identified as the main reason for generation of waste tyres:

- operators' mistakes;
- machine breakdowns;
- not a good maintenance of the equipment *(15)*.

The energy management suggested in Chapter 6, section 6.2 would help to diminish these reasons and along with them the costly rejection of wasting tyres.

Chapter 5
CURRENT ENERGY MANAGEMENT IN THE COMPANY

5.1 Energy management in Trelleborg 1

During the data collection and analysis phase, I soon realised that there is no systematic energy conservation action throughout the plant. Energy consumption data are collected, but not evaluated. Consumption data are recorded on the basis of purchased energy and the energy measuring devices, which usually do not measure the consumption of a single equipment but a complex of more machines. This makes it hard to evaluate and monitor the energy performance of single machinery.

The person, who is responsible for purchasing the energy for the plant, performs energy accounting in both the tyres manufacturing departments and the rest of the departments in the plant. Departments' leaders as well as its employees do not have a person responsible for the energy performance in their production as well as buildings heating, ventilation and lightning. Additionally, the plant does not have a group or committee who would constantly follow the energy consumption data and give suggestions towards energy conservation measures. These activities are left to the employees and management of the departments, but rarely, there were some energy proposals coming from individuals. So clearly the plant lacks good energy management structure.

Thus, obstacles towards energy efficiency measures exist, which are:

- not clear energy management structure induces lack of company's commitment to energy efficiency;
- lack of information on actual energy use and the opportunity for savings (majority of equipment are not measured alone, but in lines with other machinery);
- a view that everything possible has been done;
- lack of key human resource expertise on energy efficiency;

5.1.1 Energy efficiency measures that have been taken in Trelleborg 1

In November 1990, there was an energy efficiency audit performed in Trelleborg 1 factory. It described the company's energy use for heating, ventilation, lightning, but did not focus a lot on energy consumption in the manufacturing processes. As a result of the audit many suggestion were offered. From that time on, Trelleborg company has opened other plants in different countries of the world, thus the production and energy consumption rate has lowered in Trelleborg 1 company. According to the interviewed people in the company, this was the main reason why the energy reduction and consumption became hard to monitor because it affected the structure of the plant even though some measures for the energy efficiency were implemented.

Below listed are energy efficiency measures that have been implemented in 10 years period *(22).*

- Heat recovery from the steam in the processes to the heating of buildings was implemented, which accounts for approximately 10 % of all the heating needs.
- The management of 3 mixers was changed from manual control to computer control in 1998.This changed the accuracy of weighting of materials, the amount

of energy used per batch can be controlled since the time for batch to be in the mixers is set by computer. Computer controlled mixing had an energy saving effect of 10 % calculated on kWh/kg.

- Hydraulic rams in the 2 mixers replaced pneumatic ones. This resulted in an energy saving, but it was not documented.
- Control of compressors was changed into the automatic regulations, what induces them to stop when not in use. But the energy saving was not documented.
- In certain departments ventilation is computer controlled, which reduces energy consumption. But no one has recorded the saving of energy.
- Leaks are being constantly eliminated in the machinery by isolating pipes and tubes of the equipment. But the reflection on the reduction of energy consumption is not recorded because a lot of machines are not measured alone but in lines with other equipment.
- Lighting has been changed to more efficient lamps in certain departments. (See glossary – appendix 3 for the terms)

Apparently, many things have been done and continue to be done towards reducing energy consumption of the company. But, obviously there is no systematic monitoring of the savings in the plant. Energy consumption reflects on energy bills and the work towards reducing it is done by ‘common sense’.

Chapter 6
PROPOSITIONS FOR A MORE EFFICIENT ENERGY USE IN TRELLEBORG 1

6.1 Suggested improvements for the minimisation of energy losses on scrap, waste and rework

Figure 9 explains the two propositions concluded in order to limit the counter effects and energy usage of processes when generating scrap in the mixing and compounding department and waste in the tyre manufacturing department.

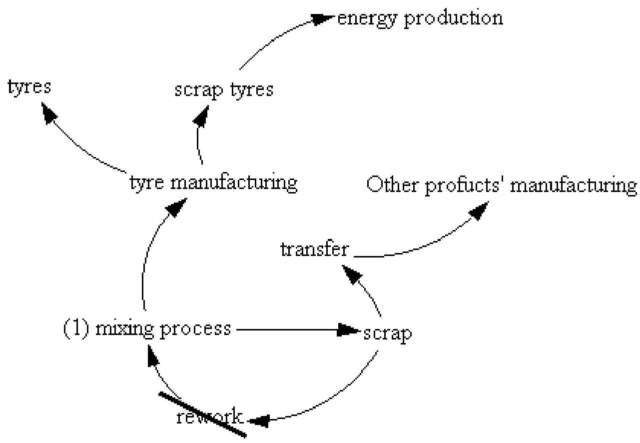


Figure 9. CLD – Propositions; non-rework energy saving in the mixing and compounding department and waste tyres as a future some energy source for the tyre manufacturing department

1). The scrap from the mixing process is actually either rework or transferred to applications other than tyre manufacturing. The idea here is since rework has considerable negative side effects on the energy losses and costs experienced, the scrap should be more directed towards a transfer to other application (figure 9) than to rework. In order to achieve this, the mixing process has to ensure that its products are in the useful range presented in figure 10.

For illustration, figure 10 pictures a simplified mixing involving two compounds. Let us assume that the mixed product directed towards tyre manufacturing lies in the range “tyre range” in figure 10. Also, products that would be directed towards the making of other products (figure 9) are in the “other’s range” in figure 10. Then, to insure that the output of the mixing will be useful for most of the cases and less energy consuming because of less reworking, it needs to be in the “useful range”.

Control of the mixing proportions of the compounds must then concentrate on finding a relationship between the amount of compounds A and B to fall in the useful range. A drawback of this action, however, is the risk to produce too many mixes in the ‘others’ range.

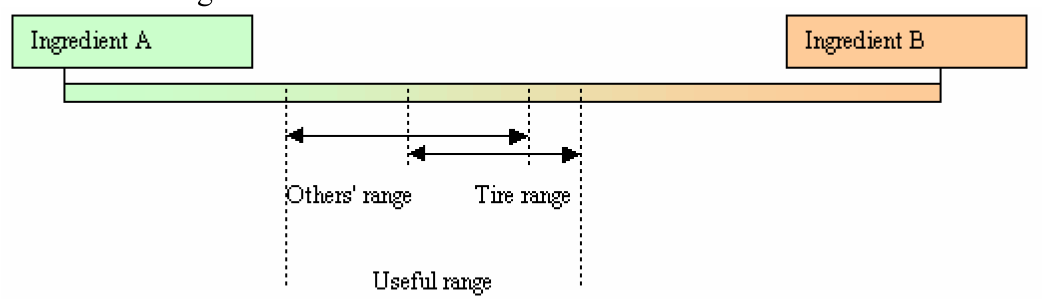


Figure 10. Simplified mixing of two compounds.

If this suggestion of non-rework was implemented then the energy saved in one month would account for 21,414 kWh or 2.67 %, and the monetary saving would be 4,925 SEK/month (see Chapter 4, section 4.1.1).

(2). The second suggestion from figure 9 concerns waste tyres. While the company actually bares costs to get rid of the waste tyres, it can avoid this cost and profit from it. The idea is to use the waste tyre as an energy source for the Trelleborg 1 company. The tyres can be burned in a boiler (to be purchased for the money earned while saving energy and not paying to get rid of tyres) and produce some steam for the tyre manufacturing department. This will cut down the cost of getting rid of the scrap tyres, and decrease the buying of natural gas to produce steam.

When considering the specification of fuels for a boiler, issues to evaluate are the fuel's combustion characteristics, handling and feed logistics, environmental concerns, and ash residue considerations. A thorough understanding of these issues allows one to engineer the combustion unit for power and steam generation.

TDF (tyre derived fuel) is defined as a waste tyre that is shredded and processed into a rubber chip with a range in size and metal content. Size normally varies in a range of 0.5-1 metres and metal content ranges from wire free, to relatively wire free, to only bead wire removed, to no wire removed *(26).* TDF's tolerable wire content is determined by a combustion unit's design considerations.

