ENERGY EFFICIENCY OPPORTUNITIES

IN THE SOLID WOOD INDUSTRIES

An Initiative supported by:

The Council of Forest Industries

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INTRODUCTION

On behalf of the Wood Products Task Force of the Canadian Industry Program for Energy Conservation (CIPEC), the Council of Forest Industries (COFI) retained Carroll-Hatch (International) Ltd. (CHI) to identify and analyze information related to industrial energy use in the Canadian solid wood industries sector and the opportunities for efficiency which may exist.

CIPEC consists of 16 task forces representing the various industrial sectors in Canada. The Wood Products Task Force is currently chaired by a representative from COFI.

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.

COFI has a mandate to create a climate for the consistent, healthy economic performance of the B.C. forest industry. Within this mandate, COFI's key strategic direction is to initiate and promote industry policy to enhance the competitiveness of the forest industry. Therefore, the CIPEC Wood Products Task Force asked COFI to coordinate an Energy Efficiency Opportunities (EEO) study on their behalf.

The information contained in this report is designed to highlight energy efficiency opportunities for the solid wood industries and also facilitate the development of a sector energy efficiency target and an action plan for realizing this target. The report was excerted from the publication "Energy Efficiency Opportunities for the Canadian Solid Wood Industries. A practical Guide Book."

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

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1.1.1 Technological Opportunities for Energy Conservation in Compressed Air Systems

The opportunities for energy conservation in compressed air systems can be categorized in the following manner (which are common for most industries):

(1) Compressed air generation;
(2) Compressed air preparation;
(3) Compressed air system integrity; and
(4) Compressed air utilization.

In compressed air energy conservation, it is of prime importance to recognize that when assessing the energy use in compressed air systems the compressed air system must be considered as a whole and not necessarily the sum of its parts. Making changes in one part of the system, without considering its interaction with the rest of the system, may result in a significant reduction in air use — but with minimal reduction in the energy requirement. This is especially true with some of the current compressor control technology available where a modulating control may require almost 70% full load power to generate negligible compressed air volume. This compressor may be efficient at the top end volume, but at low end volumes the technology dictates a disproportionate amount of energy requirement.

The following is a brief description of the more common equipment and technology applicable to the context of the solid wood and composite board sector manufacturing industries. These do not exhaust the available technology, however, the non-uniform requirements of this industry and the non-cost effectiveness of some of the new technology on a retrofit basis would preclude its discussion in the section. For a more comprehensive discussion of compressed air energy savings potential refer to Appendix C - Compressed Air Energy Conservation Seminar Presentation, contained in the source publication of this report (see introduction - front cover).

For a summary of minor and major changes that have potential for energy savings, refer to Appendix A - Opportunity for Energy Savings in Compressed Air.

1.1.2 Compressed Air Generation

Compressed air generation involves the process by which atmospheric air is compressed. Therefore, it is concerned with not only the actual air compression module but also with air intake, the air cooling and level of air pressurization.

The most prevalent method of air compression in the solid and composite wood industry is the single stage oil flooded rotary screw compressor. In wood plants where there is significant instrument air required, two-stage oil free rotary screw compressors may be used which are more efficient and operate with tighter tolerances. The reciprocating compressors that were common in the pre-1970's era have not been as common in recent years due to the introduction of the simpler (though less efficient), less expensive and easier to maintain rotary screw compressors.

The technology used to control these compressors has a very significant effect on the level of energy used. The earlier generations of the rotary screw compressor were controlled by what is referred to as a modulating controller, where the volume of compressed air generated was controlled by opening or restricting the intake of atmospheric air into the compression section. The restriction of the air intake opening, to reduce the volume of compressed air produced, created negative pressure in the inlet of the compression section as the intake butterfly valve was closed. This negative pressure significantly increases the ratio of the discharge pressure to the inlet pressure. Therefore, though the compressor discharge volume decreases, the effect of the higher pressure ratio between the atmospheric intake air and the discharge compressed air may not result in a significant energy reduction. The decrease in energy requirement to generate less than full compressor capacity is not proportionate to the volume decrease. Typically in these systems, at full design capacity, these compressors would require approximately 110% of full load horsepower while at "0" delivery. These compressors would still use 65-70% of full load horsepower. Advances in compressor controls have resulted in the design of modified modulating systems where the "0" delivery power requirements are reduced significantly. While some recent systems can bring the modulating system down to about 40% of full capacity, below which the compressor switches to a true unload mode, where the power requirement is in the 15-20% of full load horsepower range. There are some compressor manufacturers who make a load/unload-type compressor control where the compressor either produces 100% capacity or unloads to "0" delivery and the corresponding power requirements of full load horsepower down to approximately 20% at unload condition. The drawback with the load/unload system is with the highly fluctuating air requirements in typical sawmill applications which means that often the compressor has to load/unload with great frequency.

A compounding of the energy use problem occurs when multiple compressors are used. Often, because the compressor controls are not adjusted properly, the compressors may in fact be negating the effects of one another. For example, in a series of three modulating control compressors, all may be delivering air at 30% delivery (each using 75% full load power) instead of one compressor delivering 90% and using 95% of full load horsepower for one compressor with the others either unloaded at 20% each or at least one of them being off line.

In order of energy efficiency, as a general rule on a descending scale, the standard modulating control is the least efficient followed by the various modified modulating systems and then the load/unload control as the most efficient.

The following are some opportunities available to reduce energy requirements in air production:

New installations:

Compressors should be specified and selected on the basis of not only price and performance, but also on energy consumption. This would mean implementation of the more efficient control systems such as the modified modulating system or, if the application is appropriate, a true load/unload control system.

When multiple compressors are used, a system controller should be used where the controlling of all the compressors are done with a central electronic controller that sequences the compressors based upon a priority system and pressure requirements in the distribution system.

Existing systems:

In most cases, existing systems — at the very minimum — can have improved energy efficiency by systematic checking and adjusting the control mechanism to original design conditions. The older modulating types of control systems have a pressure/pilot regulator valve that easily goes out of adjustment which can cause a very inefficient operation. Some of the modulating controller systems can be retrofitted to be load/unload control systems, but these changes should be done by qualified personnel who have assessed the appropriateness of this conversion for the site specific application.

Since the majority of the solid and composite wood plants have multiple compressors, in most cases from two to five, a compressor control sequencer is a necessity for energy efficient operation. This sequencer controller can be retrofitted for just about any multiple compressor system. There are packaged systems available from most compressor manufacturers as well as companies able to custom design a sequencer controller system for a site specific application.

Minimization of pressure drop through the intake system is important for efficient air production. Any excessive pressure drop contributes to a slight negative pressure at the intake, which increases the discharge to inlet pressure ratio causing higher energy requirements.

Increased intake air temperature also has some detrimental effects for energy efficiency. Therefore, it is important that the intake air source be taken from a relatively cool area.

1.1.3 Compressed Air Preparation

Compressed air preparation involves the drying of the compressed air, the primary filtration of the compressed air and the pressure stabilization of the system.

When air is compressed, to a normal plant operating system pressure of 100 psig, and exits the compressor after cooling, its temperature is higher than plant or outside ambient temperature and is generally saturated. As the air flows down the line the temperature decreases and the water vapour condenses out in the lines. Along with this phenomena, when the compressed air is exhausted through an orifice such as a valve to atmospheric pressure, this rapid decompression effect causes a significant temperature drop resulting in more moisture condensing out of the air. In the warmer ambient temperatures, the initial condensation is taken out with a water trap. However, in the colder sub-freezing months condensation in the lines and components create freeze up problems. To combat this, separate air dryers are used.

The methods of air drying typically used in the solid and composite wood products industries are as follows:

- For inside air use only, a refrigerant-type of air dryer can be used. This system is capable of reducing the dewpoint of the air to approximately 1°C (34°F) and requires very little energy per SCFM dried.

- Typically for applications where sub-freezing conditions do occur, regenerative desiccant-type dryers are used. The most common of these are the heatless regenerative desiccant dryer (pressure swing technology) where approximately 15% of the process air that has been dried is used to regenerate the desiccant. Also the heat regenerative-type, which uses either external blower/heater or an internal heater to regenerate the desiccant. Occasionally, a compression-type dryer is used where the heat of compression released by the compressor in the compression process is used to assist in the reactivation of the dryer desiccant — minimizing the need of additional heat or dried air to regenerate the desiccant.

Of these systems, on an ascending energy efficiency scale, the heaterless dryer is the least energy efficient followed by the internal heater-type, the external heater/blower-type and then the heat of compression-type.

Regardless of the type of dryer used, energy efficiency can be significantly improved by the addition of proper regeneration control technology. In most wood plants, at any given time, the full capacity of the air dryer is not being used. With the cyclic nature of the process operations, the volume of air going through an air dryer, depending on the sizing of the dryer, can fluctuate from minimal flow up to full capacity. A dryer without regeneration purge control will supply a fixed amount of dried air (heaterless-type) over a fixed time period (or a fixed amount of heat over a fixed time period) regardless of the amount of air being dried. The regenerative purge control systems monitor the amount of moisture that has been adsorbed by the desiccant and changes the frequency at which the regenerative process takes place, thereby reducing the energy requirement.

Along with the regenerative purge control system, another energy reducing option is a dewpoint controller. This technology is able to adjust the dewpoint of the process air exiting the dryer. If the low dewpoints are not required for the specific operation, or in periods when the ambient outside temperature does not drop below freezing, the dewpoint can be elevated above what is required in the winter. Typically, most cold weather applications are specified for -40°C dewpoint. With the dewpoint controller, this can be changed to whatever is required to prevent freeze-up without maintaining the -40°C dewpoint. By doing this the regeneration process does not have to remove unnecessary levels of moisture from the desiccant, which results in energy reduction.

