Energy Efficiency Opportunities in the Canadian Rubber Industry

CIPEC

Natural Resources Canada | Ressources naturelles Canada

THE RUBBER ASSOCIATION OF CANADA
ASSOCIATION CANADIENNE DE L'INDUSTRIE DE CAOUTCHOUC

A Joint Project of
The Rubber Association of Canada,
Natural Resources Canada,
and the
Canadian Industry Program
for Energy Conservation (CIPEC)

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Published by:
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Energy Efficiency Opportunities in the Canadian Rubber Industry is a joint project of:
The Rubber Association of Canada, Natural Resources Canada and the Canadian Industry Program for Energy Conservation (CIPEC).
Technical assistance: Tire Technologies Inc.
Supervision: The Environment Committee of the RAC
Art direction: Beyond Words Inc.

ISBN: 0-662-25757-X
Catalogue #: M92-137/1997E

Aussi disponible en français sous le titre : Occasions de pratiquer l'efficacité énérgétique dans l'industrie canadienne du caoutchouc

Printed on recycled paper
using vegetable-based inks.

PRINTED IN CANADA

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Foreword

On behalf of the Rubber Manufacturing Industry's Task Force of the Canadian Industry Program for Energy Conservation (CIPEC), the Rubber Association of Canada retained Tire Technologies Inc. to identify and analyze information related to industrial energy use in the Canadian rubber manufacturing sector, and the opportunities for efficiency which may exist.

CIPEC consists of 19 task forces representing the various industrial sectors in Canada. The Rubber Industry Task Force is comprised of the Environment Committee of the Rubber Association of Canada.

The CIPEC Task Forces act as focal points for identifying energy efficiency potential and improvement opportunities, establishing sector energy efficiency targets, reviewing and addressing barriers and developing and implementing strategies for target achievements.

This handbook is a practical demonstration of the Canadian rubber manufacturing industry's commitment to reducing the production of greenhouse gases, a commitment which is essential to our common well being. Among our manufacturing members, good energy practices are simply accepted as being good business practices. The handbook is intended to assist all those in Canada who manufacture products made of rubber to maintain an ongoing effort in energy conservation and effective environmental management.

The use of corporate and/or trade names is not meant to constitute an endorsement of any commercial product or system.

I - Introduction

The intention of this handbook is to provide rubber product manufacturers with an information guide that will help them identify energy efficiencies within their facilities and processes, give them ideas on how to reduce energy costs, and provide them with a list of questions that can be used for an energy audit of their facility.

Statistics Canada published the following data about energy costs in the Canadian rubber sector for 1994.

1994 Energy Costs for the Canadian Rubber Industry

	Number of Establishments	Cost of Fuel & Electricity
Tire & Tube Industry	14	$41,160,000
Rubber Hose & Belting Industry	27	$ 7,670,000
Other Rubber Products Industries	134	$34,470,000
Total Industry	175	$83,300,000

The potential to make savings on energy is dependent on many factors but as a general guideline the following estimates may be used for an initial assessment:

- Large manufacturer with an existing energy management program - 5% to 15%;
- Small manufacturer with no existing energy management program - 10% to 30%.

Using the above data from Statistics Canada, the following table gives a guide to potential annual savings for a typical manufacturer.

Savings at 10%, 20% and 30% Cost Reduction Levels (1994 Data)

Industry	Average Energy Cost per Establishment	10% Reduction	20% Reduction	30% Reduction
Tire & Tube	$2,940,000	$294,000	$588,000	$882,000
Rubber Hose & Belting	$ 284,100	$ 28,410	$ 56,820	$ 85,230
Other Rubber Products	$ 257,200	$ 25,720	$ 51,440	$ 77,160
Total Industry	$ 476,000	$ 47,600	$ 95,200	$142,800

Based on 1997 estimated volumes and energy prices, energy costs in the Canadian rubber sector could be reduced by ten million dollars per year if an average energy saving of just 10% is made across the whole industry. This is considered to be a conservative target for the next two to three year time period.

The rubber industry offers more scope for energy savings than many other industries. Just consider what happens to a piece of natural rubber from the time that it is received to the time that it leaves a factory in the form of a finished product. How many times is it heated and cooled before it is converted into a final product? The answer will give you some indication of the scope for energy cost savings.

The following chart is an illustration of the potential savings by plant operations for two different sized facilities.

Potential Annual Savings

	Plants Spending Approx. $300,000/yr On Energy Costs	Plants Spending Approx. $3-million/yr On Energy Costs
Plant Operations		
A. Off-Load Peak Demand	$10,200	$21,000
B. Raw Material Storage	1,800	9,000
C. Mixing	9,000	60,000
D. Processing (mills, calendars, extruders)	4,200	30,000
E. Curing	7,800	24,000
F. Scrap, Waste & Re-Work	9,000	45,000
G. Finished Goods Storage	1,200	6,000
H. Boilers	3,600	15,000
I. Compressed Air	3,600	15,000
J. Cooling Water	2,400	12,000
K. Electric Motors	2,400	30,000
L. HVAC	3,000	18,000
M. Lighting	1,800	15,000
Estimated Savings	$60,000 *	$300,000 **

This chart is intended solely as a guide. Actual results may vary substantially depending on the facility.

Notes:
* Assumes a smaller firm with no or only a minimum existing energy management program.
** Assumes a larger firm with an existing energy management program.

It is recommended that each manufacturing facility establish an energy savings program. The plant engineer should take the lead role in such a program because of their knowledge of the facility and the equipment used. And, since rubber technology has such a large influence on the energy requirements in the manufacturing process, it is recommended that the chemist or engineer responsible for establishing the mixing recipes and curing conditions should assist the plant engineer with the part of the program relating to the processing operations.

II - Quantifying Energy Costs

An energy savings program should result in an action plan that consists of short term, medium term and long term actions. The program, together with the resources needed to implement the energy savings program, should be supported and approved by the senior management of the company. Progress against plans should be reviewed on a regular basis and the program itself should be updated on an annual basis.

The following sections of this handbook will provide some tips on where to look for energy savings possibilities. Read the handbook and then organize a plant wide energy audit. The audit should be carried out by people who have a thorough knowledge of the rubber industry and have good energy management skills. It is worth noting that it is sometimes possible to obtain financial assistance from government sources or utility companies for carrying out energy audits and process improvements.

Electrical Costs

There are a number of different types of fee structures for electricity. They are mainly dependent on the level of usage and on the type of customer. As a customer it is extremely important to fully understand the contents of any electrical supply contract and the way that the supplier calculates the monthly electric bill.

Most manufacturers in the Rubber Sector are on a fee structure that is classified as a "time-of-use" rate. This type of fee structure was introduced as an incentive to encourage larger energy users to shift operations to off-peak times of the day. The structure has different rates for summer and winter. It also has "peak" and "off-peak" rates depending on the day of the week and the time of the day when the energy is being used.

The monthly electric bill has two basic components:

- a charge for the energy used during the month (kWh), and
- a charge for the maximum power demand (kW) during the peak time periods of the month.

The following table illustrates a typical rate structure used by Ontario Hydro.

Ontario Hydro Rate Structure

	Winter (Oct - Mar)	Summer (Apr - Sept)
Energy Rates (cents per kWh)		
Peak (7 am to 11 pm, Monday to Friday)	3.76	3.32
Off-Peak (all other times)	2.82	2.02
Demand Rates (dollars per kW)		
Peak (7 am to 11 pm, Monday to Friday)	11.51	8.50
Off-Peak (all other times)	0.00	0.00

It should be noted that the electric utility supplier may also charge a financial penalty to customers with a poor power factor. This topic is covered in Section IV.

Electrical energy costs can be reduced in the following ways:

- Reduce peak demand;
- Move energy consumption from peak to off-peak times;
- Reduce the total energy consumption;
- Improve the facility's power factor.

Natural Gas and Fuel Oil Costs

The billing of natural gas and fuel oil is straight forward when compared to electrical energy but customers need to fully understand supply contracts and, particularly in the case of natural gas, be aware of the different types of contracts that may be available. Customers should consider the use of bulk supply rates and, when they can use fuel oil as a back up to natural gas, they should consider negotiating an interruptable gas supply contract which will provide them with better prices. Typically customers have a choice of suppliers and should negotiate for the most advantageous terms.

Summarizing Utility Costs

In order to make accurate calculations about energy use and costs, the following cost factors need to be calculated:

- electrical unit energy cost (cents per kWh);
- electrical demand cost (dollars per kW);
- natural gas unit cost (dollars per cubic metre);
- fuel oil unit cost (dollars per litre).