Depending on the wire content in the tyre, the TDF has an energy content ranging from 7791 – 8626 Kcal/kg. Combustion efficiency for TDF is generally understood to be in the 80 % range. TDF presents an ideal fuel source in that its moisture content is low (1-3 %) and its Kcal value is high. Low moisture fuels use less energy for moisture vaporisation and have a lower mass gas flow. TDF has a volatile content of roughly 66 % which indicates rather rapid heat release, and a relatively low ash content (3-5 %) which is evaluated for its ability to restrict heat absorption and decrease disposal costs *(26).* Table 6 shows the energy content of different types of fuels.

Table 6. Energy content of different types of fuels

Fuel type	**Energy content (Kcal/kg)**
Tyre Derived Fuel (TDF)	Up to 8,626
Oil	Up to 10,574
Natural Gas	Up to 12,243
Coal Sub-bituminous	Up to 5,844
Coal Bituminous	Up to 7,068
Wood	Up to 2,435

Source: Rubber Manufacturers Association (RMA), 2000.

To produce the amount of steam that was used in the tyre manufacturing department for vulcanisation processes (1,099,980 kWh/month, see table 2) it is needed 99,187 Nm^3 of natural gas.

The waste production from the tyre manufacturing department for the same month accounted for 7,830 kg/month. Having this number we can calculate the energy content, which would be gained when burning this amount of tyres, and convert it to the kilowatt-hour /month.

Energy content gained in one month when burned TDF's:

7,830 kg/month × 7791 Kcal/kg = 61,003,530 Kcal/month;

Conversion to kilowatt-hour:

61,003,530 Btu/month × 0.001163[2] = 70,947 kWh/month

70,947 kWh/month accounts for 4.4 % of the total energy consumption and 6.4 % of the total steam consumption in the department.

We can calculate the cost for the amount of steam (see Chapter 3, section 3.4) required in the tyre manufacturing department in the same month based on the internal company price for steam (see Chapter 3, section 3.2):

1,099,988 kWh/month × 0.297 SEK/kWh = 326,694 SEK/month;

Now we can calculate the cost saved when burning TDF's:

[2] Conversion factor: one Kcal = 0.001163 kWh

70,947 kWh/month × 0.297 SEK/kWh = 21,071 SEK/month;
It makes 6.4 % of the total costs for steam in the tyre manufacturing department

We should also include the amount of money that department paid for to get rid of waste tyres in the same month (see Chapter 4, section 4.1.2):

21,071 + 3,941 = 25,012 SEK/month;

We can assume that the amount of waste tyres, which was generated in April, 2000 is the average number of waste tyre per each month, *(20)* then the total cost that could be gained when burning tyres for the department needs instead of paying to get rid of them in one year is:

25,012 SEK/month × 11 months/year = 275,132 SEK/year;
Note: The month of July is a holiday month.

Now it is important to estimate the costs for the boiler:

The estimated cost for an oil-fired boiler, where tyres can be burned also, producing 70,000 kWh per month is 1.5 MSEK (including auxiliary systems, foundation, control system, accessories for environmental protection, etc.) *(14).*

The simple payback period should be calculated:
Payback period = initial investments ÷ savings;
1,500,000 ÷ 275,132 = 5.45 years
This simple method for calculating the payback period ignores all savings beyond the payback years, thus penalising suggestions that have long life potentials for those that offer high savings for a relatively short period.

Although the simple payback period was calculated, more accurate economic analysis should be performed in order to take the decisions. Even the initial investment costs might be actually lower if the market for the boilers is investigated more thoroughly. The estimate cost in this paper comes only from one interview.

In the long term, the company might find it useful to investigate the destiny of the waste tyres in other tyre manufacturing companies. It may be discovered that other companies pay money to get rid of the waste tyres, so Trelleborg 1 could incinerate this waste and benefit from it. In this case, a more powerful boiler would be required. Moreover, if a thorough economic analysis would be carried out, then the payback period may show to be shorter due to the big amount of tyres to be incinerated.

However, this suggestions still has some drawbacks. First, there will be the induced labour costs necessary for the operating of the boiler. Second, the amount of waste tyres in each month is not fixed, which implies that the energy produced will fluctuate unexpectedly.

6.2 Suggested improvements towards energy management in the plant

Chapter 5 in this paper showed that there is no systematic energy conservation action in the company. For this reason, a structure of good energy management in the plant should be introduced, which requires Trelleborg 1 to 1) tackle energy management strategically, 2) ensure energy use is monitored, 3) motivate and train staff.

The energy efficiency of a company is thus a function of the machinery being used and a material being processed, along with external influences from the surrounding environment (e.g. weather, geographical position, etc.). There is also a human dimension, both through the methods employed by the staff to operate the factory, and the people themselves. The five factors that determine the energy efficiency are illustrated in figure 11.

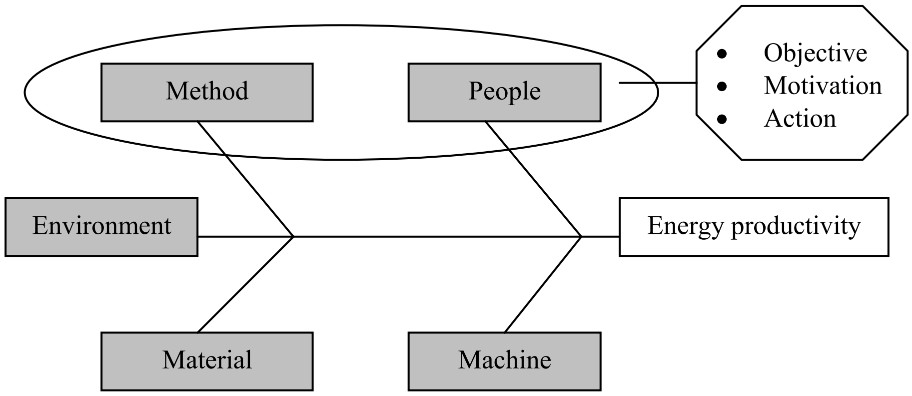


Figure 11. Five factors that determine energy efficiency
Source: Caffall, Clive, 1995.

6.2.1 A strategic approach

Thinking strategically means being alert to all of the influences on a company's operation, such as the market competitors and suppliers, as well as issues like environmental and energy concerns. Management then can assess the impact that any changes are likely to have, and look for the best opportunities for the business as a whole *(18).*

Integrating energy into good general management should result in the energy implications of every management decision being considered by those concerned. To achieve this, each manager in departments needs to take a level of responsibility for energy management. The overall energy co-ordinator would then become a functional support, like the personnel department. He would act as a source of specialist skills, leaving individuals managers to actually manage their resources.

Individual companies differ in their strategic approaches to energy efficiency. However, all approaches do have a number of elements in common. These are:

- Commencing with an energy audit;
- Obtaining senior management support;
- Monitoring energy usage (indexed to production);

- Recognising that management is just as important as technology;
- Planning that contains a number of co-ordinated energy saving projects *(2)*.

6.2.2 Assignment of a co-ordinator and creation of a committee

The degree of any future energy conservation program will be directly related to the degree of commitment by the top management of the Trelleborg 1 company. In addition to commitment, top management must also provide adequate resources to meet the commitment. This means the appointment of one person to assume the responsibility as energy performance co-ordinator in Trelleborg 1 factory is crucial. This person would be in charge of the energy audit, of listing and summarising conservation opportunities, and of implementing those opportunities that are promising and are approved.

An energy co-ordinator must have at least several basic resources to succeed: a working knowledge of the plant facility, a rapport with employees at all levels within the company and the authority to initiate a change, either in the way the process is operated or in the plant equipment.

Trelleborg 1 is a reasonably large organisation, therefore it would be necessary to assist the co-ordinator with an energy management committee. The members should be able to represent authoritatively the different business functions such as manufacturing, building services, accounting, etc., in each department.

The purpose of such a committee is to co-ordinate plans, bring in new ideas and perspectives, and to insure that actions taken in one part of the plant do not have an unfavourable effect on another part.