The following are some of the opportunities available to reduce energy requirements in air preparation.

New Installations:

Dryers should be specified and selected on the basis of performance and energy consumption. For air dryers it is very important that a realistic specification of the incoming air volumes that require drying be prepared. The temperature, pressure and volume of the incoming air is important in the sizing and the effectiveness of the dryer. An incoming temperature that is higher than the dryer design temperature means that the dryer will have to remove more moisture than it was designed for and requires more energy to regenerate the desiccant. All dryers should have a regenerative purge control system that responds to real time moisture loading as well as dewpoint control. Most dryer manufacturers make regenerative purge controllers. However, some do not have dewpoint controllers. There are firms who make retrofit dewpoint controllers which can be customized to a site specific application.

Existing Installations:

Regenerative dryers that do not have regenerative purge controllers should be retrofitted with them. This can apply to dewpoint control as well. Some of the earlier generation regenerative purge controllers were not always effective and occasionally they were disconnected by the plant personnel. These earlier generation controllers should be assessed and, in some cases, should be replaced.

Some of the earlier generation regenerative dryers had tank switching valves that were susceptible to malfunctioning and leakage by passing dried process air to atmosphere. These should also be inspected and repaired. Some manufacturers have offered retrofits to improve this situation.

The other area of significance in the drying process, that is often overlooked, is the importance of the pressure drop through the dryer system which begins at the inlet to the prefilter and ends with the outlet of the after filter. As the filters become contaminated, the pressure drop increases across the element. Likewise, as the desiccant begins to breakdown the smaller particulate begins to pack and increases the pressure drop through the desiccant bed. This increased pressure drop requires additional energy to maintain the same potential for work being done downstream. Therefore, ongoing maintenance of the dryer system is mandatory. It is not unusual to observe pressure drops of over an additional 10 psig in some systems. This should be remedied much earlier to prevent this level of additional pressure drop from occurring.

1.1.4 Compressed Air System Integrity

This refers to the general design and operation of the air system as a whole, which involves areas such as: the leakage of the system, the design of the air distribution system, and the storage capacity of the system.

Air Leakage:

Air leakage is a concern in most plant air distribution systems. This is of specific concern in the solid and composite wood sector plants because of the rugged demands put on the system and the nature of the operating environment. Vibration and physical damage is always a concern in these industries, along with the contamination level in the atmospheric air in the form of dust and "dirt". These cause fittings to leak and components to wear. The dirt and dust cause internal wear in sliding components along with damaging seals in air cylinders.

Realistically, leakage would be impractical to eliminate totally – it must be managed. Wear of moving and sliding components inside the pneumatic components is inevitable. However, this can be minimized. Experience in the wood industry has shown that leak management is a significant problem using up to anywhere from 10% of the compressor system capacity to 50% in extreme cases. One mill was observed to have a leakage level that required two of its five compressors on just to keep up with the system leakage. The industry generally looks at a 15% leakage to be a realistic target, though some mills have managed to reduce the leakage to 10%. Therefore, existing applications should manage their leakage to maintain a maximum 15% leak level. Most mills generally are in excess of this level. Most of the utility companies have some sort of compressed air conservation program where there are incentives for leak reduction. B.C. Hydro initiated a leak reduction program where a simple, but effective, orifice-type flow meter was supplied to the mill (an Airflow Energy LP07-type of flow meter) for systematic and regular monitoring of leaks under the condition that a leak reduction program was to be implemented by the mill.

Design of the Air Distribution System:

The piping distribution system must be designed properly to achieve efficient compressed air utilization. Line sizing is important to minimize pressure drops. A target for the system pressure drop should be not more than 2-3 psig in the distribution system. High pressure drops equate to additional energy requirements, and often are manifested as an apparent shortage of air or pressure. Distribution systems should ideally be of the "loop"-type header system to provide the most energy and cost effective type of system, especially in highly cyclic and extreme peaking of air requirements.

System Storage Capacity:

The level of compressed air storage in the distribution system can affect the system's operation. An inadequate storage capacity will mean that more up-front compressor capacity will be required to provide air for the short term peak requirements. Otherwise, there will be a noticeable pressure reduction at the end user, which may not provide the necessary power, or it may manifest itself as insufficient air volume causing significant slow down of an operation. By adding sufficient air receiver/reservoir capacity the air stored at high pressure in these receivers will be used at lower pressure. Air removed at lower pressure removes less air than air removed from the receiver at higher pressures. This can be further refined by adding a discharge air pressure regulator to allow only a certain air pressure to flow downstream (before doing this the system dynamics should be examined).

1.1.5 Compressed Air Utilization

The end use requirements for compressed air ultimately dictate the selection and sizing of all components of the compressed air system. If the end use requirement can be legitimately reduced, due to more efficient and effective methods, it will impact the air production and the preparation systems. In some cases, it may mean that a compressor(s) can be taken off line and reduce the moisture load on the air dryers — resulting in reduced energy requirements.

The two major areas of air utilization are:

(a) during the production process; and
(b) for non-production uses.

These non-production uses are, for example, air used for equipment blowdown, area clean-up, air tools and even for providing air pressure to keep the fire protection dry pipe valve systems charged up. If the fire protection system uses the main plant air system for its pressurization, it generally means that the main air system must be pressurized with at least one compressor on even in the off shifts.

Air Utilization: Production

The main uses of compressed air during production are typically as follows:

- Air cylinders for loaders, sweeps, kickers, gates, lifts, etc.;
- Tensioning or cushioning devices in the form of air bags/strokes;
- Air jets for keeping photocells and other optical electronic devices clear of dust and debris;
- Air jets used to prevent accumulation of dust on chutes and for cleaning conveyor belting; and
- Occasional use of air motors for agitators in anti-stain fluid tanks and for pumps in lubrication systems.

The application of air cylinders for kickers and lifts of various types in the wood products industry present a number of challenges for efficient air utilization. As a rule, the mass of the logs or lumber is not uniform and can often vary significantly. Therefore, the mechanical device (kickers, sweeps, etc.) must be designed to handle the full range of work pieces coming to it. Consequently, the force requirements vary proportionately. To provide the necessary power, the air cylinders are sized to handle the heaviest work piece at a design pressure 10 to 20% less then the system pressure. This ensures that the power will be there to move the heaviest piece. However, when pieces are smaller than maximum or at higher line pressures than the design pressure, there is excess energy available. In compressed air, if there is more stored energy available then required, the available energy will be dissipated in the equipment (kicker, sweep, etc.) whether it is required or not. This excess energy will be manifested by faster acceleration and speeds than necessary. This excess speed is then controlled by the use of flow controls.

From an energy efficiency perspective, pressure regulation should be utilized to only provide what is required to handle the "worst case" that needs to be handled. The differential between this working pressure and the system pressure remains in the distribution system as stored energy. Often, the air cylinders are sized larger than required to move the work piece to withstand the physical abuse. In these cases, the actual required pressure may be significantly less then the system pressure.

Another variation to this type of application is that, in many cases, the high forces are required in only one direction of the cylinder actuation. Equipment such as kickers and sweeps generally require the high force to move the log/lumber in one direction while the return stroke only requires the force to return the moving part of the equipment to its original position. This return stroke would then require less pressure to operate. Therefore, a dual pressure system is often appropriate for these applications where one pressure is available to the cylinder in one direction and a second lower pressure is applied in the opposite direction. The lower pressure in the opposite direction can reduce air requirement by up to 25% for a particular operation. This becomes significant in a large cylinder or high cycling application.

In some cases when the cylinder applies force in the vertical direction, the kicker or lift mechanism has sufficient weight to return to the original position by gravity. In some of these cases it may be appropriate to have the compressed air applied in the lifting direction and remove the air for the down stroke. This would duplicate the action of an "air bag"-type of application which is a single acting system. The elimination of the compressed air on the return stroke results in significant air reduction.

In applications where compressed air is used to keep optical sensing devices clear of dust and debris, alternative or more efficient technology can be employed. A common practice is to run a small 1/4 to 3/8" air line, with a manual shut off valve and with or without pressure regulation, to a optical device and leave the air jet on continuously. This can be seen frequently for photocells and some variations of simple scanners. There is current available technology that employs a variation of the vortex technology that require an order of magnitude, less compressed air, to accomplish the same purpose. To make this more efficient, the air jet can be put on a timed solenoid valve and pulsed as required.

Where line pressure air jets are used to keep chuting or conveyor belting clean, there are appropriate situations where the above vortex technology can be applied and air use greatly reduced. In the case of the belt cleaner application, an alternative method can result in significant energy savings. For example, a low pressure blower can be used instead of compressed air which may result in up to 75% of the energy being saved.

Air Utilization: Non Production Uses:

Some of the major uses of compressed air in non-production applications are for equipment clean-up/blow downs and air tools along with pressurization of the fire protection system. Again, in some applications for clean-up the vortex nozzle technology can be applied for energy savings. When a fire protection system is pressurized from the main plant air system, it generally means that the mill keeps at least one compressor running continuously. This takes place both when the mill is operating and when it is not operating, even on weekends and holidays. Since every air system has leaks, the compressor that is running must provide at least enough energy to keep the system pressured-up in spite of the leaks. This usually means that at any given time on the off-shift the compressor that is running is drawing a significant percentage of full load horsepower just by keeping up with the leaks to provide pressure to the fire protection system. Often, in a plant that may typically have a 150 horsepower compressor running on the off shifts, the compressor may be drawing 125 horsepower due to the modulating feature of the compressor control. A solution to this has been to install small compressors (3/4 to 2 HP range) dedicated to the dry pipe valves, which allow the compressors to be shutdown completely on the off shifts.