To calculate the above costs, the prior twelve months of utility bills should be summarized like the following examples.

Electricity

	Consumption		Demand	
Month	**(kWh)**	**Cost ($)**	**(kW)**	**Cost ($)**
January	158,400	5,512	926	10,658
February	292,400	10,000	891	10,255
March	330,800	11,876	750	8,633
April	304,000	9,120	920	7,820
May	382,200	11,390	1,226	10,421
June	365,000	11,133	910	7,735
July	154,800	4,799	880	7,480
August	294,600	8,750	950	8,075
September	322,000	9,490	1,114	9,469
October	384,600	13,461	1,002	11,533
November	321,200	10,985	810	9,323
December	264,400	9,518	915	10,532
Totals	3,574,400	$116,043	11,294	$111,934

Average electrical cost = $0.0325 per kWh
Average electrical peak demand cost = $9.91 per kW

Natural Gas

Month	Consumption (cubic metres)	Cost ($)
January	30,018	4,505
February	46,670	7,004
March	80,992	12,155
April	51,540	7,735
May	49,926	7,493
June	43,328	6,503
July	18,690	2,805
August	35,620	5,347
September	36,814	5,525
October	65,700	10,486
November	68,248	10,893
December	43,045	6,870
Totals	570,596	$87,321

Average natural gas cost = $0.153 per cubic metre

#6 Fuel Oil

Month	Consumption (litres)	Cost ($)
January	30,775	6,334
February	29,183	6,006
March		
April		
May		
June		
July		
August		
September		
October		
November		
December	21,072	4,726
Totals	81,030	$17,066

Average fuel oil cost = $0.211per litre
(Note: 1 litre of #6 oil is equivalent to 13.92 kWh)

III - Energy Consuming Equipment

It is recommended that a listing of all the major energy consuming equipment be prepared in advance of making an energy audit. This listing can often be formed by extracting information from the plant asset records or from maintenance files. The listing can be in the form of a flowchart or a simple listing such as the example shown below.

Major Energy Consuming Equipment

Electricity

Air Compressors:
- 1 - 60 HP screw type air compressor

Cooling Water Circulation:
- 1 - 270 L internal mixer
  - 1 - 1,500 HP mixer motor
  - 1 - 150 HP extruder motor
  - 1 - 200 HP roller die motor
  - 1 - 25 HP cooling rack motor
  - 1 - 25 HP dust extractor motor
- 1 - 160 L internal mixer
  - 1 - 400 HP mixer motor
  - 1 - 200 HP dump mill motor
  - etc.

Natural Gas

Boiler Plant:
- 2 - 500 HP boiler
- 1 - 300 HP boiler

Water Heaters:
- 2 - hot water heaters
- etc.

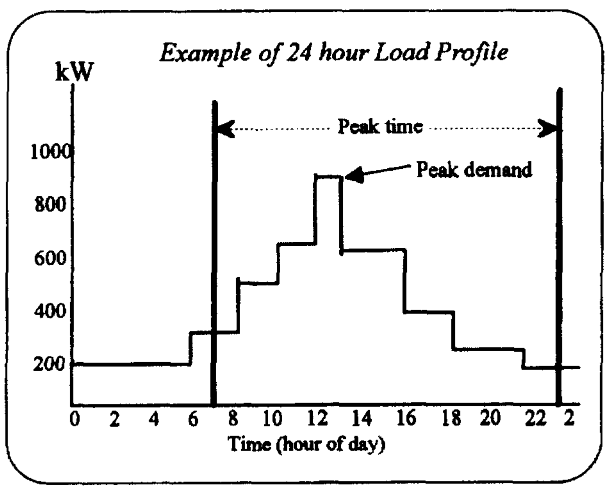
IV - Energy Saving Tips

A: Reducing Electrical Supply Costs

The subject of how electrical utilities charge for electricity was covered on page 3 in section II. In summary, there are three ways in which a customer can reduce costs without reducing energy consumption. These are:

1. reduce the peak demand;
2. move energy consuming operations to off-peak times;
3. where there is a power factor billing penalty, increase the power factor.

The chart below shows an example of a power plot for a 24 hour period of a mid-week day. It shows that there is equipment having a base load of 200 kW and that other equipment is running between 06.00 hr. and 22.00 hr. It also shows that the maximum demand of 900 kW occurs at midday and covers a time period of approximately one hour.



The peak load consists of a number of operations that are running concurrently. If some of these operations could be re-scheduled to a later time period, it may be possible to reduce the **peak demand** to 600 kW, representing a demand charge saving of 33%.

If some of the load could be moved from the peak time period to the off-peak time period, additional savings could be made on the energy consumption portion of the electrical bill.

The above example illustrates that considerable savings are possible by simply managing the time when electrical energy is being used.

Power factor is computed according to the following equation:

$$\text{Power Factor} = \frac{\text{kilowatts (resistive power)}}{\text{kilovolt-amperes (resistive plus reactive)}}$$

Electric power is a function of resistance and reactance, in which only the resistive component does the useful work. When an electric utility suspects that a customer has a power factor of less than 90%, they may install metering equipment to measure kilovolt-amperes (kVA) as well as kilowatts. They will bill the customer for the larger of:

a) the actual kW, or
b) 90% of the kVA.

Low power factors are normally caused by inductive loads such as transformers, welding machines, induction heating coils, lighting ballasts, and underloaded AC induction motors.

Manufacturers who presently have energy management controls in place may be able to **save up to 20%** of their current billing through load shifting, load shedding and power factor correction.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

✔ Seek advice from your electric utility - ask them to provide you with a load profile and recommendations on how to reduce energy consumption, reduce peak demands and improve power factor. They can also advise you about any financial incentives that may be available for equipment modifications and replacement.

✔ Obtain a load profile of your facility and its major energy consuming operations. Analyze the data and determine ways to reduce peak demand and to move load to off-peak hours. Some ideas to consider:

- re-schedule production operations to lower demand periods;
- shut down non-essential loads at peak demand times, e.g. HVAC;
- shut down equipment when not needed, switch off lights;
- charge batteries and pump water to overhead tanks at off-peak times.

Medium Cost:

✔ Low power factors are caused, mostly, by lightly loaded induction motors. It can be improved by replacing such motors with ones that are correctly sized for the job or by installing capacitors at the electrical metering station. Investment payback is usually about 18 months.

Capital Cost:

✔ Install an automatic system that will monitor and control electrical and thermal energy consumption. This is more applicable to larger energy consuming facilities.

B: Raw Material Storage

The optimum solution would be a situation where incoming raw materials were supplied directly to the production line. There would be no need to have a raw material store that requires energy for heating, lighting and the trucking equipment that is required to move the raw materials in, out and around the store. This may not be a practical solution for most manufacturers but the principle of keeping raw material storage space requirements to a minimum will result in lower energy requirements for heating and lighting.

In winter energy losses at the truck unloading bay can be considerable if doors are left open or if door seals are not employed during unloading operations.

Natural rubber needs to be pre-heated prior to mixing to ensure that there are no crystalline formations in the rubber. The normal practice in the industry is to pre-heat the rubber in hot rooms that are maintained at a temperature of about 35°C by means of convective type warm air systems. The theoretical energy requirement to raise the temperature of 1 kg of rubber 25°C is 0.012 kWh but the typical hot room may require ten times this energy because of heat losses through the walls and roof and heat losses during loading and unloading of the rubber.

Certain oils used in compound recipes also needs to be heated as they will not flow at low temperature. Holding tanks and piping should be well insulated to minimize heat loss.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

- ✔ It is not necessary to maintain the temperature of raw material stores at the same level of production areas. Install heating thermostats to control temperature.
- ✔ In order to heat rubber in the shortest time period, the pallets of incoming rubber should be re-stacked in such a way that there is a maximum surface area exposed to the heating medium. If the rubber is not being used soon after coming out of the hot room, it should again be re-stacked to minimize the exposed area in order to retain heat.

Medium Cost:

✔ Lighting quality is not critical in this area and high efficiency lighting such as high pressure sodium lamps should be evaluated.

Capital Cost:

✔ Microwave preheating is an alternative to conventional hot rooms. It is much more energy and manpower efficient but the microwave system is expensive to buy.

C: Mixing

The compounding and mixing of rubber is one of the most energy intensive operations in the rubber industry. It is also the most critical operation from a quality standpoint.

The weighment accuracy and the timing of the addition of the materials that make up the compound recipe together with the control and timing of the work done during the mixing process are the most critical elements of the mixing operation.

Almost all rubber compound mixing is now performed by internal mixers. These mixers consist of two rotors enclosed within a body. The mixers have a top door through which materials can be added to the mixing chamber, a powered ram that exerts pressure on top of the materials in the chamber and a door, located under the chamber, that allows the mixed materials to be discharged at the end of the mixing cycle.