6.2.3 Monitoring of energy use

Tight cost control over energy use can help to reduce waste energy and maintain an established level of energy efficiency. But this ideology of Trelleborg 1 company is not fully true, because cost controls by themselves do not provide the information, which is needed to show:

- whether energy is being used efficiently;
- what measures could be taken to improve the efficiency of energy use.

To establish proper control over energy use it is necessary to have information on the expected performance of the energy consuming equipment, together with dynamic information on the actual energy inputs and flows. This information has to be reconciled with other measures of what is driving energy usage, such as production volume. When combined with corresponding information on energy costs, energy use can effectively be managed in a similar manner to other operating resources.

It is surprising how few managers (or employees) in the company actually know how and how much energy they use and what that costs the company. This requires a good information system.

A well designed information system for energy management will provide:

- impartial and accurate reporting, which enables effective control over energy consumption and costs;
- data on energy use, processed and presented to enable energy management to be optimised under varying conditions,
- technical and financial information needed to make further improvements in both operating practices and the efficiency of energy using equipment;
- information to justify and support a strategy for achieving improvements through target-setting;
- a method for assessing improvements and maintaining efficiency at the new level *(29).*

Monitoring is the basis of a disciplined approach to energy management, which ensures that energy resources are used to maximum economic advantage *(2).* With a properly organised system, managers at all levels within departments will be encouraged to seek improvements in the use of energy.

The technique considered for Trelleborg 1 company would be to employ computers to analyse data that is collected manually. An energy survey has to be carried out to find out the best sites for meters and to identify discrete areas where accountability for energy use could be assigned. This paper could serve as an initial reference when identifying the biggest energy using processes in the manufacturing of tyres. Additional meters for water, compressed air, steam and electricity will have to be installed. Data then will be collected month1y and analysed using ordinary spreadsheet software on a personal computer. Reports to each department will be generated detailing their energy 'account'. Moving averages will show performance trends and encourage departments to take action.

Additionally, the company might think of simulating the energy consuming processes in the plant. A computer simulation copies the physical properties of the plant into a software program, and is advantageous as it allows experiments without physical cost. Thus, the model can be used to assess the efficiency of different methods for the same process. Moreover, an energy management system model makes it possible to evaluate the optimal energy consumption for a given production and other functioning parameters. Examples of existing energy management systems models reach savings of 5-10 % over the energy use *(2).*

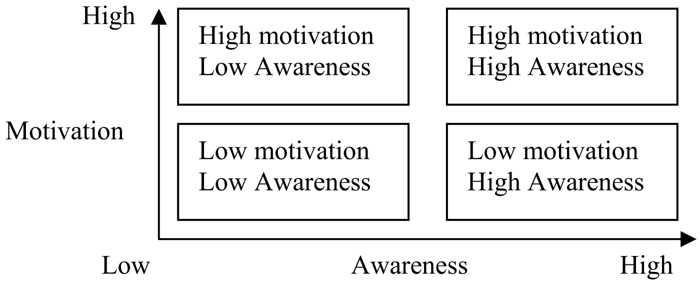
6.2.4 Motivating staff to save energy

Most of the actors in figure 11 are either fixed or relatively controllable. The human factor, however, is the most difficult to influence. The personnel requires the following:

- must have energy objectives (which can be provided through a monitoring system described earlier in section 6.2.3;
- need to be motivated to achieve these objectives;
- have to be aware of how they can achieve their objectives.

In many organisations, there is enormous potential to save energy by good housekeeping, and by raising the awareness and motivation levels of staff who are end users of energy. Savings of 10-15 % of the total annual energy bill can be achieved *(18).*

Before proceeding with any programme to encourage employees to save energy, it is necessary to identify where staff is located in an awareness-motivation grid in Figure 12. In order to achieve significant savings, staff must be moved to the high motivation – high awareness quarter of the grid. Improving one of the two factors without the other would be futile.



Source: Caffal, Clive, 1995.
Figure 12. Awareness-motivation grid

One method of assessing peoples' location on the grid is to devise a simple questionnaire that focuses on knowledge and attitude levels. The questionnaire will identify the lacking parameter (motivation or awareness) to be focussed on.

While the prime motivation to save energy for most senior managers is to cut costs, this does not necessarily work for those people in the plant who actually carry out the energy savings. The link has to be established with the personal values and interests of theirs employees, such as environmental concern and public recognition of their achievements. These personal values are the long-term self-motivating factors. It is important to suggest that energy management at home, at work and in their transport habits is the single largest contribution they themselves can make to be 'green'. Recognition and reward for achievement for employees should not be forgotten when efforts are put.

The following technique could be employed when achieving awareness and increase the willingness of the workers towards reduction of energy consumption:

- After developing an energy management information system (described in section 6.2.3), a motivation campaign has to be run by the energy management committee to stimulate all employees to save energy. A number of different media should be used to raise the awareness, even a special newspaper could be mailed to employees' homes. The campaign should focus on simple good housekeeping that all employees could practice, and a suggestion scheme afterwards should be used. It is offered to run three separate themes, to concentrate on one type of energy at a time – electricity, natural gas, steam and compressed air. Along with an increased motivation and awareness more suggestions could come from the personnel, which could result in energy savings when implemented.

It should be noted that while awareness of good housekeeping practices can be approached most cost effectively through newsletters, posters and other publicity campaigns, training may be more appropriate for groups of employees who have greater influence upon energy consumption than others.

6.2.5 Energy audits

Above all of what has been mentioned to create a good energy management structure in Trelleborg 1 factory, energy efficiency audit is crucial and prior to this company. Energy audits are detailed on site-studies of the operating efficiency of an asset. They identify specific initiatives to improve the energy efficiency of the asset and provide recommendations on how the initiatives may be implemented *(23)*.

Assets that have been identified as major consumers of energy in this paper, and those that show high levels of potential energy savings during routine performance analysis, should be subjected to an energy audit. Especially, heating and ventilation should be investigated since it consumes one third of the energy (see figure 2) in Trelleborg 1 company.

Energy audits should be undertaken by accredited organisations and should be expected to produce:

- an assessment of current performance and performance assessment criteria on an ongoing basis (e.g. applicable performance indices and associated targets);
- a review of the performance efficiency of each service and major items of equipment within the asset, and an assessment of potential energy cost savings available in each area of energy use;
- a review of the application and management of energy sources and tariffs used or applicable to the asset and its operations;
- a set of energy cost-saving recommendations for implementation over the short, medium and long term, including a cost–benefit analysis of each option *(23)*.

Energy audits may also be included as part of the commissioning schedule for new assets to confirm that the building complies with the specifications and that optimum operational and system performance has been achieved.

The Rubber Association of Canada prepared self-audit questions for rubber manufacturing industries, which could also be conducted by department leaders in Trelleborg 1 company. If carried out, a self-audit might indicate no cost or low cost measures to improve the energy efficiency in the plant. The questions are included in the appendix 4.

6.3 Performance indicators

It can be difficult to assess exactly how much energy the company should be using or how much more efficient it could become without having comparative data. The idea of benchmarking is to develop meaningful indicators, allowing firms to compare their energy performance with industry norms and best practice standards. Some industries and commercial bodies already carry out this process and are aware of the sense of motivation that can be got from benchmarking with other sites in the corporate group. For top-of-the-league plants, it can inspire a healthy sense of competitiveness and pride about being the best at what they do. And for those some way down the list, it can encourage management and staff to try harder *(8).*

'Energy benchmarking' here refers to the use of indicators – ratios, indices, etc. – to enable valid comparisons to be made between companies in the area of energy use. Such indices may refer (for example) to specific energy consumption for companies operating within the same sector, or they may even refer to energy management practices and techniques.

The concept of specific energy consumption (SEC).

The ratio, i.e. the index of fuel & power consumption divided by the production index, gives the specific energy consumption. A decrease in specific energy consumption means an improvement in energy efficiency.