1.1.6 Alternative Energy Sources for Compressed Air Applications

In some applications for compressed air the use of alternative power sources may be appropriate, cost effective and provide superior performance. One such potential alternative is the use of hydraulics instead of compressed air. Typically, a hydraulic system may be 65 to 85% efficient where a compressed air application may be in the magnitude of 15% efficient since a major part of the input energy to a compressor is lost as the heat of compression.

1.2 Hydraulic Systems

Hydraulic power systems are becoming common place in the solid wood and composite wood industry. Power transmission devices that were previously energized by electric drives and linear motions that were done through air cylinders have been increasingly replaced with hydraulic systems. Initially, the hydraulic systems were generally dedicated systems, i.e. one pump unit to one hydraulic motor. However, the current practice is to power multiple hydraulic motors and/or hydraulic cylinders from a single pumping system (hydraulic power unit).

Another significant area using hydraulics in the wood industry is in linear positioning. What was done earlier with compound stacked air cylinders of discrete increments is now being replaced with servo valve technology borrowed from the aircraft industry. This technology is now common place in sawmills for positioning saws, chipping heads, prepositioning tables, etc. In some instances, plants have attempted to duplicate the design philosophy behind a compressed air system by having multiple hydraulic pumping units pressuring up a hydraulic header system and supplying oil to multiple hydraulic motors and cylinders on demand. Some of these practices, though efficient in certain contexts, may not be an energy efficient alternative in the highly cyclic and variable loading conditions found in the wood products sector.

The following is a brief description of the applications and types of hydraulic systems commonly used in the context of the solid wood and composite wood sector and the opportunities for energy reduction. This does not exhaust the available technology but is descriptive of where the industry is in general. For a more comprehensive treatment of hydraulic systems and energy efficiency opportunities refer to Appendix E - "A General Background to Efficiency of Industrial Hydraulic Systems" prepared by Carroll-Hatch (International) Ltd. for the B.C. Hydro Power Smart Program, contained in the source publication of this report.

1.3 General Materials Handling

General materials handling applications in the solid wood and composite wood sector involve the utilization of hydraulic fluid power, both for rotary motion (hydraulic motors) and linear motion (hydraulic cylinders).

In sawmilling, plywood and OSB applications hydraulic motors are frequently used to drive conveyors and multiple chain transfer decks. The log handling functions often are powered with hydraulics. Log conveyors and log transfer decks, because their high shock fluctuating loads and frequent stop-start requirements, tend to be good applications for hydraulics. In certain sawmilling applications for lumber handling (where there are highly fluctuating loads, frequent stop-start and variable speed requirements) hydraulic motors are being used as well.

For linear motion applications hydraulic cylinders are beginning to replace compressed air cylinders for equipment such as log kicker arms and log stop and loaders. Some of what were traditional compressed air applications are now being done with hydraulic cylinders, especially in some of the extreme cold weather and extreme high load applications.

Though occasionally hydraulic systems are being used "just out of preference" instead of for tangible reasons, hydraulics generally are being applied for valid reasons.

Conditions that would be better served by hydraulic motors are those applications that are characterized by high shock overloading, wide fluctuations in loading, frequent stop-starting and reversing and speed variation with the above conditions. These types of applications would create acute demands on many electro-mechanical drive systems causing electric motor burn-out or premature mechanical failure unless the drive was grossly oversized.

Some typical hydraulics applications are in the log handling area:

- Log infeed decks;
- Log infeed conveyors to bucking and debarking operations;
- Log storage decks; and
- Log singulator and unscramblers.

Often, hydraulics for log handling systems and multiple drives are integrated in one power unit, resulting in lower connected horsepower because of shared loading. (However, if the system is not designed with energy efficiency in mind, there could be significant energy wasted.)

In the lumber handling area:

- Lumber unscramblers;
- Highly loaded lumber transfers;
- Lumber indexing transfers; and
- Lumber sorters and lumber package handling equipment.

These appear where loads are high and operation is frequently stop-start.

Conditions that are often served by the use of hydraulic cylinders are applications that are subject to high loads and extreme cold temperatures. In many large log applications, the forces required to "kick", "sweep", or "rotate" the large logs exceed the forces that can be generated by the maximum diameter air cylinder sizes commonly available.

Coastal operations that traditionally had been operated by the "old steam" cylinders are frequently being converted to hydraulic cylinders.

In some of the northern interior mills, hydraulic cylinders are replacing compressed air cylinders because of the extreme winter cold causing air cylinder freeze-ups. These cold weather hydraulic applications have their own set of challenges.

Other applications where hydraulic cylinders are replacing air cylinders occur when accuracy in speed control is required. Since hydraulic cylinder speed is dependent on pumping volume or flow control setting, accurate speed variation can be attained quite simply — unlike the limitations of compressed air.

However, since the energy conversion efficiency from electrical energy to hydraulic energy is much higher than conversion to compressed air energy, serious consideration should be given to hydraulic cylinders where it is practical and does not jeopardize the performance required.

1.3.1 Major Machine Control

A significant percentage of wood manufacturing hydraulics are dedicated to OEM machine control. Major sawmill, plywood and composite board equipment frequently come as a package with their own sophisticated hydraulic systems. For example in the composite board industry, board presses are designed with large complex hydraulic systems, while in the sawmilling sector the canter systems and edger systems generally all come with their own hydraulic systems. Often these are dedicated systems and require specific rigid performance requirements.

However, since the machinery industry is very competitive, often the design and supply of the hydraulics have been based on low bid with little concern for system energy efficiency. There is a significant opportunity to alert the users to consider energy efficiency alternatives in the design of systems and in the selection of more efficient components.

1.3.2 Servo Hydraulics

Servo technology from the aircraft industry has had a significant impact in the wood manufacturing industry. In the last decade, servo valves have been used extensively to achieve fast, precision control of cylinders or motors and have been used in extremely close tolerance applications such as setting edger saws, plywood lathes as well as in applications having medium tolerance requirements.

However, for a servo valve to satisfactorily perform to its rated specifications, there must be approximately 1000 psi pressure drop across the valve, which translates into a high heat loss across the valve (consequently horsepower). With the advanced technology and availability of reliable proportional valve technology, which operate at approximately 300 psi drop across the valve, there are opportunities for energy savings in many applications by using proportional valves instead of servo valves. This is especially true in cases where fine precision is not required.
Most modern sawmills will have many servo systems and older mill retrofits/modernizations generally involve the addition of some servo valve applications.

1.3.3 Energy Conservation Opportunities

To determine the energy reduction opportunities in hydraulic systems in wood manufacturing plants, a variety of factors need to be considered and understood. It is important to clearly define the performance requirements of the piece of equipment, the nature of the loads imposed on the hydraulic system, as well as the frequency and the variabllity of the load over a fixed time period (along with an appreciation for the types of hydraulics systems commonly used for those applications). From this the potential for improvement can be demonstrated.

1.3.4 Specific Types and Nature of Application Using Hydraulics

In mills where hydraulics are used they will generally be found performing functions such as driving conveyors, transfer chains, hoists or rollers as well as for operating arms, bars or paddles that push, sweep or kick logs or lumber from one location to another. Some sample hydraulic circuits can be found in Appendix F of the source publication of this report.

Conveyors, transfer chains and roller drives are applications that generally have highly fluctuating loads and frequent stopping and starting. Often this loading will see severe load spikes when logs or lumber are dropped onto the conveyor, when logs or lumber get jammed up or when the conveyors start up under full load and the inertia has to be overcome. In some cases, there is a need for speed variation. These operating requirements are generally the rule and not the exception, thus the hydraulics must be able to handle this.

There is no one type of hydraulic system that is commonly used for these applications. In many older mills this type of application may have a fixed displacement pump controlled with a flow control and an open centre control valve that bleeds off the excess oil volume through a flow control/divider. When the drive is not operating, low pressure oil is pumped back to the tank through the open centre of the control valve. A large number of these applications would now have a pressure compensated pump with an on/off directional control valve that pumps oil at a fixed pressure setting and delivers oil only as required. A few systems would have an additional load sensing control on the pressure compensated pump which not only delivers the flow necessary, but also provides only the pressure required up to a maximum pressure setting. Another type of system, if speed variation is required while operating, is the hydrostatic system. This is a closed loop system and the volume control of the pump is varied from a controller signal as required. This system provides only the pressure necessary.

Kickers, sweeps, loaders, gates and lifts are applications where logs or lumber must be moved, usually one at a time, from a transfer chain to a conveyor, conveyor to conveyor, conveyor to transfer chain, pushing onto a storage deck, loading into a machine or lifting gates, stops or rollers. Again, these loads may vary significantly for any given application, especially in log handling where most often logs are processed at random diameters, lengths and even moisture contents vary significantly. When this type of handling is used for lumber, the lumber sizes may be more uniform, but again depending on the specific function (e.g. kicking boards behind a bandmill headrig) the boards may vary greatly in size. This loading is not continuous since the action is only required when a log or lumber requires discharging. These applications would use hydraulic cylinders (pistons).

Again there is no one type of hydraulic system that is commonly used for these applications.

In many older applications fixed displacement pumps were used with open centre control valves where the oil flowed at low pressure through the open centre of the valve and back to the tank when the action was not needed. In some very inefficient circuits, the excess flow or flow when the actuator was not being used would be sent over a relief valve to tank. More recently these circuits have been designed with pressure compensated pumps with or without load sensing.