Mixers come in many different sizes ranging from small laboratory devices to large industrial machines with chamber sizes of up to 620 litres capable of mixing batch sizes of 600 kg. There are two different types of mixers, one where the mixing action is carried out between the tips of winged rotors and the mixer body, and the other where the main mixing action is between two intermeshing rotors. The larger mixers are the most efficient when measured in terms of the amount of energy that is consumed to mix a kilogram of compound.

In the most basic mixing systems, materials are manually weighed and added to the mixer through the upper loading door. More modern mixing processes have fully automatic material handling systems that convey materials to weigh hoppers where they are automatically weighed and held until needed during the mixing cycle. Material handling systems for fillers, such as carbon black, often incorporate pneumatic conveying technology.

Oils that are used in compound recipes are usually automatically weighed and injected into the mixer by hydraulic cylinders. These automatic weighment systems are designed to give a high degree of weighment accuracy and to deliver the material quickly to the mixer chamber.

Some of the powder materials used in rubber compounding produce dust. And dust suppression systems, incorporating dust extraction and separation plant, are normally used to keep the working environment clean. These dust systems may consume a significant amount of energy.

The recipe for a compound provides a listing and weight of the ingredients in the recipe and the mixing procedure for a compound provides the instructions on how to make the compound. The procedure may be a simple instruction that tells the operator to load all the materials, bring the ram down and mix for "x" minutes and then discharge the batch of compound. Modern mixer control systems are fully computer controlled and can give the compounder the ability to control such variables as mixer speed, timing of material additions, mixer cooling, ram pressure, ram position, and mixer discharge according to time, temperature, integrated power or a combination of these.

Modern mixing control systems are designed to give the compounder a high degree of flexibility in order that he can obtain good mix quality with consistent physical results, in the shortest time cycle.

Several different techniques are used by compounders to mix rubber compounds. The one that is used is usually dependent on the type of equipment that is available, the product requirements and the support services.

A **single stage mixing process** is one where the masterbatch is mixed in the mixer, dropped into a dump mill and then transferred to other mills where curatives are added. The final compound is sheeted off and cooled on a cooling rack prior to stacking.

A **dual stage mixing process** is one where the masterbatch is mixed in the mixer, dropped into a dump mill, transferred to a sheeter mill, and cooled on a cooling rack prior to stacking. After aging of the masterbatch, the masterbatch is re-introduced to the mixer where it is re-mixed along with curatives and various other chemicals. It is then transferred to the mixer downstream and processed in the same way as the masterbatch.

A **multi stage mixing process** is required for some compounds. This process can involve a pre-mastication stage for natural rubber, first and second masterbatch stages, a re-mill stage and a final mix stage. The downstream equipment may be similar to that described for a dual stage mix.

It should be noted that an extruder and roller die system or an extruder and mill combination may be used in place of the dump mill and sheeter mill that is described above in the dual and multi stage mixing processes.

The energy consumption, measured in terms of kWh/kg of final compound, is dependent on many different factors. The main factors are:

- the raw materials and the recipe;
- the physical properties of the final product;
- the type of equipment being used (mixer and downstream);
- the services that are available to operate the mixer;
- the mixing procedure;
- production planning and efficiency.

The raw materials, the recipe, and the physical properties of the final product are beyond the scope of this handbook. The tips and audit questions that follow are, therefore, limited to the other factors.

The potential to save energy in a mixing process is dependent on the level of the compounding and process technology that is currently used. Some companies may be able to **reduce energy consumption by as much as 50% and improve equipment productivity by 100%** by making various changes to their equipment and compounding techniques.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

✔ Larger batch sizes, shorter mix cycles and less downtime will result in better mixer energy efficiency (kWh/kg).

✔ Determine the kg/hr and kWh/kg for similar compounds for each mixer system. Operate the most efficient mixer on a continuous basis (no stops).

✔ Install accurate temperature probes and kilowatt meters to accurately measure mix temperature and power consumption. Install recorders to record temperature and power versus time.

✔ Establish a program to maximize the batch size for each compound.

✔ Establish a program to reduce the number of mixing stages for each final compound.

✔ Establish a program to increase the available mixing time for the most efficient mixers by eliminating unnecessary delays, eliminating lost time at shift change overs and operating the mixers through break times.

✔ Cooling cavities for the mixer, mills and extruders should be de-scaled on a regular basis to improve heat transfer efficiency.

- ✔ Obtain recommendations from raw material and equipment suppliers on how to save energy.

Medium Cost:

- ✔ Where several mixers are used eliminate the least efficient mixer through the optimization of the most efficient mixers. This action will save more than just energy!
- ✔ Improve the capability of the various weighment systems (polymer weighment's, hand weighment's of chemicals, carbon black weighment's, automatic chemical weighment's, oil weighment's, etc.). The weighing systems should be accurate to +/- 0.2%. This will reduce the amount of off-spec compounds and, therefore, reduce total throughput requirements.
- ✔ Install kilowatt-hour meters and power integrators on all mixers to record electrical consumption for each batch. Data can be used to determine mixer efficiencies, batch to batch variations, run to run variations, experimental, etc. A power integrator is a device that deducts the mixer base load and integrates the effective mixing load to provide a measure of the energy that is consumed by the compound. Evaluate mixing procedures that use load and energy conditions in the same way as time and temperature conditions are used. Complete systems are available from mixing equipment specialists.
- ✔ Establish a program to minimize the total mixing cycle by making changes such as given in the following examples:
    - speed up loading time (belt speed, door open and close, delays);
    - speed up discharge time for blacks and other chemicals that must be added mid cycle;
    - install high speed oil injection system;
    - reduce number of ram up and down movements, speed up movements;
    - increase ram force (increased pressure, larger cylinder);
    - increase mixer RPM;
    - speed up mixer discharge time (door open, dwell and close times).
- ✔ Compressed air is an expensive way to provide the mechanical energy to move the mixer ram, door and gate. Conversion of these systems to hydraulic power should reduce energy consumption. The use of a hydraulicram also gives the capability to accurately control the position of the ram.
- ✔ Install a computerized mixer control system that will help with the optimization of the various variables that can affect mix quality, mixer throughput and energy consumption.

- ✔ Use variable speed drive for dust extraction systems to optimize flow by controlling the pressure drop across the filters.
- ✔ Install variable speed controls for the mixer and mill drives and use speed, in conjunction with integrated power, to optimize energy consumption during on-load and off-load conditions. The use of variable speed drive will also enhance the potential for single stage compounding.

Medium/Capital Cost:

- ✔ Consider finalizing compounds by adding curative at the downstream process of the mixer. This may involve adding additional milling equipment that will give the required degree of temperature control and curative dispersion.

Capital Cost:

- ✔ Replace inefficient mixers with larger and more efficient mixers.

D: Processing (Mills, Calenders and Extruders)

The processing area of a rubber factory is the part of the operation between mixing and vulcanization. The consumption of energy in this area depends on the type of product being produced. Products like tires consume a large quantity of energy whereas injection molded products consume relatively small amounts of energy. This part of the operation is not only significant because of the energy expended in processing the product through this section of the factory, it may also impact the energy requirements to cure the product.

During the last mixing stage of a rubber compound, curatives are added to form what is commonly known as a stock. At this point the stock is in a plastic state and can be readily shaped. The chemistry of the stock has to be designed in such a way that it will remain in this plastic state during processing operations and will not convert into an elastic state until it is vulcanized in the curing operation.

Vulcanization or curing is the chemical bonding (crosslinking) of rubber chains, usually via the action of sulfur and accelerator under pressure and at an elevated temperature.

When a stock is in a plastic state, it can be formed (shaped) by the application of force and the stock will retain the shape imposed upon it. Forming is mostly achieved by passing the stock between rolls (milling and calendering), by passing it through an orifice of the desired shape (extrusion) or by confining it under pressure in a mold of the required dimensions. These operations are usually called processing operations. Processing operations such as milling, calendering and extrusion perform work on a stock and this work causes the temperature of the stock to rise.

The chemistry of a stock is designed in such a way that it will withstand a certain period of processing and elevated temperature before the onset of vulcanization. This time period is called the scorch time. If the total processing time exceeds the scorch time, the stock will scorch (starts to cure). The scorch time for a stock should reflect the typical processing times in the factory plus some additional time for safety. After processing and the stock is ready for curing, there is normally some scorch time left in the stock. This is called the residual scorch. The time needed to cure the stock is the sum of the residual scorch time and the crosslinking time. The crosslinking time is the time required to take the stock from the scorch point (start of cure) to the fully cured state.