SEC is energy usage per unit (kg) of rubber compound. This indicator allows general comparison of energy performance on a world-wide basis *(9).*

Having the total production in the mixing and compounding department and the total energy consumption (including lightning, heating, and the production of other compounds along with tyre compounds) we can calculate the key figure, that is energy needed to produce 1 kg of compound in this department (1999 data) *(21)*:

19,340,951 kWh/year ÷ 25,163,000 kg/year = 0.77 kWh/kg/year

The surveys done in UK show that the mixing and compounding departments in the tyre manufacturing companies of similar type and output of production as in Trelleborg 1 have SEC ranging from 0.37 to 0.80 kWh/kg *(9).* Because of the number of parameters affecting the SEC, sufficient information has to be provided to allow individual compounders to make valid comparisons with SEC figures of other compounders.

The same strategy and way of calculation applies to the tyre manufacturing department (1999 data) *(22)*:

28,704,639 kWh/year ÷ 5,482,000 kg/year = 5.23 kWh/kg/year

The data from the same surveys in UK in the tyre manufacturing departments of tyre companies show the SEC ranging from 1.8 to 10.3 kWh/kg *(10).* This is the most simple and general indicator of comparing energy performance with the other companies and company's past performance. The more accurate comparison would be achieved if the comparisons would be done on the monthly basis.

The same specific energy consumption (SEC) indicator could be made more specific if looked at certain processes. The processes identified in this paper include major energy consuming processes in both departments for the production of tyres and are based only on the energy used to run the particular machinery.

Mixing and compounding department. The major energy consuming process identified is the two stage mixing process (see table 1). The key figure then is the electricity needed to produce 1 kg of tyre compound, which equals to 1.718 kWh/kg/month (see Chapter 3, section 3.3).

Tyre manufacturing department. The major energy consuming processes identified in this department are listed in table 2. The key figures then are the energy needed for the machinery to produce 1 kg of tyre in each sub-department:

Preparation of materials = 0.65kWh/kg/month (see table 3);
Calendering = 0.77 kWh/m/month (see table 3);
Light and heavy tyres = 2.54 kWh/kg/month (see table 3).

These SEC indicators are calculated on a monthly basis. They are simpler and more accurate to use since they do not require a lot of information from other companies to make valid comparisons. These indicators focus just on energy performance of the machinery, so the evaluation and eventual optimisation of the major energy consuming processes could be done when comparing with other companies' major energy consuming processes.

Energy management practices and techniques

More sophisticated benchmarking practices do not just compare cost data but consider factors which include cycle time, quality, optimisation of service delivery, customer satisfaction and various productivity measures. Energy management practices can also be compared by measuring a degree to which certain practices are utilised within an organisation *(24)*.

The importance of the comparing the energy management practices is because of the following aspects:

- Firstly, when comparing with the competitive companies, Trelleborg 1 will be able to identify and describe the current priority attached to different aspects of energy management.
- When comparing it will be easy to decide which areas in energy management practices most need to be developed further.
- Measures the degree to which certain practices are utilised within an organisation and enforces company's energy management.

The efficiency of the implemented energy management practices and techniques can be checked within the company and compared with other plants using the matrix that has been developed by the UK's Energy Efficiency Office, which is included in the appendix 5.

Chapter 7

GENERAL CONCLUSIONS

This study reviewed the energy flows in the Trelleborg 1 company, particularly the processes of tyre manufacturing. The biggest energy consuming processes were identified and are listed in tables 1 and 2. The key figures of energy consumption related with the production were identified and are listed in sections 3.3, 3.4, and 6.3. These calculated figures can be used for comparison of the processes and eventual action towards improving the energy use. In fact, the processes with the largest energy consumption figures should be the primary targets of any reduction of energy consumption efforts.

The generation of scrap, waste and rework in the tyre manufacturing departments indicated one aspect of energy usage that is often overlooked in the company. Based on the major energy using equipment identified earlier, a conclusion was made that for the production of tyres Trelleborg 1 is wasting 4 % of the former energy when generating scrap, waste and rework. A suggestion was made in order to eliminate 75 % of the wasted energy, thus reducing it to 1 % of the consumption of the major processes. This could be achieved if the mixing process would employ control methods aimed at directing all of all the compounds to fall into the useful range defined in section 6.1, so that the rework process for tyre compounds would be eliminated and that instead the compounds would be used for other products.

The other proposition in the study suggests using waste tyres as an energy source for the tyre manufacturing department. Burning waste tyres could replace more than 6 % of the natural gas that is used to produce steam for this department. This proposal requires investments for purchasing a boiler, for which the simple payback period was estimated to be in the order of 5.4 years. The initial investment costs as well as the payback period might actually be lower if the market for the boilers and the economic analysis were investigated more thoroughly.

The energy used on scrap, waste and rework as well as on other functions could be minimised through a good energy management in the company. The key in achieving any savings is to take a strategic approach to managing energy use. However, to ensure that an energy management strategy is effective, it is important to get real commitment from senior management at the outset.

During the study, it was observed that there is a lack of energy use monitoring in the company. In order for any future energy saving programs to succeed, it is strongly recommended to have an energy survey for identifying the best sites for meters and employing computers to analyse the data. A good monitoring of energy use will identify whether energy is used efficiently and through certain actions improve the efficiency of energy use.

The study also shows that while energy-efficient technologies have a significant role to play in reducing energy use in the company, it is just as important to ensure that employees are using energy wisely. This requires the application of management techniques. Through a number of different media to raise the awareness, a motivation campaign has to be run by the energy management committee to stimulate all employees to save energy as well as to suggest ways of saving energy.

However, an energy audit should be considered in the first place to assess the current energy efficiency in the company. Meanwhile, the company will be engaging the techniques towards strategic energy management.

Good energy management practices could not only cut the company's costs, but also induce a broader understanding on energy related environmental effects, such as harmful greenhouse gases and climate change, and on the limited non-renewable energy sources.

Appendices

Appendix 1 *(30)*

Tyre manufacturing processes

Process flow diagram in figure 1 in the paper represents general tyre manufacturing processes.

The following paragraphs explain processes more specifically. (See glossary – appendix 3 - for the terms used in this appendix).

1. Preparation of materials

The manufacture of tyres begins with preparing materials for rubber compounding, and for pre-treatment and subsequent rubber-coating of cords (to wrap them in rubber) so that various raw materials processed can be used for later processes of making intermediate products (members).

1.1 Rubber compounding (mix formulation and compounding)

A variety of raw material elastomers and various compounding ingredients are used for tyres by mixing and compounding them for use in respective members. Intensive mixer is of enclosed type and computer-controlled so that raw material elastomers, various compounding ingredients, and oil are automatically fed, and compounded. Fig. 1 shows this process schematically.

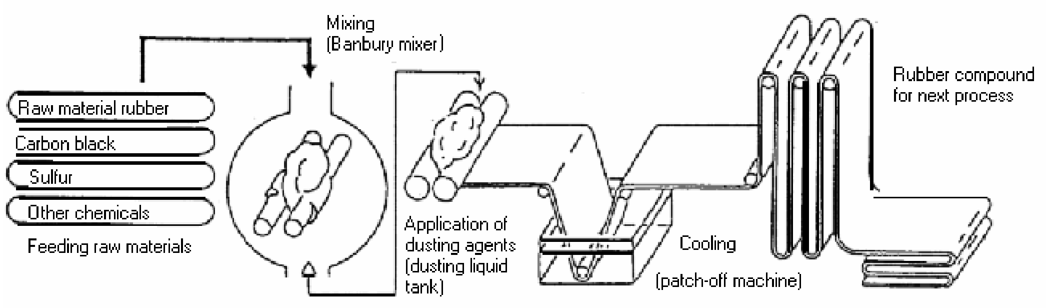


Figure 1. Diagram of mixing and compounding processes

Since the properties of rubber, uncured and cured, vary greatly depending on various factors as described below, attention has focused on producing rubber compounds to specifications with a slight variance by computer control. The various factors include the kind, quantity, order and time of feeding, the extent to which ingredients are mixed evenly, compounding time, and temperature of raw materials elastomers and compounding ingredients.