In both this case, and the conveyor, transfer, roller drive cases, often the hydraulic system has one pumping system supplying oil to a number of hydraulic motors or cylinders. Many times it is a mixture of motors and cylinders. Often the actuators do not act at the same time and the maximum and average pressure requirements vary significantly. From the energy perspective, this causes concern since if a pressure compensated pump is used, then whenever oil is required, the pump will always deliver oil at the maximum pressure setting.

Major equipment feed rollers, chains and roll lifts have varying load sizes, though generally these major machines are not constantly stopped and started. However, since these machines process single logs, cants or boards one at a time, unless the pieces are "ribbon fed" (i.e. are right after another "butted up" end to end), there will be a period of time when only the chain or rollers are driven.

These systems can be driven with the same variety of hydraulic systems mentioned in the previous category.

1.3.5 Linear Positioning (Servo-Hydraulics)

With the increasing production levels, and the need for more accurate cutting of the wood, linear positioning has become increasingly more significant, especially in the setting of saws to the right width locations or positioning the work piece in the right orientation to optimize the recovery of lumber out of the work piece. In the past these functions were done manually or with a combination of air cylinders. However, this is increasingly being done with servo valves and, more recently with the technology advance, proportional valves. In these applications, saws are being set or lumber is being oriented one piece at a time. Therefore, the use is not continuous. The average loading for these is generally constant, since only saws or locating arms are being moved rather than the work piece, with the noticeable exception of the linear positioners for setting the log orientation on the log carriage feeding the bandmill headrig. On each of these systems there is generally multiple positioning cylinders that operate off a single pumping system.

The types of hydraulic system most often used in these applications are pressure-compensated pumps with servo valves and linear positioning cylinders with a linear transducer to provide feedback of locations to the servo valve. These servo valves use very small orifices to achieve the performance accuracy characteristics which require, generally in the neighbourhood of a 1000 psi pressure drop across the valve. This pressure drop constitutes energy loss as heat. In contrast to this proportional valves are increasing in popularity because of its lower capital cost and greater tolerance to contamination. Also they require a significantly lower pressure drop across the valve to achieve its performance specifications.

1.3.6 Opportunities for Energy Savings

The opportunities for energy savings in these types of applications are two-fold. The first is to consider the use of efficient components such as more efficient pump designs, valving design, motor designs or pump control design. The other opportunity comes from the design of the hydraulic circuit itself, especially if multiple functions are being performed by a single pump. Along with this is the optimization of the efficient components with the hydraulic circuit.

The most efficient system would ideally be the most efficient pump pumping oil through the most efficient valve driving the most efficient motor or cylinders with only the pressure necessary and only when necessary. However, since normal applications in the wood products industry are not like that, because of cost or operational restrictions, other alternatives are considered.

For conveyor drives where speed variation is required, if it is a single function system then a hydrostatic transmission in a closed loop system would be a more efficient system as compared to a pressure-compensated pump with a proportional flow control. In this latter case the pump would always deliver at a maximum pressure setting including losses through the proportional flow control.

In these drives or linear cylinders, where speed variation is not required and multiple functions are being served by a single pump, the common practice of feeding them with a pressure-compensated pump can be very energy intensive. When this system is used whenever oil is being pumped it is always delivered at the pressure compensator setting which is the maximum pressure setting that the pump must deliver to service the highest pressure requirement imposed on it. Therefore, if the maximum setting is at 2000 psig and the average pressure requirement is 1000 psig, there is approximately a 50% reduction in energy required, but the pump will still develop 100% of the energy requirement and lose the 50% not doing work as pressure drop across a flow control or valve creating heat. If only one of the functions requires the maximum pressure and the rest require only 15-25%, again the pump would deliver oil at the maximum pressure setting therefore wasting significant energy.

This can be made more efficient by:

- Segregating functions into similar pressure requirements if they are continuous requirements being serviced. Each of these pressure categories would have its own pressure compensated pump. If the pressure requirements were not continuous then the pump should have load sensing added to it.

- Isolating each function with its own pumping system. With a properly sized fixed displacement pump for each system only the pressure required for each function would be provided. This will generally be more cost intensive.

- Adding a load sensing control to the pressure-compensated pump with appropriate feed back valving will provide only the maximum pressure and the volume needed by all the actuators at any given condition. This is not as efficient as the other two options but more efficient than the initial case.

In cases when linear positioning is required, there are significant opportunities for energy use reduction by considering the use of proportional valve technology if its performance is acceptable for the applications. The proportional valve not only requires less pressure drop but it does not require as fine an absolute filtration such that oil cleanliness and filter pressure drop are not as significant.

The opportunities for energy improvement in these systems are very site and application specific and each must be assessed in its particular context. Therefore, to generalize on typical savings may often be no more than a gross generalization.

1.4 Fans

Fans are essentially pumps used to move gases of all types, with the most common gas being air. The fan moves the air by creating a higher pressure at the fan's outlet than at its inlet. This difference in pressure is referred to as the delta P or ΔP. The fan impeller not only imparts a static pressure (or potential energy) to the air, but since the air is made to move through the fan it also imparts a velocity pressure (kinetic energy) to the air.

Most fans are powered by electric motors. The power that the motor must supply equals the work done to force the air through the fan, plus the friction losses. This heat from friction is also generated in the fan's bearings and the drive system between the motor and the fan. In order to minimize the electrical power used to drive the fan, a fan and its system must be chosen that has the least losses.

As noted previously in this report, fans and blowers offer by far the largest potential energy savings in wood products plants. One of the major reasons for the large potential is that fans and blowers tend to operate continuously and also tend to draw a high percentage of the connected motor kW capacity (or nameplate horsepower), all-the-time. This contrasts, for example, with a mill conveyor which on average uses a small percentage of its connected kW since its motor kW capacity is chosen to ensure the conveyor can start up (overcoming static friction) when the conveyor is totally overloaded. Also when there is little material on the conveyor it needs very little energy.

Firstly, axial fans (or "propeller" fans). These fans have a much lower capital cost than centrifugal fans but are very limited in the ΔP they can create, usually less than 51mm of water column (w.c.) pressure (2-inch w.c.). By far the greatest connect kW of axial fan capacity is in lumber dry kilns and some veneer dryers (rotary dryers, flash tube dryers and many veneer dryers utilize centrifugal fans).

These axial fans, installed in lumber dry kilns, circulate the internal heated air/vapour through the stickered spaces between courses of lumber. This circulation brings heat to the lumber for the evaporation of water and creates the velocity to pick up the resulting water vapour from the lumber surface and carry it away. Exactly the same drying process takes place in a veneer dryer. One large kiln will often have 120 HP (90 kW) of connected motor capacity driving its axial circulation fans, and one mill will have from one to seven large kilns.

There are two major areas where energy conservation can be made:

- Fan wheel design; and
- Adjustable speed drives (ASD).

The kiln circulation fans are somewhat special in their design, because the direction of circulation must reverse periodically to ensure uniform drying throughout the kiln. It is desirable that the fans be equally efficient in either direction of rotation. Great advances in kiln fan wheel design have taken place since 1972 by such companies as Aerovent, Hartzell and Smithco. Many kilns have fan wheels of very old design or, alternatively, fan wheels designed for flow in one direction only with the reverse direction resulting in sub-optimal efficiency.

So a sizeable efficiency improvement can be achieved by changing the fan wheels to a newer, more efficient design. This change almost always includes the speeding up of fan rotation and may require a change in bearings. This change can reduce the electrical energy required by up to 40%.

The second area of savings is through the installation of adjustable speed drives on the fan drive motor(s). This usually comprises a solid state, variable frequency converter (maintaining the existing alternating current motor).

The reason that energy savings are available from this technology, is that the circulating velocity within the kiln need not be maintained at its highest level throughout the drying cycle. To explain, wood dries according to a "drying curve" (not a straight line). Each species has a particular curve. The drying rate is highest at the beginning when the wood is wettest. At that time, the kiln requires the most heat to be delivered by the circulating air/vapour flow and the most vapour "take away" capacity. The drying rate decreases as the wood becomes dryer and so the circulation rate can be decreased accordingly.

The power required to drive a fan in a circulation system varies approximately with the cube of the circulation flow rate. So when this flow rate is decreased, as the wood dries, then the fan drive electrical energy decreases greatly.

Many evaluations show that the electrical energy overall can be reduced by 40% through the judicious use of an ASD on the kiln circulation fans.

1.4.1 Centrifugal Fans

Many centrifugal fans are used around the mill site for such things as:

- Low pressure air convey.
- Machine centre dust take-away systems.
- Combustion air for fuel oil, natural gas or residue wood-fuelled furnaces heating: boilers, thermal fluid heaters, direct-fired dry kilns and veneer dryers, etc.
- Induced air fans on boilers, thermal fluid heaters, hot water heaters, rotary dryers, flash tube dryers, etc.
- Recirculation fans on direct-fired kilns, veneer dryers, rotary dryers, etc.
- Negative draft for veneer stackers.
- Emission abatement control equipment cleaning (e.g. automatic bag cleaning in a bag house).
- Induced draft (ID) fan(s) on fume cleanup equipment (e.g. ID fan(s) on wet or dry electrostatic precipitators, electrified gravel bed scrubbers, fan wheel scrubbers, etc.).

There are many methods of reducing energy requirements of centrifugal fans, e.g.:

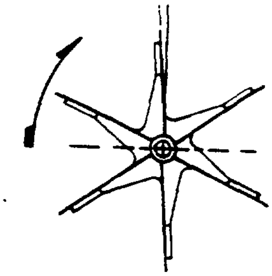
- More efficient fan design;
- Reduced flow rate requirement; and
- Reduced losses in fan system (less loss in ducts, elbows, heat exchangers, orifices, etc.).