Products with high residual scorch times have cure times that are longer than necessary and therefore consume more energy than is required. These situations are also wasteful from a capital investment and productivity standpoint as they reduce the capacity of the curing equipment.

A stock that is processed through a number of different production operations, particularly those with several milling processes, may have a highly variable processing time. It is the extremes of these processing times that are used to determine the scorch time and cure time for a stock:

- the highest processing time determines the scorch time, and
- the difference between the highest and lowest processing times plus the crosslinking time for the stock determines the cure time.

A milling operation is a good example of a process that may have highly variable processing times for a stock. The throughput of the mill and hence the processing time for the stock on the mill can vary depending on the rate of production, the time required for making size changes, and the mill operating practices used by the various mill operators. One of the worst practices is when high mill banks are used "dead" stock may sit on top of the mill for considerable time before being pulled into the mill nip.

In order to reduce the energy consumption of processing operations, the following actions will yield the best results:

- reduce the number of different operations on a stock, especially those that heat and then cool the stock;
- reduce the processing time for each operation;
- reduce processing temperatures (by non-cooling means);
- replace hot feed processes with a more energy efficient cold feed extrusion system.

In order to reduce the energy consumption at curing operations, the following actions will give improvements:

- reduce processing time variations;
- reduce dimensional variations of the product.

Companies that presently use hot feed extrusion systems to prepare product prior to curing may be able to reduce processing energy costs by more than 50% by changing to a cold feed extrusion system. In addition to these savings, curing energy savings should also be possible since cold feed systems have less process variability than hot feed processes.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

- ✔ Review milling procedures and where necessary, revise them to include techniques that will reduce processing times and reduce the variability of processing times. Reducing mill banks will reduce processing times and their variability. Tighter nip settings will reduce processing times (widen or double up feed strip as needed).
- ✔ The stock being fed into a calender nip should be evenly distributed across the face of the calender roll and the stock in the nip should be minimal such that there are no "dead" spots (when the compound is not being pulled into the nip).
- ✔ Mills, calenders and extruders must be emptied out during stoppages. Stock should be sheeted out and placed on cooling racks to avoid using up excessive processing time.
- ✔ When equipment is not in use it should be switched off together with any ancillary services such as heating, cooling, exhaust fans, pumps, etc.
- ✔ Cooling cavities for mills, calenders and extruders should be de-scaled on a periodic basis to improve heat transfer efficiency.
- ✔ The pumping of cooling water can consume a considerable amount of energy and the use of cooling water should be minimized wherever possible. Thermometers should be installed at water inlet and outlet positions and the water flow rate should be regulated to a pre-determined temperature delta. This regulation can be carried out manually by the production operator or by automatic means.
- ✔ Look for ways to pipe cooling water in series to reduce the total requirement. Such an example is where a stack of cooling cans is being used to cool a calendered sheet of material. The cooling cans should be piped in series in such a way that the cooling water enters by the last cooling can and exits from the cooling can that is closest to the calender.
- ✔ Many companies have several extrusion and calendering lines that perform various functions. Look for ways to optimize the more efficient lines with a view to shutting down the less efficient lines.
- ✔ Cements are often used to obtain good adhesion between different rubber layers of a vulcanized product. Where solvent based cements are used, they should be converted to water based cements, or eliminated entirely by technical changes to the compounds and processing methods.

Medium Cost:

- ✔ The most effective way to reduce milling temperatures is to reduce the surface speed of the mill roll.
- ✔ Eliminate the use of compressed air wherever possible. If air is needed to dry an in-process material after contact with water, an air blower should be used.

Capital Cost:

- ✔ Modern cold feed extrusion systems require considerably less energy consumption than hot feed extrusion systems (a saving of up to 70% may be possible). They can also provide other benefits such as increased quality, improved scorch control, better productivity and less space requirement. Multi-extrusion systems may also reduce the number of processing operations. Cold feed extruders should also be considered as a replacement for mills that feed calender operations and, in some cases, entire calender lines.

E: Curing/Vulcanization Processes

There are many different methods for curing rubber but they fall into two basic categories - molding and continuous cure. The following is a brief description of some of the more common molding techniques used:

Compression Molding
Rubber is placed in a mold and an applied force causes the rubber to flow into the desired shape. Heat is transferred to the rubber via the mold.

Transfer Molding
This is a similar process to compression molding except that pre-heated rubber is forced through a channel into a closed mold from an external source. Using this method, multicavity molds can be supplied from one charge. Cure times are less as the rubber is already heated when it enters the mold. Heat is transferred to the rubber via the mold.

Injection Molding
The rubber is fed through a screw extruder and into an injection ram that injects the heated rubber into the mold. This is a process that is normally used in high volume applications as it offers a high degree of automatic control over the curing conditions. The capital cost is higher than other molding methods. Heat is transferred to the rubber via the mold.

Belting Presses
The pre-fabricated belt is fed between the open platens of a press. The platens are closed and a force is applied to the belt. Heat is applied to the belt via the platens.

Tire Curing Presses
Tire curing is a form of compression molding except that heat and pressure are also applied to the inside of the tire by means of a rubber bladder that inflates inside the tire. Steam and/or pressurized hot water are the most commonly used methods for heating the internal and external parts of a tire.

Steam Autoclaves
Autoclaves are used to cure large products that are not suitable for conventional molding presses. These products can be large off-the-road tires, re-treaded tires, large extrusions, hoses, rollers, large moldings, etc. The product inside the autoclave may be heated directly by steam or indirectly by air or inert gas that is heated by steam.

Steam Tube Continuous Vulcanization

Cables, hose and products that are reinforced can be cured by high pressure steam. A step-down system consisting of high pressure steam, pressurized hot water, low pressure water and atmospheric air is often attached to an extruder.

Drum Vulcanization

Drum vulcanizers are used to cure sheeting and proofed fabrics by heating them on rotating drums. When a consolidating pressure is required, a flexible steel belt is used to apply this pressure to the surface of the sheet material. The drums are heated by steam.

Fluidized Beds

These systems are typically installed in-line with extruder systems that make profiled strips or cables. The fluidized bed consists of ceramic or glass beads that are held in suspension by jets of hot air or inert gas. The fluidized bed supports the product as it is pulled through the bed and heat is transferred to the product by conduction and convection. The air or inert gas is usually pre-heated by steam.

Salt Baths

This is a similar process to the fluidized bed process except that molten salts such as sodium and potassium nitrates are used in place of the fluidized bed of beads. A good exhaust system is needed to remove the fumes from this process. The salts are usually heated directly by electrical elements or by gas firing.

Hot Air Ovens

Products, supported on trays, are heated by natural or forced air convection. Heating of the oven is usually done by electrical elements or gas firing.

Microwave Curing

The capital cost for microwave heating is higher than for other continuous cure systems but it offers rapid and even heating of the product and high energy efficiency. It is limited to the curing of polar compounds and those with added carbon black. After the initial heating of the product by microwave, it is normal to maintain the temperature of the product by conveying it through a tunnel of hot air.

Induction Heating

Electrical induction heating is sometimes used to cure the rubber on rubber coated metal rollers and larger objects with metal inserts. The metal insert is used as the conductor.

Because of the large variety of products and the different types of curing processes used, it is impossible to provide a general energy consumption target that manufacturers can use to compare themselves against. As a base level from which to make comparisons, the following theoretical consumption may be useful:

Heat rubber to cure temperature of 180^{0}C	0.085 kWh/kg
Force rubber into mold at 250 Bar	0.007 kWh/kh
Estimate to move press components	0.003 kWh/kg
Total energy consumption	0.095 kWh/kg

A recent UK survey of rubber product manufacturers found a wide range of energy consumption for products produced from presses, ranging from a low of 0.3 kWh/kg to a high of 278 kWh/kg.

It is suggested that each manufacturer determine for themselves (or as a group of manufacturers making similar products) an indicator that can be used to measure energy consumption in their curing operation. Using this indicator, performances can be measured, comparisons can be made and targeted improvements can be established.

The effect of processing operations should be considered in any energy reduction plan for the curing operations.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

✔ There are a number of manufacturing variations that result in the cure time for a product being longer than is theoretically required. Time may be added to the cure time for factors such as residual processing time, excessive material gauge, lower than specified cure temperatures, timer inaccuracies, etc. Safety factors may extend theoretical cure times by as much as 25%. A reduction in the variations that cause them can yield big savings in curing energy consumption and, as a bonus, curing capacity will be increased.