1.2 Pre-treatment of cords

Pre-treatment of tyre cords is very important process aiming not only at processing fibrous materials and rubber for good adhesion, but also at modifying the properties of fibers, particularly synthetic fibers, including nylon, polyester, and rayon, into ones fit for the tyre cords. It is a process in which cords are dipped in adhesives, and, at the same time, subjected to a great tension at high temperature so that they are made not to be readily stretched out and thermally stable to be best fit for the tyre cords. This process requires a large equipment in which dipping ad drying can be carried out simultaneously.

1.3 Calendering

Calendering, also called rolling, is a process in which coating operation is carried out by covering treated textile fabric or steel cords with thin rubber layers on both sides so that materials to be used for sandwiched plies and belts can be made. The quality and thickness of rubber layers depends on respective applications.

The important point in this process lies in the accuracy of thickness in both directions of length and width. Inaccurate thickness leads to the poor performance of tyres and further to vibration due to increased imbalance. Accuracy is therefore required to 1/100 mm. A calender with three or four rolls is used. The temperature of rolls and gauges are computer controlled.

In addition to the use for coating cords and canvas, a calender is also used for preparing various kinds of rubber sheets, squeezes (belt-like rubber sheets for reinforcing plies), and strips (strings), and is one of the important equipment at the rubber factory.

2 Preparation of members

In the later sections on the processes of preparing necessary members according to respective sizes of various tyres, the forming of a bead, cutting of rubberised cords including plies and belts, and extrusion of a tread and a sidewall will be described.

2.1 Rubber coated cord cutting

The operation is called "cutting", in which rubber coated cords and canvas are cut to the angle and width according to respective kinds and applications of tyres. The machine used is called "a bias cutter", classified into two types: one is a cutter as used for press-cutting paper or thin steel sheets in principle, while the other is a ring cutter that runs at high speed along the beam used for checking the cutter and cords. Two types are available for cutting devices: one is a vertical one with which coated materials, wound off the roll and suspended vertically, are cut after they have been held down, while the other is a horizontal one with which coated materials, wound off the roll onto the conveyor for horizontal lamination and are cut while they are held down. Since the width and the angle of cutting are required to be accurate at present, a horizontal type is more widely used. Fig. 2 shows the conceptual drawing of a horizontal bias cutter.

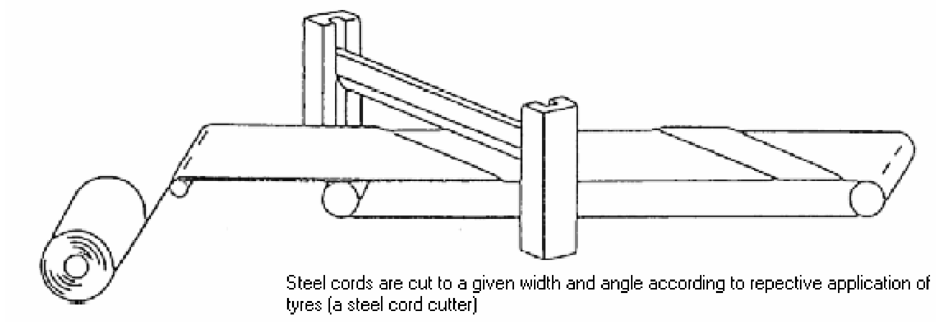


Figure 2. Process flow sheet of cutting steel cord

2.2 Extrusion of treads and other mouldings

An extruder is used for preparing rubber members with definite cross-sections, such as treads and sidewalls. Figure 3 shows a schematic drawing of this operation. Rubber for treads, compounded in the mixer, is softened by kneading rolls, fed to the extruder, forced through the tread die with a given cross-section, and cut to a desired length after cooling.

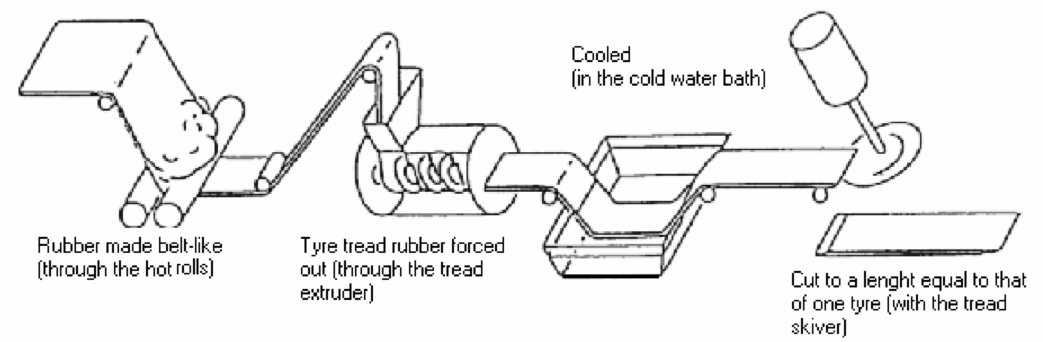


Figure 3. Tread extrusion process flow sheet

The process of extruding treads is one of the most important ones in the manufacture of tyres, the uniformity of which is strictly required, because the tread, accounting for nearly half of the total weight of a tyre, tends to cause trouble when imbalanced. It is therefore important that the extruded and cooled tread is cut to a correct and uniform length, thickness, shape, and weight.

2.3 Bead moulding

Beadwires, arranged at a given interval and in given number, are rubber coated and extruded to a flat bead, which, in turn, is wound around the core drum, with an inside diameter given according to respective kinds and sizes of tyres, by the number of steps required. This is a process most commonly used. Figure 4 shows a schematic drawing. Usually, thin rubberised fabric tape, called bead-covering tape, is wound further with apex rubber attached thereon. This process is carried on by another equipment

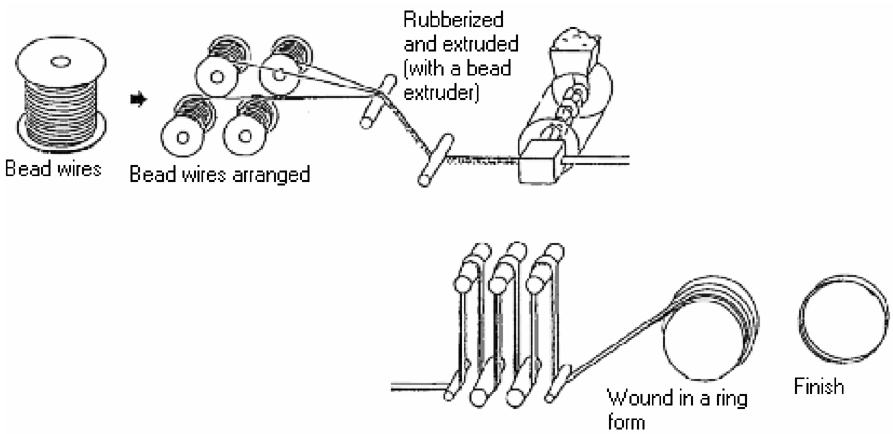


Figure 4. Bead making process flow sheet

3. Manufacture of tyres

Tyres are made by the moulding process, in which various members, prepared through the processes described earlier, are laminated. Two methods are available for moulding: one is used for bias tyres, and the other for radial tyres, each differing in carcass structure.

In the tyre moulding section, green tyres cylindrical in shape are bias tyres, laminated on the flat drum, for use under low pressure, while radial tyres are close to finish in shape. Figure 5 shows how green tyres differ from each other in shape when used for radial and bias tyres.

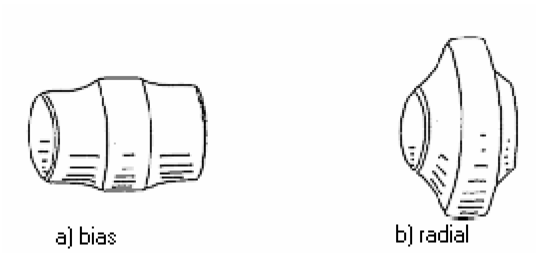


Figure 5. Shapes of green tyres

4. Vulcanisation of tyres

Moulded tyres are fed to a mould (a metal mould with a tread pattern, a side pattern, a marking, and a trademark carved thereon) of the specified vulcaniser, pressed against the inside of the mould from the inside, and heated simultaneously from both sides, internal and external, with heating media, such as steam and hot water, so that, after a given period, vulcanisation proceeds throughout the entyre tyre. Thus, a finished tyre with a vulcanised rubber structure is elastic and stable.