Regarding fan design, there are several basic fan wheel designs (see Figure 2):

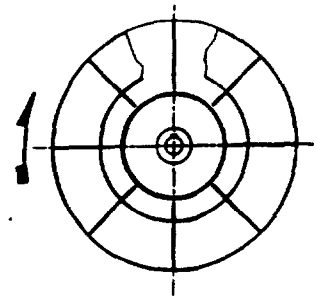
- Radial blades;
- Backwardly inclined blades or backwardly curved blades;
- Air foil blades; and
- Forward curved blades (not applicable to industrial applications).

Most of the fans installed in wood products mills are radial blade fans. They are simplest and cheapest, but the least efficient. Where there is a heavy load of dust passing through the fan, a radial blade fan is required. The key is to utilize as efficient a radial bladed fan as possible.

RADIAL BLADED (OPEN RADIAL BLADED)



RADIAL BLADED (RADIAL SHROUDED)



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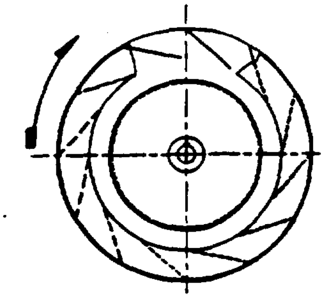
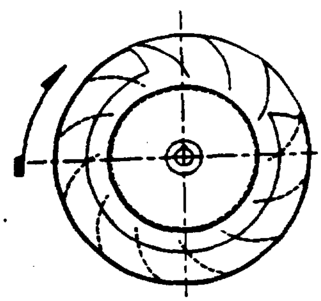
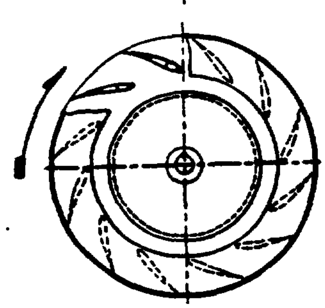


BACKWARDLY CURVED



AIR FOIL



FORWARD CURVED

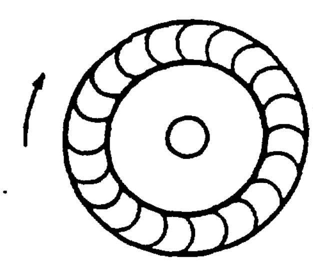


FIGURE 1: CENTRIFUGAL FANS

The two basic styles of radial bladed fans are:

- Open radial bladed; and
- Radial shrouded.

Often the fan will be an open radial blade fan which is very rugged, but not very efficient. The fan wheel comprises a large cast spider centred on the centre-line of the blades. The air must pass into, over and along this spider with great losses along the way. These fan systems have been instrumented in mills and shown static efficiencies as low as 45%. Normally, they are 50-55% efficient with a maximum "published" static efficiency of 66%.

The radial shrouded fan is much more efficient and, if properly built, will handle heavy dust loads. Its published efficiency is up to 72%, although this is rather optimistic.

Where dust loads are light or non-existent, then a backwardly inclined or backwardly curved fan is a very good choice for a heavy-duty industrial fan with efficiencies up to 82%.
The airfoil fan produces the best efficiency, to 90%, but is not tolerant to dust loadings or to abrasive conditions. Also it is very difficult to repair or rebuild in a wood products mill environment.

The backward inclined fan is perhaps the best compromise between efficiency, rugged design, dust tolerance and ease of maintenance.

1.5 Air Conveying Systems

1.5.1 High Pressure Air Conveying Systems

Hundreds of this class of air convey system are found in wood products manufacturing plants. Sometimes, a mill will have as many as four, or even five, of this type of convey systems. These are always used when the convey distance is relatively long, say, 200 ft. to 1,000 ft. These systems are used to convey:

- Green sawdust;
- Planer shavings/sawdust;
- Hog fuel;
- Sander dust;
- Pulp chips; and
- Chip fines (following the chip screens).

The basic layout of a high pressure air convey system is shown in Figure 2.

Air convey systems are high energy users. The blowers use power to not only convey the material, but to move great quantities of air. More power is used to move the air than the material, although the high pressure/low volume air convey system is much more efficient than the low pressure system (discussed below).

Energy savings are achieved in either system by:

- Reducing the air pressure against which the blower or fan must work;
- Reducing the volume of air moved per unit time (flow rate) (reducing the m^3/s^* or cfm);
- Installing more efficient blowers or fans; or
- Redesigning the air convey system to reduce losses.

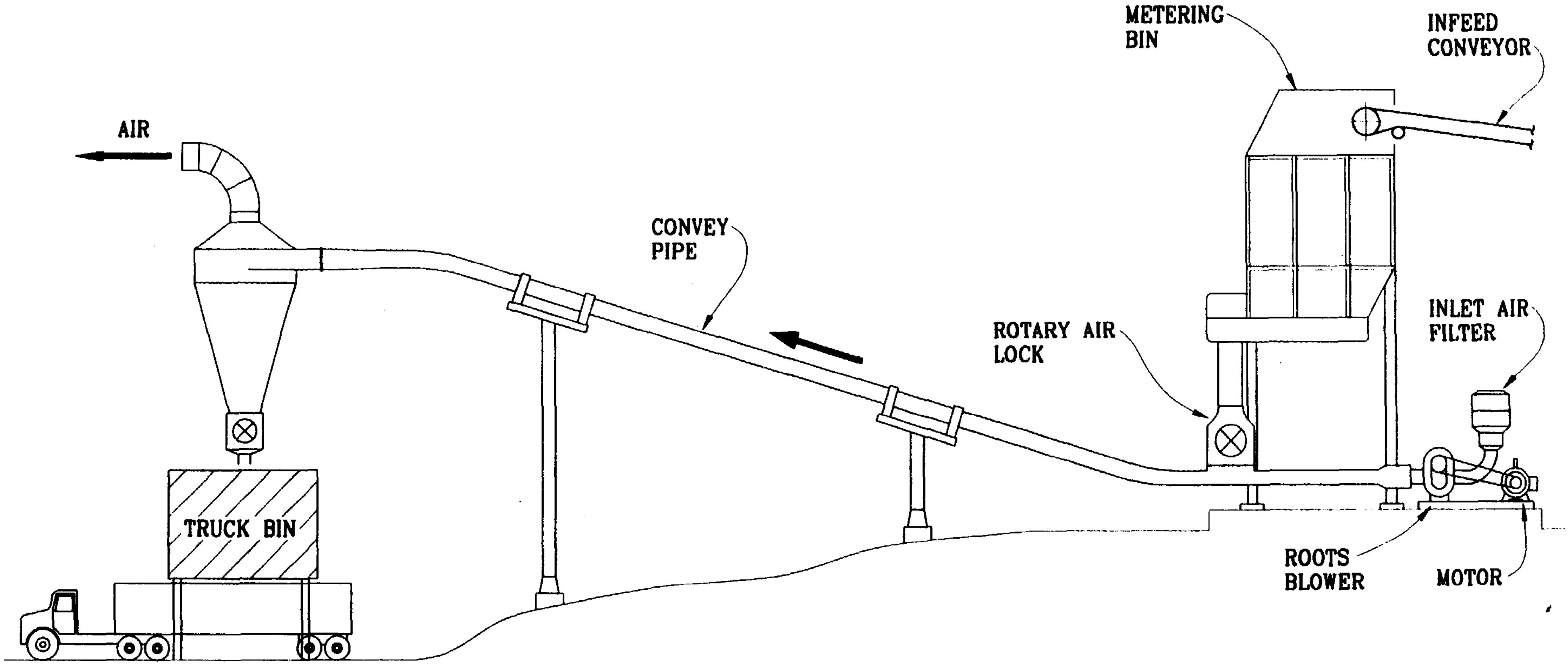


FIGURE 2: – CROSS SECTION OF A HIGH PRESSURE AIR CONVEY SYSTEM

If the flow rate of air can be reduced, then the power required decreases at a rate proportional to the flow rate reduction cubed (all other things remaining constant). It is easy to see that even a small reduction in flow rate will provide a sizeable reduction in energy use.

An analysis of the system to determine potential energy savings can be performed step-by-step:

- Determine weight of material being conveyed per unit time.
- Determine the relative material surge rates.
- Determine the volume of air being pumped by the blower (m^3/s).
- Determine the pressure against which the blower is working.
- As a check, measure the Amps and Volts on each phase to the blower drive motor.
- Measure the pipe diameter and calculate the air velocity.
- From the type of material being conveyed determine whether the weight of convey air per kilogram of material is appropriate. If it is markedly higher than required, then either the blower should be slowed down (usually very easy) and, if necessary, consideration should be made as to reducing the air convey pipe size. Before slowing down the blower a check must be made to ensure that the pipe velocity will not be lower than the sedimentation velocity of the particular material being conveyed.

Often the flow rate is higher than required. This is often because the estimate of material to be conveyed before start-up was "conservative" or, in other words, the system was "over designed" to take care of unforeseen variables. An analysis at a later date usually provides the opportunity to save energy.

If there are relatively sizeable surges, with the maximum rate being, say, 2.5 times the average rate (not uncommon in a wood products mill) and if there is no metering bin (see Figure 2) then the air convey system will be approximately twice the size it should be (some excess capacity over "average" must be maintained). The installation of a metering bin will allow for a very sizeable reduction in energy consumption.

One interesting energy saving opportunity exists at many mills which load the pulp chips into railroad gondola cars. Almost universally the loading system incorporates a high pressure/low volume air convey system where the chips emit from the end of the pipe right into the car. The pipe end is mounted from a gantry straddling over the car. The end of the pipe wig-wags back and forth as the car is loaded; with the car also moving along as it fills. The chip velocity packs the chips tightly into the car, increasing the weight of chips considerably, say by a factor of 50%. Since the cost to transport a car of chips from the wood products mill to the pulp mill is based on a price-per-car, the more chips packed into each car the lower the transportation cost. However, as discussed above, the air convey method is a high energy consumer.