✔ Much of the thermal energy that is lost in a curing process is accounted for by the specific heats of molds and machinery, many times larger than the product itself, and heat losses from the molds, platens, machinery, piping, etc. The process should be examined in great detail to determine ways whereby heat losses can be reduced or recovered for other useful purposes. The use of insulation material is normally the most effective way to reduce thermal energy loss.

✔ When a curing operation is interrupted for loading, unloading, size change, product shortage, machine breakdown, etc., energy is wasted. It is more energy efficient to have five machines operating at 100% than to have ten machines operating at 50%. Look for ways to reduce the non-curing time and shut down presses that are surplus to requirements.

Medium Cost:

✔ The time needed to cure a product is dependent on the chemistry of the compound used and on the temperature of the curing process. It may be possible to make changes that would reduce the time and the energy required to cure the product (equipment changes may be needed to achieve this).

✔ Molding operations should be fitted with automatic time and temperature controls in order that curing can be controlled and energy waste is avoided.

✔ Many molding operations use electricity to heat the molds. This can be expensive, particularly at peak times. Steam or direct gas should be evaluated as an alternative.

✔ In the curing of some types of tires, lower temperatures and high internal pressures are required. To achieve this condition, high pressure hot water systems are used but these systems are very energy inefficient. A newer process, using a mixture of steam and nitrogen, will give the same result but with lower energy consumption.

✔ Many mechanical presses use hydraulic power to operate them. The hydraulic power plant is often oversized, being designed to operate several presses simultaneously when in practice only one press opens at a time. Some of the hydraulic pumps run continuously, bypassing fluid when the operating pressure is reached, instead of switching off the motor. Energy savings can be achieved by replacing the pump motor with a pressure controlled variable speed drive and fitting the presses with interlocks that prevent presses opening simultaneously.

F: 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.

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

In much of the industry 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 on a percentage work-off basis. This concept is far from the truth. Although it usually more cost effective to rework material than to scrap the material, consider 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 rework;
- the additional energy needed to convert rework into a usable form.

Some manufacturers in the rubber manufacturing sector are wasting in excess of 5% of their total energy spending on the generation of scrap, waste and rework.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

- ✔ The goal should be to produce zero waste. The quantities and reasons for scrap, waste and rework should be accurately recorded and reviewed on a daily basis. Plans should be in place to eliminate the causes for any waste and rework.
- ✔ If scorched compound is a problem in the post-mixing process, check the mill operating and calendering practices. Mill banks should not exceed 150 mm and calender nips should have a rolling bank that should not exceed 15 mm in diameter. When operations are stopped for any reason mills, calenders and extruders should be emptied.
- ✔ Variation is the cause of most scrap, waste and rework. A good quality system incorporating employee involvement techniques, such as Statistical Process Control (SPC), will reduce process variations considerably.

Medium Cost:

- ✔ If there is a significant variation in mixed compound physical properties and batches are being rejected, check the accuracy of the weighment's (automatic and hand) that are being fed into the mixer. Also check that the batch to batch sequencing of the various mixer functions are controlled. Weighment systems and mixer controls may need to be upgraded or replaced.
- ✔ If the water cooling system on a mill is working efficiently, the next most effective way to reduce the compound temperature is to reduce the speed of the front roll.
- ✔ Vulcanization processes require reliable energy sources that can be accurately controlled with respect to temperature, pressure and time. Good instrumentation that is calibrated on a regular basis and a control system that provides flexibility and reliability are essential.

G: Finished Goods Storage

The optimum solution would be a situation where finished goods are removed directly from the end of the production line and loaded onto a truck for delivery to the customer. There would be no need to have a finished goods store that requires energy for heating, lighting and the trucking equipment that is required to move the finished goods in, out and around the store. This may not be a practical solution for most manufacturers but the principle of keeping finished goods storage space requirements to a minimum will result in lower energy requirements for heating and lighting.

Energy losses at the truck loading bay can be considerable if doors are left open or if door seals are not employed during loading operations.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

✔ It is not necessary to maintain the temperature in this area at the same level as production areas. Install temperature controllers. Consider the installation of a dry sprinkler system if there is a risk of freezing. Use radiant heaters at the loading dock for the comfort of the truck loading personnel.

Medium Cost:

✔ Lighting quality is not critical in this area and high efficiency lighting such as high pressure sodium lamps should be evaluated. Consider the use of motion sensors to turn lights off when no one is present.

H: Boilers and Steam Distribution

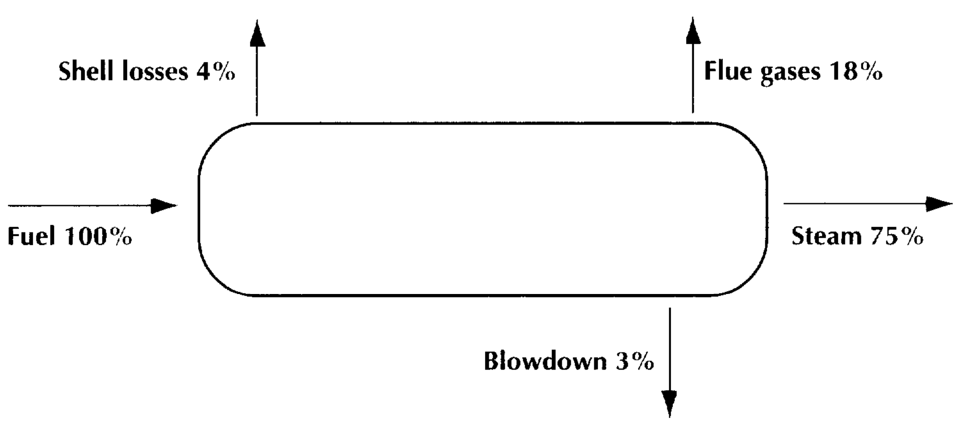
Most rubber factories use boilers for the generation of steam which is mostly used in the curing process and for heating the factory.

In some operations the cost of the fuel to run the boiler plant can be as much as 50% of the total energy bill. It is important, therefore, to ensure that the boiler operation and the distribution system associated with it is utilized in the most energy efficient way. This section presents some of the basics for the efficient operation of a boiler plant and identifies some elements of the operation where energy efficiencies may be improved. It should be remembered that the design and maintenance of a boiler plant and its associated distribution network is a highly specialized skill and expert help must be sought before making engineering or operational changes to a system.

Boilers

The following chart illustrates an example of inputs and outputs for a typical oil or gas fired steam boiler. The thermal efficiency of the boiler is 75%. (Note: based on the gross calorific value of the fuel, a gas or oil fired shell boiler that produces steam should operate in the 75% to 77% efficiency range.)

Boiler Input and Losses



The following paragraphs describe the major controllable factors that impact on boiler efficiencies and, therefore, offer the best opportunities for improvement:

Flue Gas Heat Loss

The major factors influencing flue gas heat loss is the exit temperature of the flue gas and the degree of excess air present. Losses can be minimized by having good combustion which is achieved through proper burner set-up and maintenance, and by using air at the right rate with sufficient turbulence.

Heat Loss to Carbon Monoxide

When carbon is not converted to carbon dioxide, the fireside heat transfer surface of the boiler becomes fouled with soot causing a loss in boiler efficiency. This condition can occur when there is insufficient combustion air, inadequate fuel and air mixing, or when the combustion air is too cold. The level of carbon monoxide can be kept to a practical minimum by controlling the amount of dark smoke produced.

Blowdown Heat Loss

The amount of blowdown required is dependent on the level of total dissolved solids (TDS) allowed in the boiler water, the quality of the make-up water, and the amount of uncontaminated condensate that is returned to the boiler plant.

Steam Distribution

The purpose of the steam distribution and condensate return systems is to efficiently deliver steam from the boiler plant to the process and heating equipment and to return condensate to the boiler for re-use.

The following paragraphs describe the major controllable factors that impact on the distribution system energy efficiencies and, therefore, offer the best opportunities for improvement.

Redundant Piping

In older plants where processes have changed significantly, there is often a large quantity of redundant piping. There may also be situations where, because of a reduction in steam requirements, large pipes are carrying very low volumes of steam.

Insulation

The insulation and the selection of the correct insulating material are important factors in reducing heat losses from steam lines, flanges, valves, condensate lines, etc. Lack of insulation on steam lines also causes the steam to condense and this adversely affects steam quality and heat transfer to production processes.

Steam Traps

Steam traps are designed to remove condensate from pipework or from a production process, to stop steam from escaping, and to release any gases from the steam carrying part of the system. It is not unusual to find 10% of the steam traps installed in a manufacturing plant to be faulty.