Automatic vulcanisers are used. With these machines, insertion of tyres, and taking out and transfer of cured tyres are carried out completely automatically with no one attending. Operators have only to prepare green tyres and watch the process.

Since synthetic fibers shrink by nature if left standing when hot, hot tyres after vulcanisation diminish in size when left standing. A device (a post-cure inflator) is therefore provided, with which bias tyres in which synthetic fibers are used are inflated by applying air pressure immediately after vulcanisation, and cooled in an inflated state.

Two types of moulds are used for moulding tyres: one is full mould that splits into upper and lower parts, and mainly used for moulding bias tyres, while the other is a split mould widely used for moulding radial tyres. The split mould is one that splits into 6 to 9 segments along its perimeter. Figure 6 shows conceptual drawings of a vulcaniser and a split mould in use.

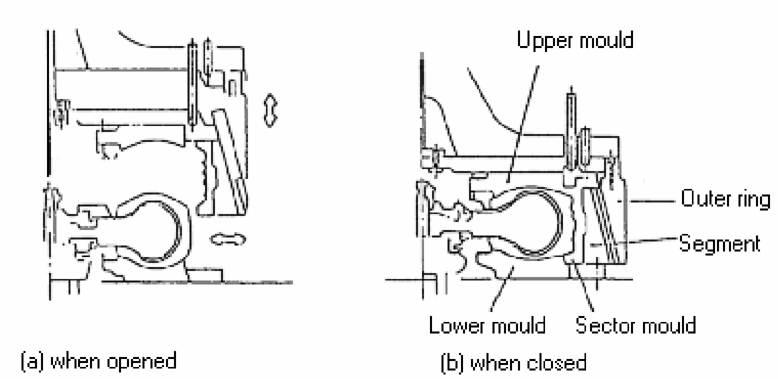


Figure 6. Conceptual drawing of a vulcaniser

5. Finishing of tyres

When finishing tyres, a vent hole, drilled right through a metal mould, is used for discharging air from the space between the tyre and the mould. An excess rubber is forced out and forms hair-like vent spew in the vent holes and other shapes of spews at the split parts of upper and lower moulds and joints parts between mould segments. These spews should be removed in terms of good appearance. Automatic finishing machines serve for this purpose. The finished tyres are subjected to 100 % inspection including that of appearance (a sensory test by an inspector) for rejection of defective units. Those for use in passenger cars, trucks, buses, and aircraft are subjected further to a balancing test to screen unbalanced units. A uniformity machine is also incorporated in the production line for measurement of uniformity of tyres for use in cars, trucks, and buses.

Appendix 2 *(30)*

Name of tyre parts:

Figure 1 (a) is a cross-section of the steel belt radial tubeless tyre, and Figure 1 (b) shows the appearance and the internal structure of both bias and radial tyres for better understanding.

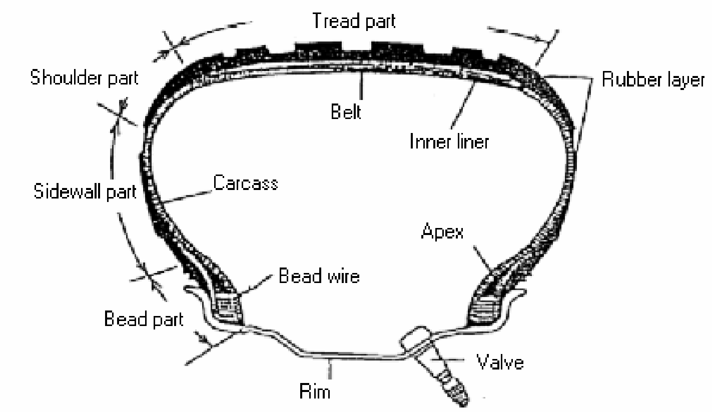


Figure 1 (a). Cross-section of passenger car radial tyre

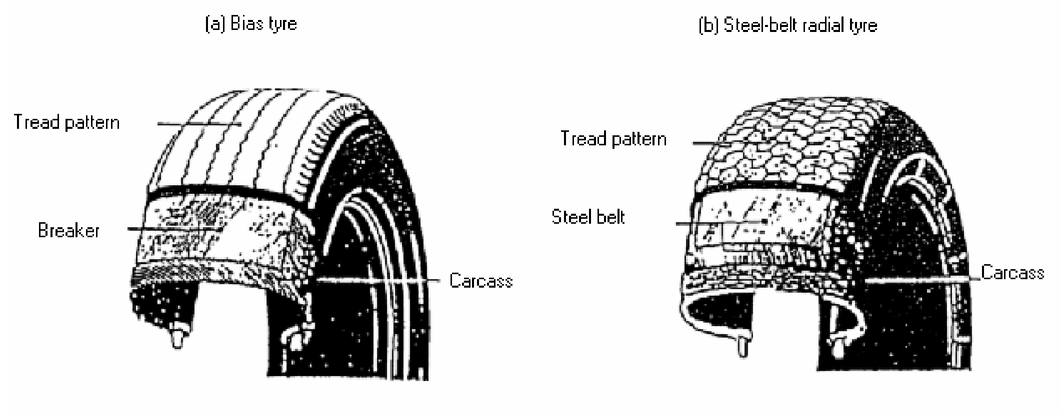


Figure 1(b). Structure of bias and radial tyres for passenger car

Names of tyre parts (see glossary – appendix 3 for the names of the parts)

Appendix 3 *(11)*

Glossary

1. Apex
Apex stands for the uppermost peak of a triangle. It is a hard rubber member with a triangle-shaped cross-section, sometimes added onto bead wires to put the bead part in shape as well as to give rigidity. It is called “apex”, and sometimes “bead filler” or “stiffener”. This member is an essential for supporting a radial structure with a low degree of carcass rigidity since a ply cord has no angle, and used for truck tyres of bias type that carry heavy loads.

2. Bead
A portion made to suit the rim, with a circular assembly of steel wires wrapped with plies.

3. Bead wires
A circular assembly of steel wires wrapped with plies.

4. Belt
In a radial tyre, it is placed in the same position with a breaker, with textile material, durable and hard to stretch out, arranged almost circumferentially around the tyre to give a hoop effect.

5. Breaker
One to several layers of textile material, inserted between the tread and the carcass of a bias tyre to protect the carcass from a road shock or from external damage.

6. Calendering
Operation where calender is used, which produces smooth, uniform sheeting and coats, and frictions textiles. It consists of 2-5 chilled cast-iron or steel rolls, 500-2000 mm in length. The nip between the rolls may be adjusted; the rolls are hollow and may be heated or cooled. To overcome deflections caused by pressure the rolls are cambered, the amount of camber depending on the type of process. The order in which the rolls are placed distinguishes them as I, F, L, and Z calenders.

7. Carbon black
The various types of blacks differ basically in structure, processing properties and in reinforcement and the physical and chemical properties, which they impart to rubber.

8. Carcass
A portion constituting the structure of a tyre composed mainly of ply and bead parts, including the belt. In some cases, it includes a breaker.

9. Compounding
It involves deciding what ingredients, and in what proportions, should be mixed, with the goal of providing, in the mixed and cured compound, the properties required for the end application.

10. Cord fabric
Used as reinforcement of rubber products like tyres. Made of rayon, polyamide or polyester, etc.

11. Crosslinking
A term associated with high polymer products indicating the formation of a network, normally with a three dimensional network, by intermolecular bridges consisting of molecular chains with

reactive groups. The main chains in crosslinked products may be separated only by thermal degradation or highly reactive agents. In elastomers such crosslinking is termed vulcanisation.

12. Curatives

Also called cure activators, of which relatively small additions to a compound considerably increase the degree of vulcanisation. Often, no vulcanisation will take place if the cure activators are omitted.

13. Curing

See 'vulcanisation'.