An alternative method is to utilize mechanical-type conveyors (belt, chain, flight, etc.) to convey the chips, and then to utilize an adjustable flinger system hung from the gantry to pack the chips into the car. Depending on the distance from the source of the chips in the mill (the chipper or chip screen) to the car loading site, the energy required by the latter system would be one-fifth to one-tenth the energy required by the air convey system. Instead of, say, 400 connected horsepower, the latter might have 60 HP and operate at a lower percentage of nameplate motor capacity as well.

Another interesting energy saving opportunity is to use an innovative air convey system which moves the material through the pipe in slugs of material, much like pushing successive pistons (slugs) along the pipe. This system completely eliminates the need for great quantities of air, and the necessary energy, because there is no need to ensure that the velocity is higher at all times than the sedimentation velocity of the heaviest particle in the material being conveyed.

This system was developed at British Columbia Research (UBC Campus) under contracts from the Federal Government of Canada.

The energy savings associated with this system will again be dependent on the distance to be conveyed, the weight per hour of material, the type of material and the characteristics of the present system. However, the energy savings would range from 50-80%.

An added advantage of this system is the absence of a cyclone or any other separation device at the end of the convey pipe. This exclusion eliminates the energy loss, maintenance cost and emissions associated with these devices. The end of the pipe can simply protrude through the top of the end wall of the destination bin. The slugs simply emit from the pipe and drop into the bin. The very small quantity of air between each slug is simply vented from the bin.

1.5.2 Low Pressure Air Conveying Systems

The low pressure air convey system uses a centrifugal fan (see Figure 3). The traditional design would utilize an open radial bladed fan of very low static efficiency (The material to be conveyed would pass through the fan, thence along a duct to the destination where the material would be separated from the convey air in a cyclone (or more recently, in a bag house; or a combination of the two).

Since the material passes through the fan, a radial bladed fan is required.

Reductions in electrical energy can be achieved as described under "fans" above. However, since this type of air convey system in wood products mills is so often used to extract sawdust, shavings and other residues from processing machines (such as saws, planers, sanders, etc.) and then conveying this residue to a truck bin, or a fuel storage silo or an incinerator, it will be covered in more detail.

The first big opportunity for power reduction is a new, much higher efficiency fan from, say, a very normal radial bladed fan at 50% static efficiency to a backwardly inclined fan at 80% — for an energy reduction of 38%. This is not achieved by simply replacing the fan with the new high efficiency fan because the new fan will not be tolerant of a high dust loading. The convey system must be altered, somewhat, to a "clean fan" arrangement where the fan is located downstream of the cyclone (or other) separator (see Figure 3). This arrangement is perfectly acceptable and can be observed in operating mills.

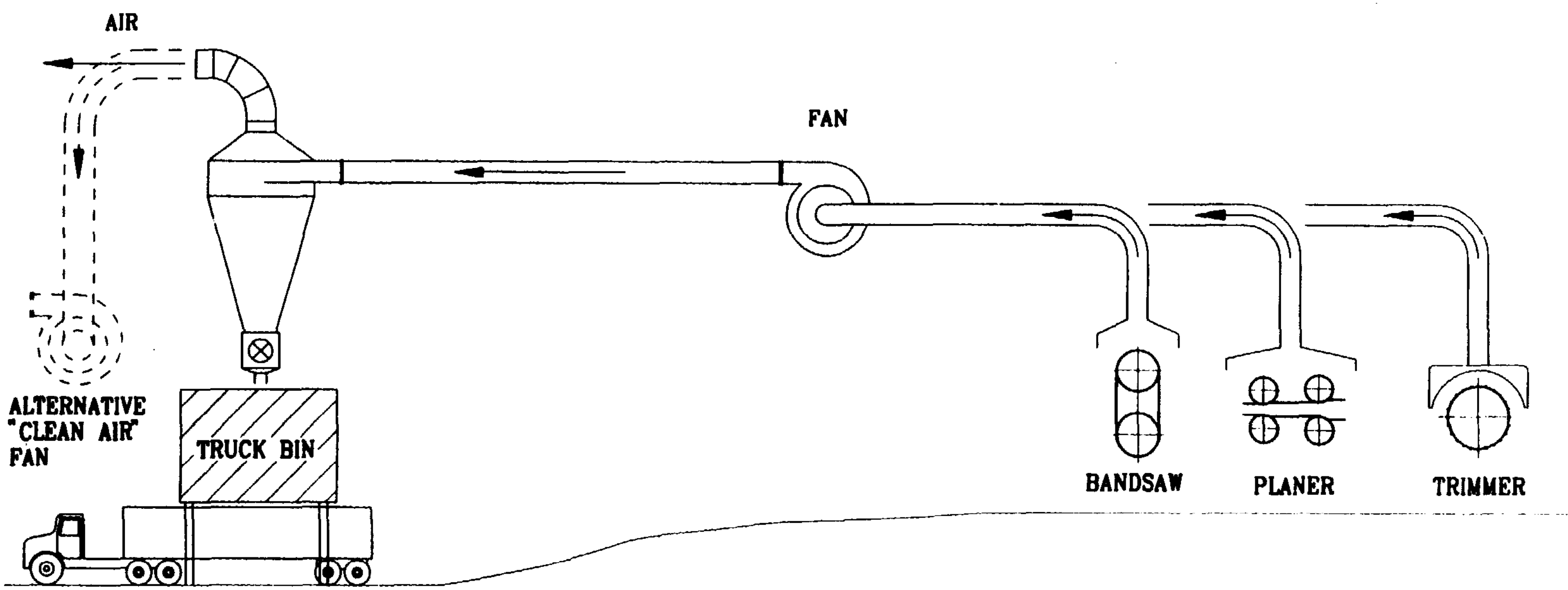


FIGURE 3: – CROSS SECTION OF A LOW PRESSURE AIR CONVEY SYSTEM

The second area of energy conservation is the reduction in air flow rate (m^3/s or cfm). Again, a small reduction in flow rate provides a large energy savings as explained above. Often the air volume flow rate is much higher than required to transport the material at its maximum delivery rate. In addition, the velocity through the ducting is often far higher than the sedimentation rate of the material. Then the flow rate can be reduced.

Where a reduction in flow rate will curtail the ability of the air flowing into the hoods to capture or "pick-up" the material, the hood must be altered to increase the velocity therein (and to increase the ΔP required of the fan). This alteration will reduce the amount of energy savings from the change in flow rate, but the overall result will still be a sizeable energy reduction.

Another opportunity for power savings is at the separator or collector; often a cyclone. Typical cyclones at wood products mills will have a Δ P against which the fan must push (or pull) of 38mm w.c. (11/2 in. w.c.) to 152mm w.c. (6 in. w.c.). There is no guarantee that high Δ P cyclones have a better collection efficiency than a low Δ P cyclones. The key is that the cyclone is the correct size and configuration to meet air quantity requirements at minimum Δ P. However, a rather simplistic cyclone evaluation should be conducted on the cyclone since often cyclones are creating more _P than they need to. The inlet should be smooth, entering the cyclone with no obstruction or needles orifice. The inside should be smooth (not full of dents and/or wear plates with protruding ends, or bindicators protruding into the lower cone). All these deficiencies can be fixed very easily and will reduce ΔP and will reduce fan kW draw (and will reduce particulate carry-overs as well).

The easiest power saving can be made by determining the quantity of air being drawn into the system from leaks in the ducting. Practically every system in every mill has leaks. It is obvious that the system does the job with the leaks (or the leaks would have been fixed). So to save energy, the leaks should be fixed and the fan flow rate reduced to maintain the flow rate at the same rate that it was drawing before the leaks were fixed.

With regard to fan wheel replacement, a rather attractive concept for a dramatic reduction in fan energy would be to simply replace the existing fan wheel with a more efficient wheel, in the same casing. So far this has never proved feasible. The fan wheel must "match" its casing and it seems that newer, more efficient fan wheels do not "match" older, existing casings. It would be possible to achieve this concept if a service existed to custom design and manufacture fan wheels for existing casings. However, it is doubtful that the cost of a whole new high efficiency fan would be greater than the custom designed and manufactured fan wheel.

More applicable to the design of a new, low pressure dust take-away system is the attention that should be spent on the design of the pick-up "hoods" at the machine centres (saws, chippers, screens, conveyors, etc.). It is the sum total of the open area of these hoods multiplied by the velocity required to capture the particles that determines the ultimate size of the system and the continuous flow of energy required. The "capture" velocity is created by pulling a ΔP. Many systems operate at 250mm m.c. (10 in. w.c.) and higher. Many systems do not require this high an equivalent velocity head.

Another method of saving power on a new system is to split the system into two, or more, with those machine centres requiring higher pressure on one system and the rest on a lower pressure system or systems.

1.6 Drives

The most common method of driving equipment in industry is to utilize a combination of electric motors, flexible drives, couplings, gear reducers and roller chains.

The potential for energy conservation in equipment drives is generally applicable to solid wood and composite board industries.

1.6.1 Flexible Drives

Flexible drives are used for a speed reducing (or multiplying) connection between the motor and the gear reducer. They also dampen-out vibrating forces and absorb shock loads. The different types of flexible drives include flat belt, v-belt, timing belt and roller chain.

Flat Belt

A flat belt has an efficiency of about 98% when properly selected and installed. The efficiency of this type of drive is greatly affected by proper tensioning of the belt.