Heat Transfer

The efficient transfer of heat from steam to the production process is critical for the efficient performance of the production operation. The presence of scale, condensate and air films on the metal wall of the steam side of the heat transfer device can greatly reduce the efficiency of heat transfer.

Condensate Recovery

Condensate may contain 20% of the original heat used to generate the steam. The condensate should be returned to the boiler plant where the heat can be recovered and the water can be re-used as feed to the boiler. As the water is chemically pure, pH adjustment is the only treatment required.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

✔ Pressure gauges, temperature indicators and flow meters are needed to provide information about conditions at various critical positions of the system. Information from some of these indicators should be charted for record purposes.

✔ Boiler efficiency should be checked on a regular basis. The simplest method is to measure the volume of fuel used over a period of time and the amount of steam generated over the same time period. Convert both into energy units (kJ or Btu) and the ratio of the two is the efficiency of the boiler.

✔ To determine whether the correct amount of combustion air is being used, check the levels of oxygen and carbon dioxide in the flue gas with a flue gas analyzer. The levels for oxygen should be in the following ranges:

- natural gas - 2.0% min. and 2.7% max.
- heavy fuel oil - 3.3% min. and 4.2% max.

A reduction of 10% in excess oxygen will reduce the flue gas temperature by 2.5% and increase boiler efficiency by 1.5%.

- ✔ Insufficient combustion air can cause soot build up on the fireside of the boiler heat exchanger. Soot blowers or manual lances should be used to remove any buildup. A scale buildup of 1 mm will increase fuel usage by 2%.
- ✔ Excessive blowdown can cause a considerable loss of thermal energy as well as the chemicals used to treat the water. Periodic testing of total dissolved solids (TDS) should be made and blowdown levels should be adjusted to a minimum requirement.
- ✔ Establish a maintenance program to inspect, repair and replace steam traps. A trap leaking 7 bar steam through a 2 mm orifice will lose 10 kg of steam per hour.
- ✔ Establish maintenance programs to descale heat transfer surfaces, both steam side and process side, on a periodic basis.

Medium Cost:

- ✔ Check the temperature of the flue gases. A number of different systems are available to recover heat from flue gases. The most commonly used system is the economizer which is a heat exchanger that uses heat from the flue gases to heat the boiler feedwater. A reduction of 20°C in the temperature of the flue gases will improve boiler efficiency by 1%.
- ✔ Blowdown can be collected in a flash tank to generate low pressure steam for use in heating systems or for deaerators. Other heat can be used to preheat feedwater.
- ✔ The disposal of used oil can be expensive. It is possible to fit boilers with burners that will mix waste oil with the regular boiler fuel. This is a solution that saves on both fuel costs and disposal costs.
- ✔ Reuse condensate as feedwater.
- ✔ Remove redundant piping. Oversized piping should be replaced. Piping layouts should be reviewed and optimized every five years.
- ✔ Establish an insulation program and provide regular funding for new insulation and the replacement of damaged insulation.

I: Compessed Air

Compressed air is used extensively in some rubber manufacturing plants to power components of production equipment, to operate air tools, and sometimes to remove water or dust from the surfaces of products and equipment.

Compressed air is a very inefficient and, therefore, a very expensive form of energy. Every effort should be made to reduce its usage and to improve the efficiency of the compressed air system.

The pressure of compressed air used in a system is determined by the operation that requires the highest pressure. Compressors are normally of the screw type or reciprocating type.

Leaks are common with compressed air systems. The following table illustrates the result of leakages through various sized holes in a 600 kPa gauge system using electricity that costs 5 cents per kWh:

Hole dia.	Air Leakage	Cost per Month
1 mm	1.0 L/s	$10
3 mm	10.0 L/s	$111
5 mm	26.7 L/s	$298
10 mm	105.0 L/s	$1,182

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

✔ Reduce the system air pressure to the minimum pressure that is required to operate the various pieces of equipment. Check that the system being operated is not faulty (requires higher than design pressure) and that there are no piping problems causing system pressure drops.

- ✔ Eliminate all leaks in the distribution system. Losses normally occur at joints, valves, fittings, and hose connections.
- ✔ Avoid water in the system. Water causes corrosion of the pipes resulting in flow resistance, pressure drop, and pitting that can lead to leaks.
- ✔ Air intake for compressors should come from the coolest possible location, normally outdoors. If air is used to cool the compressors, discharge outdoors during the summer and indoors for heating during winter.
- ✔ Switch off compressors when production is shut down. If compressed air is needed for instrumentation, install a separate compressor for this function.
- ✔ When reciprocating compressors and screw compressors are used in parallel, always maintain screw compressor at full load. When partial loads are required, use the reciprocating compressor and shut down the screw compressor.

Medium Cost:

- ✔ Review all operations where compressed air power is being used and develop a list of alternative ways to perform the same function.
- ✔ If compressors are water cooled, look for ways to recover heat from the cooling water circuit.
- ✔ When more than one compressor is needed, sequence the compressors so that one or more compressors are shut off rather than have several operating at part load when the demand is less than full capacity.

J: Cooling Water

When substantial quantities of cooling water are required, a system to recirculate the water through a water cooling tower should be employed. In this way the cost of purchasing the water and sewage disposal fees are kept to a minimum.

A cooling tower system requires electricity for the fans and pumps, chemicals to treat the water, water make-up to compensate for evaporation, and maintenance. These are some of the costs that have to be accounted for when determining the economics of installing such a system.

Any operation that requires cooling water should be carefully monitored to ensure that the minimum of cooling water is being used. When an operation is in a shut down condition, cooling water should be switched off.

Cooling water is often used in the rubber industry to compensate for oversized equipment that causes the product to overheat during processing. If ways are found to reduce this overheating effect, cooling water requirements are reduced and the energy used to operate the process will also be reduced.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

✔ The flow of water through a process should be regulated according to the amount of cooling that is required and shut off when no cooling is required. This can be done manually but is better performed with automatic controls.

Medium Cost:

✔ Single pass cooling is a parallel system where cooling water enters a process from the cooling water source and is then returned to the source or dumped to the sewer. Multi-pass cooling is a series system where the cooling water passes through two or more processes before being returned to its source or dumped to the sewer. The multi-pass system is much more energy efficient.

✔ Review some of the tips given in the section titled "Processing (mills, calenders & extruders)".

✔ Look for ways to remove and reuse heat from the cooling water after it has passed through the production process.

K: Electric Motors

In a typical industrial business electric motors consume 80% of the total electricity supply. It is, therefore, important to use electric motors that will convert a high percentage of the electricity used by them into mechanical power. In many industrial applications, electric motors are grossly oversized for the work they have to perform and as a result, operate well below their rated capacity. Most motors are designed to operate efficiently in the 75% to 100% range of their rated capacities. The main cost penalties for motors that operate outside this range are:

- at loads of less than 50%, the efficiency of the motor drops off significantly resulting in higher energy costs;
- at loads of less than 75%, the power factor reduces to a level that can result in billing penalties for inefficient use of the electricity supplied;
- higher motor purchase costs for the larger motor.

High efficiency three-phase induction motors are available in sizes from 1 hp up to 200 hp. They are more expensive than standard motors but will reduce energy (kWh) and demand (kW) costs relative to standard motors by 7 to 10%. To put the initial cost and energy costs in perspective, the cost of electricity consumed during the life of a motor is usually 75 times the initial cost of the motor.

The straight replacement of a standard motor with an energy efficient motor may not be economically viable but the replacement of an oversized standard motor with an energy efficient motor that is correctly sized for the task being performed may well be a good investment.

Each application where electric motors are used has to be evaluated to determine what actions, if any, should be taken.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

✔ When smaller motors fail, replace them with energy efficient motors.

Medium Cost:

✔ When larger motors need to be rewound, replace them with energy efficient motors. The difference between the cost of a new motor and the cost of rewinding can usually be recovered in a relatively short time period through energy savings.

✔ Motors that operate at less than 50% of their load rating should be considered for replacement with energy efficient motors.

L: Envelope

In most parts of Canada, buildings need to be heated in the winter and kept cool in the summer. This can be achieved through the use of a well designed HVAC system but this can add considerably to the cost of a manufacturing operation. It may be possible to reduce heat loss and heat gain by making changes in the following key areas:

- reducing heat transfer through walls, roof, and windows;
- reducing air leaks through doors, windows, and other openings.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

✔ Consider the use of absorbing or reflective glass for office windows to reduce the absorption of solar energy during the summer and to permit the absorption of low angle sun rays during the winter.

✔ Outside doors should be sealed to prevent air from leaking in or out of the building. Revolving doors, vestibules and automatic doors should be considered for areas of high traffic. Door seals should be used at loading docks.