14. Elastomer

Natural or synthetic vulcanisable products, which reveal elastic properties after crosslinking, can be stretched to at least double their length at room temperature and, on removal of the tension, quickly return to their original length.

15. Extruding

Continuous method of shaping profiles by means of an extruder. A screw through an opening (die) forces the compound, which is the correct shape of the profile.

16. Hydraulic ram

The ingredients to be mixed are pressed down in the mixing machine by a hydraulic ram.

17. Inner liner

In a tubeless tyre, it is a thin butyl rubber layer, made gas tight to hold air pressure, and used for lining a carcass. In a tyre with an inner tube, the tyre is lines only with an ordinary rubber layer since the tube itself is made of highly gas tight butyl rubber.

18. Master batch

Precompound of rubber with a compounding ingredient in a higher concentration than in the final compound.

19. Mix formulation

It involves deciding what equipment to use, and the speeds, pressures, temperatures, times, and procedures required, blending the chosen ingredients into an adequately mixed compound.

20. Mixer (internal)

Machine with profiled rotors rotating in an enclosed chamber in opposite directions. Used to masticate rubber and to mix compounds.

21. Moulding

Building a tyre from the different members that composes it.

22. Ply

Ply is a thin layer of rubberised fabric.

23. Pneumatic ram

The ingredients to be mixed are pressed down in the mixing machine by a pneumatic ram.

24. Shoulder

An interval between the tread part and the side part. The boundary is not definitely defined.

25. Side

A portion between the tread and the bead. The surface rubber layer only of this portion is sometimes called a sidewall.

26. Stacking

Rubber compounds arranged in stacks

27. Tread

That proportion of a rubber layer, which contacts the road surface. The tread pattern is so engraved on the surface as to give the property of a non-skid.

28. Tyre cords

Used as reinforcement of rubber products like tyres. Made of rayon, polyamide or polyester, etc.

29. Vulcanisation

Arises from "vulcan" being the God of the fire and the smithery. Also called curing. When adding sulfur to a rubber compound, the sulphur forms cross-links between the polymer chains, making the rubber elastic.

Appendix 4 *(3)*

Audit questions (mark X in box if an action is required)

Reducing electrical supply costs

Demand

- ❑ Is the load profile known? Is there a system in place to prevent the load from exceeding a given value during peak hours?

- ❑ Can equipment presently being run during peak demand time periods be re-scheduled to off-peak times or to other peak times when load is low?
- ❑ Can some non-essential equipment be shut off during peak demand periods by use of timers or by production operators?

Consumption
- ❑ Is there a procedure in place to shut off production equipment and auxiliary production equipment when not in use?
- ❑ Is lightning switched off when buildings, storage areas, offices, etc. are unoccupied? Can outside security lightning be controlled by motion sensors?
- ❑ Is there a policy to replace old motors with energy efficient motors?

Power factor
- ❑ Is the power factor, as noted on the electrical bill, less than 90 %?

Raw material storage
- ❑ Is the heating in the area controlled and is temperature being maintained at the minimum acceptable level for raw material store?
- ❑ Are air seals used around truck loading doors? Are loading doors closed when not in use?
- ❑ Can the lightning levels be reduced? Is the high efficiency lightning being used?
- ❑ If electric fork trucks are being used, are batteries being charged in off-peak times?
- ❑ Is the hot room adequately insulated and are the doors well sealed to minimise heat loss?
- ❑ Are the hot room doors kept closed except when loading and unloading?
- ❑ Are the rubber blocks stacked in such a way to maximise surface contact with the heating medium?
- ❑ Are heated oil tanks and associated piping adequately insulated?

Mixing
- ❑ Are the mixers fitted with temperature and kilowatt recorders?
- ❑ Are the mixers fitted with kilowatt-hour meters?
- ❑ Are the weighment systems capable of + / – 0.2 % accuracy?
- ❑ Are there external factors that cause any delays between batches?
    - Initial loading of mixer (belt speed, door movement, delays discharge times for blacks, chemicals, etc.)
    - Loading of oil
    - Ram movements
    - Mixer speed
    - Unloading of mixer.
- ❑ Is the mixer motor operating at or close to the minimum rated load? If not, can the ram load be increased?
- ❑ Can the mixer fill factor be increased, i.e. can the batch size be increased?
- ❑ Can the number of mixing stages be reduced through equipment or processing changes? Can curatives be added at downstream mills?
- ❑ Is the most efficient mixer working on all shifts, through meal breaks, shift chage-overs, etc.?
- ❑ Is the output from the most efficient mixer reduced because of any unnecessary delays?
- ❑ Is the mixer fitted with a modern computer control system that optimises the efficiency by controlling mixing operations through time, temperature, load and integrated power variables?
- ❑ If there is more than one mixer on site, can one mixer be shut down if another mixer is fitted with a larger motor?
- ❑ Can a new efficient mixer replace a number of less efficient mixers?
- ❑ Are dust extraction systems fitted with variable speed drives?
- ❑ Can the exhaust air from the ram be utilised in other systems such as a pneumatic material handling systems?
- ❑ Is it possible to replace any compressed air operated components, such as the ram, with hydraulic or electrical linear power?
- ❑ Can the heated cooling water from the mixer or mills be used to warm up oils or fresh air make up?

Processing (mills, calenders and extruders)
    - ❑ Is there any evidence of stock being scorched during processing operations?

- ❑ Is the residual scorch time for each stock tested on a routine basis? Is there a high degree of variability in residual scorch times?
- ❑ Is there a need to reduce the temperature of the stock anywhere in the process?
- ❑ Are mills bank heights and nip settings satisfactory?
- ❑ Are mills slabbed off when interruptions occur?
- ❑ Is equipment shut off when not in use?
- ❑ Review the various cooling water uses in the process. Are there opportunities to reduce the quantity of cooling water being used?
- ❑ Is there a routine maintenance procedure to de-scale cooling activities?
- ❑ Does the stock flow evenly in the calender nips?
- ❑ Is the temperature of the calender rolls and extruder zones controlled automatically by temperature control devices?
- ❑ Are cements being used in the process?
- ❑ Is it possible to re-organise operations by moving products from less efficient to more efficient lines and thus shut down a complete line?
- ❑ Review the parts of the process that use compressed air. Are there any opportunities to reduce or eliminate the use of compressed air?
- ❑ Can any part of the operation be converted from a hot feed to a cold feed process?
- ❑ Is there a system to control the gauges of the product at calendering and extrusion processes? Would improved dimensional control result in cure time reductions?

Curing / vulcanisation processes

- ❑ Are there large safety factors built into the cure time? Do these safety factors result in slower processing speeds in the case of continuous cure operations or longer cure cycles in the case of other operations?
- ❑ Can the chemistry of the compounds or the temperature of cure be changed in order to reduce curing times and decrease energy consumption?
- ❑ Is the insulation of moulds, platens, machinery, piping, etc. adequate to ensure minimum heat losses?
- ❑ Is there good instrumentation to measure the temperature and pressures of curing services and cure operations? Are gauges calibrated on a regular basis?
- ❑ Are presses fitted with automatic temperature and time controls?
- ❑ Are there any interruptions to the curing process that result in energy being wasted? Can the open and close cycle for moulding operations be reduced in order to reduce heat losses? Is there live heating services connected to idle equipment? Y improving the up time on individual presses, is it possible to shut down any presses?
- ❑ Would it be possible to use a cheaper alternative source for thermal energy?
- ❑ Is there a more energy efficient way to operate hydraulic power in the plant?
- ❑ Can any waste heat be recovered for other purposes such as factory heating, boiler feedwater pre-heating, oil heating, etc.?

Scrap, waste and rework

- ❑ Is the quantity and reason for scrap, waste and rework known? Are the levels excessive in comparison with other producers of rubber products?
- ❑ Is there a good quality system in place and are the production operators involved with thw system? Are there control charts at the production workstations?
- ❑ Are the mixer weighment and control systems adequate?
- ❑ Are compounds being adequately cooled prior to stacking at the mixer downstream?
- ❑ Are mill, calender and extruder operators using good work practices?
- ❑ Is there an effective salvage operation to repair and re-cycle faulty products or in-process materials?
- ❑ Is there sufficient instrumentation and recording equiomeent to enable employees to set up equipment correctly and to enable engineers to trouble shoot?