V-Belt

The efficiency ranges from 70-96%. The torque load has the largest effect on efficiency. The lower the load, the lower the efficiency. For example, at 20% design torque the efficiency could be 80% while running at close to design torque the efficiency could be upwards to 96%.

V-belt efficiency is affected greatly by proper tensioning. Tensioning should be done on a regular basis so that slipping does not occur. Slippage becomes energy lost in the form of heat.

Proper pulley selection has an effect on efficiency as well. Larger pulley diameters translate into higher efficiencies. However, centrifugal force imposes an upper limit on the diameter. As v-belt speed approaches 4200 feet per minute the centrifugal force tends to lower the force of the belt against the sheave, reducing efficiency and increasing wear.

Timing Belt

Timing belts do not rely on friction to transmit power so they are not as sensitive to proper tensioning as are v-belts and flat belts. Timing belt efficiency is around 98%. Proper alignment is important for the belt to operate over a lengthy period (say five years) without maintenance.

Roller Chains

Chain drives are commonly used as a final connection from the gear reducer to the equipment. Tensioning is not as critical as for belt drives and efficiencies could be as high as 98.9%.

Chains require proper lubrication and alignment. Proper sizing is important to minimize stretching which can cause premature sprocket wear and inefficient operation. Oversizing the chain pitch will result in increased chordal action which will contribute to vibration and noise.

1.6.2 Gear Reducers

The purpose of the speed reducer is to convert the high speed, low torque electric motor output to a low speed, high torque requirement of the equipment. The speed reduction involves moving parts in the reducer which create efficiency losses due to friction.

The types of reducers available include worm, cycloidal, planetary and helical. Each type of reducer has different efficiencies due to their inherent design.

Gear reducer diagrams are contained in Appendix H in the source publication of this report. Potential changes for energy savings are contained in Appendix B of this report.

Worm

Worm gears are a screw thread (worm) engaging a gear (wheel) at right angles. The efficiency varies greatly with the ratio of the unit. Lower ratio worm gears have higher efficiencies then high ratio worm gears. For example, a 5:1 ratio worm gear could have an efficiency as high as 94% while a 40:1 worm gear could be as low as 75%.

As with other gear reducers, the worm will operate less efficiently at loads much lower than the rated capacity. Oversizing the reducer to handle the starting torque will lower the overall efficiency.

Cycloidal

Cycloidal reducers are similar to a stationary sun gear and internal planet gear arrangement. Large reductions as high as 87:1 can be obtained with a single stage.

These reducers generally have efficiencies higher than worm gears and could be as high as 95%. As with all reducers, proper maintenance must be performed to maintain optimum efficiency.

Planetary

The planetary gear reducer has an internal "sun" which drives "planet" gears around inside a stationary outer ring. The overall efficiency of the reducer is determined by the number of stages required to achieve the desired ratio. Efficiency is around 97.5% per stage.

Helical

Helical reducer gear sets are similar to standard straight cut (or spur) gears, but with tooth faces on an angle to the shaft, thereby forming a helix. Some helical gear reducers use multiple reductions to achieve ratios similar to those of single reduction worm gears.

A well designed helical gear set can have an efficiency of 98% per stage of reduction.

1.6.3 Potential Energy Savings Opportunity

Efficient operation of drive components can mean energy savings. Proper maintenance and service are minor cost items that can potentially increase energy savings. Major changes include replacing inefficient units with more efficient ones. A detailed analysis should be performed to determine the return on investment before any major changes are made.

A major analysis of gear reducer economics vis-a-vis potential electrical energy savings showed that the value of electrical energy savings through replacing worn gear reducers of 20 HP and less with helical reducers were less than the analyzed costs. So it would be wise to concentrate on higher horsepower drives.

The table in Appendix B lists minor activities and major changes that can be done to potentially increase energy efficiency.

1.7 Motors

Most wood industries use larger motors than the average power use would necessitate. The reasons for this oversizing are as follow:

- Insurance against motor failure in critical processes;
- Ability to increase production; and
- Large load fluctuations....the motor must be able to handle the peak load.

The selection of oversized motors cause the motors to run under loaded. It is desirable to operate a motor at 75 to 100% load, which is the peak efficiency range. When a motor is operated below 75% load, the efficiency drops off considerablly (see Figure 4).

Power factors should be kept above 50%, because the power factor decreases as the load of a motor decreases see Figure 4. This decrease may cause the overall power factor of a plant to drop below 90%. In British Columbia when this happens, a surcharge is added to the power bill.

High efficiency motors have greater efficiency than standard motors due to design changes, better material and manufacturing improvements. The minimum efficiencies in Table I are often exceeded and in some cases a good deal of improvement over standard motors can be achieved.

Some utilities over the last five years have provided industry with monetary rewards when industry changes to the use of high efficiency motors. Although this program is reduced in scope today, industry has adopted these motors as a standard.

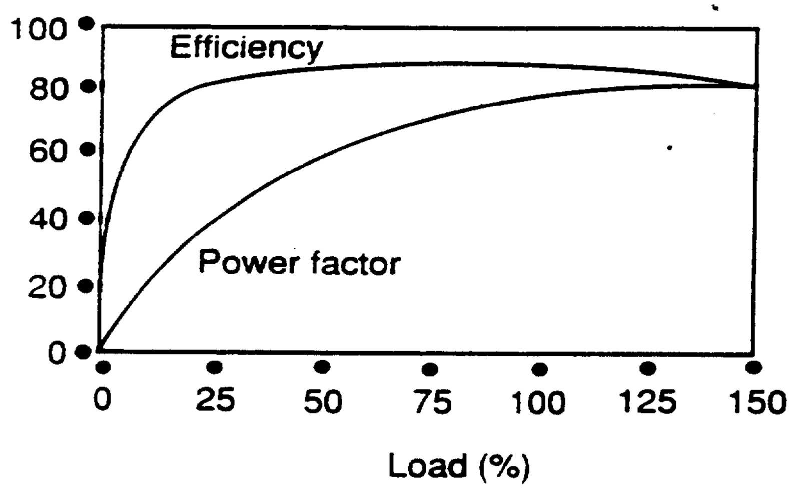


FIGURE 4: EFFICIENCY AND POWER FACTOR VS MOTOR LOAD

HP	High-Efficiency Motors Minimum Efficiency 1800 RPM (%)	1200 RPM (%)
1	80.5	80.0
1.5	80.5	82.0
2	81.5	82.5
3	83.0	84.0
5	85.0	86.0
7.5	87.0	87.0
10	87.0	88.0
15	88.5	89.0
20	90.0	89.0
25	91.0	90.5
30	91.0	91.0
40	91.5	91.5
50	92.5	91.5
60	92.5	92.0
75	93.0	92.5
100	93.0	93.0
125	93.0	93.0
150	93.5	93.5
200	94.0	94.0
250	94.5	94.5
300	95.0	95.0
400	95.0	95.0
500	95.0	95.0

TABLE 1: MINIMUM MOTOR EFFICIENCIES OF HE MOTORS

1.8 Natural Gas

The majority of wood products mills in Canada utilize natural gas fuel. This fuel is used for plant heating and in many instances for process heating, such as:

- Lumber dry kilns;
- Log conditioning for veneer, plywood and strands;
- Veneer dryers;
- Rotary dryers - particleboard, OSB; and
- Heating/drying ovens for finger jointing, paint lines, etc.

Often the main fuel is residue wood with natural gas as a stand-by fuel. On the other hand, many plants utilize their residue wood and bark to provide both space heating and process heating with some plants using natural gas as a stand-by fuel. The main reason that so many plants still use natural gas, even when they have large quantities of residue wood to dispose of, is that natural gas is a very low cost and convenient fuel. There is not a return-on-investment for the mills to install the wood burning equipment to allow conversion from natural gas to residue wood fuel.

Plant evaluations to determine when the natural gas can be used more efficiently have provided the following:

- Energy waste because the solution to heating cold areas of the mill has been solved by the simple addition of unit heaters. The philosophy here is to throw enough heat at it and it's bound to heat up to a workable temperature, rather than a proper evaluation of the problem and the design of a well laid out heat distribution system. In addition, the minimization of factors that allow the cooling of the area, such as poor door design through which raw material (such as logs, or peeler blocks) enter the mill or where product (such as packages of lumber) leave the mill. Up to one GJ/hour of energy can be wasted in areas such as these.

- Many dust extraction systems in wood products manufacturing plants draw out large quantities of air with the dust and thereafter separate the dust from the heated air after exhausting to the outside. One system alone can withdraw 5 GJ/hour of heating energy. This will be approximately double all the energy required to heat the mill (if the dust extraction system was not drawing out all the heat).

There are at least two methods that can be used to drastically reduce the heat loss; the first being far less costly than the second:

(1) Duct outside cold air to those machine centres from which the dust extraction is removing the dust and air.

(2) Planers, are usually housed in an enclosure or separate room that can be equipped with a large duct to the outside. Large low loss multi-louvered barometric dampers are included in the duct which automatically shut off when the dust extraction system is shutdown (at the time of maintenance or when the mill is not running). A unit heater can be provided in the enclosure which starts up when the dust extraction system stops so as to heat the room for the maintenance people.

It was found that most of the process heating was relatively efficient, with the lumber dry kilns being the best. Some heat could be saved where door seals and the doors themselves were leaking, but there are more powerful reasons to fix these so as to improve drying uniformity than to save heat. Regarding insulation, most insulation is sub-optimal but the small heat loss through the insulation compared to the other losses discussed, and the high cost of replacing insulation in most mills, does not provide adequate return on investment.

Veneer dryers are never as efficient in heat use as kilns, but by and large are operated in a relatively efficient manner from the heat use point of view with a large part of the dryer operating at positive pressure to reduce the tramp air being induced into the dryer (which must then be heated up and blown out the stack to the atmosphere....a direct and total loss of heat energy).