✔ The only practical way to upgrade the wall insulation of an operational building is to add insulation to the external surface of the walls and cover it with weatherproof cladding.

✔ Most of the winter heat loss and summer heat gain in flat roofed buildings occurs through the roof. Insulation improvements should be evaluated before making any major repairs to the roof as the payback on the additional costs may make them a worthwhile investment.

✔ Windows in older factories are usually single glazed and leak air. Consider replacing them with double glazed fiberglass or plastic panels. These panels pass light, are energy efficient and are unbreakable.

M: HVAC

Heating, ventilation and air conditioning systems are mainly provided for people comfort. They are designed to counteract the effect of heat loss and heat gain through the provision of temperature, ventilation and humidity control.

HVAC systems consume a considerable portion of the energy usage in a rubber producing factory. In Canada most of this energy is used for the heating and ventilation systems. Few companies have found it necessary to provide air conditioning systems for their production operations. Companies that have done little work on energy conservation may find that their HVAC system offers some real opportunities to save on costs.

Heating and Ventilation

Heating and ventilation requirements can be reduced in a number of different ways. Some general suggestions that should be evaluated for each area of the manufacturing operation are listed below:

- improve building insulation and reduce air leaks (see section L - "Envelope");
- establish lowest acceptable temperatures for each area of the building for both working and non-working periods;
- reduce the level of air entering the building from the outside to the minimum regulated standard;
- reduce the level of air exhausting from the building to a minimum;
- avoid stratification during winter time;
- recover waste heat from process and use to heat building.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

✔ When a building is unoccupied, shut down unnecessary HVAC equipment.

✔ Where possible, use zone heating and control each zone by a thermostat. Set each thermostat to the minimum acceptable temperature for employee comfort. Use temperature setbacks for periods when the building is unoccupied.

✔ During winter time, avoid stratification. This is when the warm air rises to the roof and the cooler air is at working levels. This layering is caused by high ceiling heights and lack of air circulation. The use of destratification fans will reduce this effect. Note, however, that stratification is beneficial in hot weather, therefore fans should be switched off when heating is not required.

Medium Cost:

- ✔ Where fumes from processes such as milling and curing need to be exhausted, construct a hood above the part of the operation that is giving off the fumes and remove the fumes with an exhaust fan.
- ✔ Design the fresh air intake to the building according to the minimum standard required by regulation. This requirement may vary depending on employee activity. The use of a control system to switch on and off intake and exhaust systems should be considered.
- ✔ Avoid pressure differentials between the outside and inside of the building. Negative pressure in the building will cause cold air to enter the building through door openings, cracks, etc. Positive pressure in the building will cause heated air to escape to the outside.
- ✔ The rubber manufacturing process offers many opportunities to recover waste heat. Several examples were previously identified in section J: "Boilers and Steam Distribution." It is normally possible to recover 65% of the heat from the exhaust air.
- ✔ Reduce costs by replacing electric resistance heating with direct or indirect gas, or by using a boiler.

Captital Cost:

- ✔ The use of solar energy for heating is a practical solution but has a high initial cost. Payback may take several years at today's energy costs - but may be much less at future fuel costs!

N: Lighting

The first step in determining the level and type of lighting that is appropriate for the different areas of an operation is to make a lighting survey of the location. The survey should contain details of the existing lighting:

- the location;
- the task being performed at the location;
- the type of lighting, and
- the lighting level.

Lighting levels can be measured with a photometer which measures the lighting level in lux (lumens/square metre).

After completing the survey, the data should be reviewed to determine if the existing levels are appropriate and whether there are opportunities to save energy by changing practices or by making equipment changes. The following table gives some general guidance on the lighting levels suitable for a number of different tasks.

Lighting Levels

Type of task/activity	Lighting Level (lux)	Examples
Open parking area	20	
Entrance to building	50	
Tasks occasionally performed	150	Warehouse, prod. storage areas
Indoor walkways	150	Corridors
Low detail production jobs	300	Milling
Medium detail production jobs	750	Calendering, tire building
Office	750	
Inspection	1500	Finished product

In a rubber factory a typical lighting arrangement would be one that has general lighting providing 150 lux and specific task lighting where required. The following table provides information on the most commonly used lighting systems.

Typical Lighting Systems

Lighting Type	Efficacy Lumens/Watt	Lamp Life (Hours)	Relative Capital Cost	Relative Maintenance Cost
Incandescent	10-35	1,000+	low	high
Fluorescent	40-100	10,000+	medium	medium
High Pressure Sodium	50-140	20,000+	high	low

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

✔ Employees should be encouraged to switch off lights when not in use. As a guide, fluorescent lighting should be switched off if not in use for more than 15 minutes and high pressure sodium for more than 1 hour.

✔ Delamp areas that are over lit. When doing this the ballast for fluorescent and high pressure sodium lighting should be removed as the ballast consumes electricity even when the bulb is removed.

✔ Use timers, photocells and motion sensors to automatically switch lighting for such functions as security patrols, warehousing operations, etc.

✔ Dimming of lighting saves energy. This can be effectively used in the general production area when there is no activity and the office area during office cleaning.

✔ Dirty bulbs, reflectors, and covers reduce the efficiency of a lighting system. A routine cleaning program is necessary.

Medium Cost:

✔ Reduce the level of general lighting to a minimum and provide task lighting at work stations as required.

V - Energy Monitoring and Control Systems

An energy monitoring and control system is a computer based system that collects data from meters and transducers and performs control functions on energy consuming devices. The systems are designed to manage energy functions in such a way that the correct amount of energy is being used while keeping costs to a minimum. These systems used to be very expensive and were only affordable by the larger companies but, with the reduction in the cost of computers and the higher costs of energy, they are now economically viable for smaller companies.

A system can be a simple stand alone system that automatically monitors and controls a single piece of equipment such as a thermal control unit for an extruder, or it can be an integrated energy management system that monitors and controls all the electrical and thermal devices that used in the heating, ventilation, air conditioning, and lighting of a building.

The following table illustrates what can be monitored and controlled.

Equipment to Monitor /Control

	Monitored	Controlled
Lighting	fluorescent, incandescent	on/off, level, modulated
Temperature	space, ambient, zone, area	on/off, preset, setback
Flow	liquid, gas, steam	on/off, preset, rate, level
Pressure	liquid, gas, steam	off/off, preset, rate, level
Energy	electrical, mechanical, thermal	on/off, preset, rate, level
Position	angular, linear, circular, rotational	on/off, preset, angular, linear, circular, rotational
Machine	operation, position	on/off. preset, position

It should be noted that control systems used for production processes normally provide quality and productivity benefits as well as energy savings.

Tips

(Low/No Cost - 6 months; Medium Cost - 3 years requiring retrofit; Capital Cost - over 3 years and new equipment)

Low/No Cost:

✔ Determine which parts of the process would yield improvements and savings with some form of automatic control. Develop a system design that incorporates the features required for the long term but that can be implemented on a modular basis.

Medium Cost:

✔ Utility bills provide some information about energy consumption but this is not nearly sufficient data for the implementation and management of an effective energy program. Energy managers need to know the flow rates, temperatures and pressures of steam, water and compressed air for the total process and for the major users of these services; they need to know where, when, and how much electricity is being used at the various operations in the plant; etc. As a first step install sufficient monitoring and recording equipment that will provide a good picture of the energy consumption patterns.

Capital Cost:

✔ Provide automatic energy management systems in the following areas:
- peak demand management;
- HVAC;
- boiler plant;
- mixers;
- curing.