Finished goods storage

- ❑ Is the heating in the area controlled and is the temperature being maintained at the minimum acceptable level for a finished goods store?
- ❑ Are air seals used around truck loading doors? Are loading doors closed when not in use?
- ❑ Can the lightning levels be reduced? Is high efficiency lightning being used? Are the lights switched off when not needed?

- ❑ If electric fork trucks are being used, are batteries being charged in off-peak times?

Boilers and steam distribution

- ❑ Is the boiler efficiency checked on a regular basis? Is the efficiency acceptable for the type of boiler and fuel being used?
- ❑ Is the boiler fitted with a dual capability to use natural gas or fuel oil to take advantage of interruptible gas supply contracts?
- ❑ Are the flue gases checked for carbon dioxide and oxygen content on a regular basis? Are they within the acceptable range?
- ❑ What is the flue gas temperature? Is a heat recovery system being used?
- ❑ Is there any evidence of soot build-up on the fireside surface of the boiler? Is the flame in the combustion chamber bright and clear and does it fill the combustion chamber without impingement?
- ❑ How is the blowdown rate controlled? What is the rate and is it at the level recommended by water treatment specialists and based on the dissolved solids contents of the boiler water? Is there a system in place to recover heat from the blowdown?
- ❑ Is waste oil from process burned in the boiler?
- ❑ Is condensate re-used?
- ❑ Is there redundant piping or oversized piping that causes excessive loss of heat?
- ❑ Are steam lines, flanges, valves, condensate lines, etc. adequately insulated?
- ❑ Is there evidence of steam leaks?
- ❑ Is there a maintenance program for the inspection, repair and replacement of steam traps? What percentages of traps are found to be faulty?
- ❑ Is there a program in place to remove scale from heat transfer surfaces of equipment?

Compressed air

- ❑ Can any parts of the process be converted from air power to a more efficient form of power?
- ❑ Identify the part of the process that requires the highest air pressure. Can another source of power be used to enable the compressed air system pressure to be reduced? If not, can it effectively operate at lower air pressures?
- ❑ Is there evidence of air leaks?
- ❑ Is there evidence of water in the system?
- ❑ Is the air intake for the compressors coming from the coolest location?
- ❑ If air is being used to cool the compressors, is it exhausted outdoors during summer and used to heat during winter?
- ❑ Is heat being recovered from the compressor cooling water?
- ❑ Are compressors shut down when production is shut down?
- ❑ Is there system to control the sequencing of the compressors according to the demand for air?

Cooling water

- ❑ Is a recirculated water cooling system being used?
- ❑ Is there any evidence of process cooling water being dumped to the sewer?
- ❑ Can any parts of the cooling system be converted from single-pass to multi-pass?
- ❑ Is the flow of cooling water at the various production processes being varied according to cooling requirements?
- ❑ Is the cooling water at production processes shut off when the production process stops?
- ❑ Can any heat be usefully recovered from the cooling system?

Electric motors

- ❑ Are there any motors running at less than 50 % of their rated capacity?
- ❑ Is there a billing penalty for poor power factor?
- ❑ Is there a policy to replace smaller motors with energy efficient motors?
- ❑ Are rewind versus replacement evaluations made when motors fail?

Envelope

- ❑ Is the wall insulation adequate? Is there evidence of frost or condensation on the inside of external walls?
- ❑ Is the roof insulation adequate (snow melts quickly on a poorly insulated roof)?
- ❑ Are windows single glazed? Is there broken or cracked glass? Are there gaps between the building and the window frames?

- Are east, south or west facing office windows using reflective glass or fitted with shades?
- Are external doors free from drafts when closed? Are frequently used doors such as the main entrance designed to minimise movements of air in and out of the building? Are doors at loading docks fitted with dock seals? Is there evidence of doors being left open?

HVAC
- Is HVAC equipment shut down when buildings are unoccupied?
- Are thermostats used to control building temperatures and are the temperature settings appropriate for the type of work being carried out? Are setback temperatures used when buildings are unoccupied?
- Do processes that produce fumes or dust have hooding with exhaust fans?
- Is the balance between intake and exhaust air satisfactory? Is the volume of fresh air intake excessive? Is there a way to reduce levels when the production process is topped or working at lower levels of production?
- Are there any problems with stratification during the winter period?
- Can any process heat or exhaust heat be recovered to heat incoming fresh air?
- Is there a cheaper alternative energy source for heating?

Lightning
- Are lights left on when not needed? Observations during non-working times need to be made.
- Are there areas that are over lit? Are there areas that are under lit?
- Are dimmers used to reduce lightning levels of areas according to the task being performed?
- Are the lights clean?
- When ordering replacement bulbs, are the most energy efficient bulbs specified?
- Can any of the lightning systems be replaced with a more energy efficient system?

Appendix 5

Energy management practices *(19)*

The efficiency of the implemented energy management practices and techniques can be checked within the company and compared with other plants using the matrix that has been developed by the UK's Energy Efficiency Office. The matrix below provides a quick and easy-to-use but effective method to establish an organisational profile. Each column of the matrix deals with one of six issues, which contribute to effective energy management: policy, organising, motivation, information systems, marketing and investment. The rows represent five levels (numbered 0 to 4) of increasingly sophisticated handling of these issues.

Table 1. The matrix- performance indicators to follow energy management practices in the companies

	Energy Policy	**Organising**	**Motivation**	**Info. System**	**Marketing**	**Investment**
4	Energy policy, action plan and regular review have commitment of top management as part of an environmental strategy	Energy management fully integrated into management structure. Clear delegation of responsibility for energy consumption	Formal and informal channels of communication regularly exploited by energy manager and energy staff at all levels	Comprehensive system sets targets, monitors consumption, identifies faults, quantifies savings and provides budget tracking	Marketing the value of energy efficiency and the performance of energy management both within the organisation and outside it	Positive discrimination in favour of 'green' schemes with detailed investment appraisal of all new build and refurbishment opportunities
3	Formal energy policy, but no active commitment from top management	Energy manager accountable to energy committee representing all users, chaired by a member of the managing board	Energy committee used as a main channel together with direct contact with major users	M&T reports for individual premises based on sub-metering, but savings not reported effectively to users	Programme of staff awareness and regular publicity campaigns	Same payback criteria employed as for all other investment

2	Unadopted energy policy set by energy manager or senior departmental manager	Energy manager in post, reporting to ad-hoc committee, but line management and authority are unclear	Contact with major users through ad-hoc committee chaired by senior departmental manager	Monitoring and targeting reports based on supply meter data. Energy unit has ad-hoc involvement in budget setting	Some ad-hoc staff awareness training	Investment using short term pay back criteria only
1	An unwritten set of guidelines	Energy management the part-time responsibility of someone with only limited authority or influence	Informal contacts between engineer and a few users	Cost reporting based on invoice data. Engineer compiles reports for internal use within technical department	Informal contacts used to promote energy efficiency	Only low cost measures taken
0	No explicit policy	No energy management or any formal delegation of responsibility for energy consumption	No contact with users	No information system. No accounting for energy consumption	No promotion of energy efficiency	No investment in increasing energy efficiency in premises

Effective programmes can be shown to be those where activities in each column are developed to a high level. Examining where an organisation lies in the matrix is a good indication of which areas of activity require further development for an efficient and effective programme.

Referencing the matrix (see table 1), the initial state of energy management in Trelleborg 1 company can be marked in the table below.

Table 2. Indication of current energy management state in the company

	Energy Policy	**Organising**	**Motivation**	**Info. System**	**Marketing**	**Investment**	
4							
3							
2							
1							
0							

The steps for the activation of comparing these energy management techniques have to start with an initial assessment to benchmark company's position (table 2). During and after the ongoing programmes on energy efficiency that will be initiated by the future systematic energy management in the company, energy co-ordinator with his committee has to re-asses their position in the company. This has to be constantly co-ordinated until best practices across the matrix are achieved.

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