Conversion Factors

Energy

1 kWh	3,412 Btu
1 Therm	100,000 Btu
1 Therm	29.31 kWh
1 m natural gas	10.35 kWh (varies slightly by supplier)
1 US gallon #2 Oil	41.03 kWh
1 US gallon #4 Oil	42.20 kWh
1 US gallon #6 Oil	44.55 kWh
1 boiler horsepower	9.812 kWh
1 mechanical horsepower	0.746 kWh
1 Mj	0.278 kWh
1 Mj	948.5 Btu

Pressure

1 bar	14.50 psi

Contacts

Provincial Government Energy Management Programs

Alberta
Energy Efficiency Branch
Alberta Department of Energy
7th Floor, North Petroleum Plaza
9945 - 108 Street
Edmonton, Alberta T5K 2G6
Tel: (403) 427-5200

British Columbia
Energy Management Branch
Energy Resources Division
Ministry of Energy, Mines and Petroleum Resources
617 Government Street, Room 418
Victoria, British Columbia V8V 1X4
Tel: (604) 387-3048

Manitoba
Energy Management Branch
Department of Energy and Mines
555 - 330 Graham Avenue
Winnipeg, Manitoba R3C 4E3
Tel: (204) 945-1111

New Brunswick
Energy Branch
Department of Natural Resources
P.O. Box 6000
Fredericton, New Brunswick E3B 5H1
Tel: (506) 453-3949

Newfoundland
Energy Efficiency and Alternative Energy Division
P.O. Box 8700
St. John's, Newfoundland A1B 4J6
Tel: (709) 576-2776

Nova Scotia
Department of Natural Resources
P.O. Box 698
Halifax, Nova Scotia B3J 2T9
Tel: (902) 424-5351

Ontario
Programs and Technology Branch
Ministry of Environment and Energy
56 Wellesley Street West, 14th Floor
Toronto, Ontario M7A 2B7
Tel: (416) 327-2955

Prince Edward Island
Energy and Minerals Branch
P.E.I. Economic Development and Tourism
P.O. Box 2000
Charlottetown, P.E.I. C1A 7N8
Tel: (902) 368-5010

Quebec
Direction de l'éfficacité énergétique
Ministère des Ressources naturelles du Québec
5700, 4e Avenue Ouest, pièce B-406
Charlesbourg (Québec) G1H 6R1
Tel: (418) 646-9395

Saskatchewan
Energy Branch
Saskatchewan Energy and Mines
1914 Hamilton Street
Regina, Saskatchewan S4P 4V4
Tel: (306) 787-2618

Electric Utilities

Alberta Power Limited
Market Development
P.O. Box 2426
Edmonton, Alberta T5J 2V6
Tel: (403) 420-7644

British Columbia Hydro
Energy Management Division
1177 Hornby Street, Suite 900
Vancouver, British Columbia V6Z 2E9
Tel: (604) 663-3286

Edmonton Power
Customer Services
Century Place
9803 - 102A Avenue
Edmonton, Alberta T5J 3A3
Tel: (403) 448-3020

Hydro-Québec
Efficacité Énergétique
1010, Ste-Catherine Ouest
C.P. 6162
Montréal, Québec H3C 4S7
Tel : (514) 392-8164

Manitoba Hydro
Energy Management
P.O. Box 815
Winnipeg, Manitoba R3C 2P4
Tel: (204) 474-3341

Maritime Electric Co. Ltd.
Customer Services
P.O. Box 1328
Charlottetown, P.E.I. C1A 7N2
Tel: (902) 566-1599

New Brunswick Power
Conservation and Energy Management
P.O. Box 2000
Fredericton, New Brunswick E3B 4X1
Tel: (506) 458-3196

Newfoundland and Labrador Hydro
Economic Analysis
P.O. Box 12400
St. John's, Newfoundland A1B 4K7
Tel: (709) 737-1354

Newfoundland Power
Energy Management
P.O. Box 8910
St. John's, Newfoundland A1B 3P6
Tel: (709) 737-2854

Nova Scotia Power
Corporate Programs
P.O. Box 910
Halifax, Nova Scotia B3J 2W5
Tel: (902) 428-6455

Ontario Hydro
Energy Services and Environment
700 University Avenue (H19-A20)
Toronto, Ontario M5G 1X6
Tel: (416) 592-3321

SaskPower
Energy Management Services
2025 Victoria Avenue
Regina, Saskatchewan S4P 0S1
Tel: (306) 566-2914

TransAlta Utilities
Energy Efficiency Programs
P.O. Box 1900
Calgary, Alberta T2P 2M1
Tel: (403) 267-7345

West Kootenay Power
PowerSmart
1260 Commercial Way
Trail, British Columbia V2A 3H5
Tel: (604) 493-3818

Winnipeg Hydro
Customer Services
223 James Avenue
Winnipeg, Manitoba R3B 3L1
Tel: (204) 986-2214

Natural Gas Utilities

BC Gas Utility Inc.
Senior Product Engineer, Industrial
1111 West Georgia Street, 6th Floor
Vancouver, British Columbia V6E 4M4
Tel: (604) 443-6772

Canadian Western Natural Gas
Industrial Marketing
909 - 11 Avenue South West
Calgary, Alberta T2R 1L8
Tel: (403) 245-7740

Centra Gas Ontario Inc.
Senior Engineer
200 Yorkland Boulevard
North York, Ontario M2J 5C6
Tel: (416) 496-5221

Centra Gas Manitoba Inc.
Senior Engineer
510 444 St. May Avenue
Winnipeg, Manitoba R3C 3T7
Tel: (204) 934-3227

Gaz Metropolitan Inc.
Director of Development and Technology Assistance
1717 Du Havre Street
Montréal, Québec H2K 2X3
Tel: (514) 598-3461

SaskEnergy
Manager, Energy Management
1945 Hamilton Street, 11th Floor
Regina, Saskatchewan S4P 2C7
Tel: (304) 777-9368

The Consumers' Gas Company Limited
Director Industrial/Commercial Marketing
2235 Sheppard Avenue East, 10th Floor
North York, Ontario M2J 5B5
Tel: (416) 496-5315

Union Gas Ltd.
Director of Development and Technology
50 Kiel Drive North
Chatham, Ontario N7M 5M1
Tel: (519) 436-4671

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 billing 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 lighting switched off when buildings, storage areas, offices, etc. are unoccupied? Can outside security lighting 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 a raw material store?
- ❑ Are air seals used around truck loading doors? Are loading doors closed when not in use?
- ❑ Can the lighting levels be reduced? Is high efficiency lighting 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 minimize heat loss?

- ❑ Are the hot room doors kept closed except when loading and unloading?
- ❑ Is the volume of rubber being heated in the hot rooms sufficiently high to justify the purchase of a microwave heating system?
- ❑ Are the rubber blocks stacked in such a way to maximize 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?
- ❑ Can any of the following ancillary operations be speeded up?
  - 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 maximum 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 change-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 optimizes 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 utilized in other systems such as a pneumatic material handling system?
- ❑ 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 mill 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 cavities?
- ❑ 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-organize operations by moving product from less efficient lines 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 / Vulcanization 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 molds, 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 many interruptions to the curing process that result in energy being wasted? Can the open and close cycle for molding operations be reduced in order to reduce heat losses? Is there live heating services connected to idle equipment? By 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 the system? Are there control charts at the production work stations?
- ❑ 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 equipment 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 lighting levels be reduced? Is high efficiency lighting 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 content 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 percentage 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 a 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 minimize movement 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 stopped or working at lower levels of production?
- ❑ Is 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?

Lighting

- ❑ 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 lighting 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 lighting systems be replaced with a more energy efficient system?

Notes for Follow-up

Notes for Follow-up

The Rubber Association of Canada

Acton International Inc.
Air Boss of America Corp.
American Biltrite (Canada) Ltd.
H.A. Astlett & Co. Inc.
Bandag Canada Ltd.
Bayer Inc.
Bekaert Steel Wire Corporation
Biltrite Rubber (1984) Inc.
Bridgestone/Firestone Canada Inc.
Cabot Canada Ltd.
Canadian Rubber Testing & Development Ltd.
Cancarb Limited
Columbian Chemicals Canada Ltd.
Continental General Tire Canada, Inc.
Continental Waste Management Corp.
Cooper Tire & Rubber Company
Custom Cryogenic Grinding Corp.
Dunlop Tires (Canada) Ltd.
Du Pont Canada Inc.
Dura Undercushions Ltd.
Escalator Handrail Company
Exxon Chemical Company
Farrel Corporation
Flexsys Co.
GE Canada Silicones
Gates Canada Inc.
GenCorp Vehicle Sealing Division
Goodyear Canada Inc.
Hamilton Kent
Hankook Tire Canada Corp.
Henkel Canada Ltd.
Imperial Eastman
Industrial Tires Limited
Integrated Tire
I.R.P. Industrial Rubber Ltd.
ITRM Inc.
Kumho Canada, Inc.
L.V. Lomas Limited/Limitee
Mark IV Automotive Canada
Michelin North America (Canada) Inc.
NRI Industries Inc.
Nokian Tyres (North America) Ltd.
Pirelli Tire Inc.
R.M. Ferguson & Company Inc.
Recovery Technologies Inc.
St. Lawrence Chemical Inc.
Scandura Canada
Standard Products (Canada) Limited
Sumitomo Rubber Industries Ltd.
Techno Rubber Inc.
Thona Inc.
Toyo Tire Canada Inc.
Trent Rubber Corp.
Uniroyal Chemical Ltd.
United Tire & Rubber Co. Limited
Van Waters & Rogers Ltd.
R.T. Vanderbilt Company Inc.
Waterville TG Inc.
Yokohama Tires (Canada) Inc.
Zochem Ltd.