The two areas that always need attention are:

- Door seals; and
- End baffles (running on the entrance and exit rolls at each end of the dryer).

Some dryers experience excessive corrosion, especially along the bottom of the doors and the lower door sills. These simply have to be maintained to minimize the induction of tramp air (and to minimize the loss of vapour out of the dryer into the plant . . . rather than up the stack where it should go).

The areas on rotary dryers where the efficiency of heat use can be improved:

- Reduced leakage at the front drum (face) rotary seal.
- Reduced blend air or increased temperature difference (face temperature minus exit, or tail, temperature). This approach to heat savings must be evaluated against the quality of furnish drying and against the emission created by higher temperature drying. The analysis of these and other "trade offs" is quite complicated. The analysis should be performed before changing the operating parameters.
- Installing a recycle system where stack gas (vapour/air mixture) is used for blend air rather than fresh air.
- Many rotary dryers are direct-fired by residue wood burners . . . a guaranteed method of savings natural gas usage.
- Flash tube dryers would respond to many of the same improvements as described above under rotary dryers . . . except the discussion of face seal leakage, because flash tube dryers do not have a face seal.

2.0 NEW ENERGY EFFICIENCY TECHNOLOGIES

2.1 Electrical Energy Efficiency

There are technologies available that could potentially improve energy efficiency in the wood products industry. These technologies are in place in other industries and their applications could be introduced to the Canadian wood products industry in the next five to ten years.

Improvements in energy efficiency would include analyzing present equipment and plant systems such as compressed air, hydraulics and carriage drives.

2.1.1 Carriage Drives

Technology improvements have gradually changed the way the headrig log carriages have been driven. Present drives include the "gun shot" with a steam cylinder and also with pressurized water, the amplidyne motor-generator DC drive and more recent technology using a solid state AC variable frequency drive.

2.1.2 Gun Shot Steam Drive

Natural gas or other fuels are used to heat the water to steam in a boiler with the attendant efficiency loss of the boiler. The cylinders are usually sized larger than required to handle a wide range of loads, thereby requiring more steam than necessary. The exhausted steam is vented to the atmosphere which is a large wastage of heat.

2.1.3 Gun Shot Water Cylinder

An electric motor is used to drive a pump which supplies pressurized water hydraulic power to move the cylinder. In this circuit there are losses in the pumps, the piping and the valves all of which create wasted energy in the form of heat. This heat must then be removed by a water cooler and exhausted. This lost heat was originally supplied by the motor and is lost to the atmosphere.

2.1.4 Amplidyne AC/DC Drive

This type of drive utilizes an AC motor that drives a generator to convert the power to DC. This power then drives the DC motor which moves the carriage back and forth utilizing cables, cable drums and a gearbox. Efficiency losses are incurred in the entire system, including the AC motor, generator, DC motor and gearbox.

2.1.5 AC Solid State Variable Frequency Drive

This drive uses the same cable drum and gearbox, but uses an AC motor instead of a DC motor. The AC current is converted to variable frequency in a solid state convertor. The carriage speed is varied by adjusting the frequency of the current supplied to the AC motor. When the carriage is decelerated, the power is converted back into the mill power supply. This is the most efficient system and should slowly supplant the other systems in use.

2.1.6 Electric Motor-Driven Linear Actuator

A technology that has not yet found its way into the carriage drive application is the electric motor-driven linear actuator. This actuator utilizes a motor-driven, recirculating ball nut which meshes with a long rod which has a ground ball race thread.

2.1.7 Linear Motors

This system would avoid rotating equipment, with its bearings and inherent losses, all together. It would resemble the Vancouver Sky Train drive and would be absolutely simple.

2.1.8 Actuators

There are many actuators used in a wood products mill. These are usually comprised of a piston inside a cylinder with the piston rod moving axially providing the force and motion required.

Most of these cylinders are powered by compressed air, some by pressurized hydraulic fluid. The compressed air actuators are the least efficient. A great deal of motor power is required to compress air. During the compression, heat is generated which must be expelled to the atmosphere — a direct energy loss. Then the compressed air, after cylinder activation is expelled to atmosphere under pressure — another direct energy loss. This type of energy transfer is very inefficient. A more efficient system is the use of hydraulics as discussed elsewhere in this report. However, in hydraulic systems the fluid becomes over-heated and must be cooled with a direct loss of energy to the atmosphere.

A much more efficient method of achieving a forceful linear actuation would be by an electric motor powered recirculating ball actuator as described above in Section 2.1.1 - Carriage Drives. These units have found limited usage as setworks actuators in wood products plants, but should in future be used for general mill actuators with greatly improved electrical energy efficiency.

Another technology which will potentially reduce electrical energy use is the "slug"-type air convey system. This system is described under Section 1.5.1 - High Pressure Air Conveying Systems.

2.2 Natural Gas Efficiency

There are some areas of improved efficiency that do not really use new technology, but instead apply existing technology in a different manner.

One example would be mills which use natural gas-fired fluid boilers which, in turn, supply steam for plant space heating and lumber dry kiln heating (or other process heating).

It is almost invariably more energy efficient to heat the mill space or the process directly; so called direct-firing (whereas the boiler system would be called indirect-firing). The direct-firing method directs the hot combustion gasses from the burner directly into the process or heated space, thereby eliminating the efficiency loss associated with the boiler. (It also reduces the complexity of the operation, reduces the operating cost and reduces the maintenance cost.)

Another area of energy conservation is specifically associated with the operation of lumber dry kilns. Often the lumber in the kiln is pre-conditioned, at the beginning of the drying schedule, or post-conditioned (stress relieved). The conventional way that this is accomplished is to inject live steam into the kiln. This is wasteful from the energy point-of-view since only about half of the injected steam is actually used to increase humidity — the rest vents out of the kiln and is lost. Also, the "feed water" that was supplied, chemically treated and heated, is lost and must be made up with replacement cold, fresh water.

Another problem with this system, when used for post-conditioning, is that the hot steam is introduced into an already hot kiln onto hot lumber. The condensation of this steam gives up a great deal of heat, at a time when the kiln does not need any more heat . . . The result is that the dry bulb temperature of the kiln goes up instead of down — this is not at all satisfactory.

An alternative to this system is the use of water atomizing sprays mounted on manifolds that extend through the length of the kiln. This has been tried over the years and always found "wanting". The sprays did not atomize the water thoroughly, resulting in the lumber having water stain marks on its surface. Also, water drainage was often a problem.

Recently there has been extensive research on this system, the nozzles and pressure requirement. This research has resulted in a new system using nozzles which include a target against which the water impinges, breaking it into sub-micron vapour. This new system has now been installed in kilns and is operating in a satisfactory manner. The energy required to pump the water to the nozzles is a small fraction of the natural gas energy required by the boiler for the same lumber conditioning treatment. This new system should be considered for any kiln that uses conditioning steam — it will provide energy savings and potentially a better lumber conditioning environment.

3.0 PROGRAM ASSESMENT

3.1 Electrical Energy Conservation

Almost all utilities have a power conservation program. These programs are generally broken down into these sectors:

- Residential;
- Commercial; and
- Industrial.

Wood products manufacturing mills comes under the "industrial" sector.

B.C. Hydro has one of the most active and successful programs — the Power Smart Program. As an example of its effectiveness, the annual energy savings achieved, as at December 30, 1993, were as follows:

• Residential	340 GWh	
• Commercial	652 GWh	
• Industrial	321 GWh	
TOTAL	**1,313 GWh**	**Annually**

With a total system load of 46,346 GWh the savings achieved by the ènd of 1993 amounted to 3% of total annual load, after only three years of effort — truly impressive.

B.C. Hydro has a plan to invest approximately $ 600 million over 20 years to reduce consumption by 5,600 GWh, or 12% of the present load.

With a fairly intimate knowledge of the activities in the wood products manufacturing sector, it is absolutely clear that the potential for electrical energy conservation has "just been scratched". However, the effort expended in the industrial sector has been small compared to the residential and commercial sector . . . as the results show.

Some industrial programs have worked very well, some not so well. As an example, the high efficiency motor program has worked very well. The purchase by mills of high efficiency motors has become almost "conventional wisdom". The major enabling circumstance of this program is that mill motors have a limited life so the mill is continuously replacing motors. The Power Smart rebate made it cheaper to buy a new high efficiency motor than to buy a standard efficiency motor. Thus the program has been extremely successful.

The same could be said for the lighting program. The technology (from the mill's point-of-view) is almost as simple as buying a particular motor (a high efficiency one). Lighting contractors will quickly provide quotes on the cost to replace the low efficiency lighting fixtures (incandescent and fluorescent) with the high efficiency ones (pressurized sodium and metal halide). The plans for replacement in various sections of the mill can be formulated with no up-front expenditure. However successful these programs have been, they do not have the size of potential energy savings that other technologies offer.

The fan program with its air convey component has very large potential savings, as shown in Figure 8, but has not been as successful. One reason for this is that the actions required to achieve the savings needs a good deal of specialized engineering analysis and design. The mills' personnel by-and-large do not have the expertise or the time to provide this analysis and design.

When the potential return on investment is not known or guaranteed (to be satisfactory) the mill is unlikely to hire a consultant to do the analysis and design required. This would involve considerable up-front expenditure just to find out if the project would have a satisfactory return on investment and thereafter be included in the mill's capital plan.

Even where the utility offers to pay 50% of this up-front expenditure, the mills usually find it difficult to come up with the other 50%. Of course, there is a reason for this: energy cost to the mill is a small proportion of its total cost of production. A reduction in the cost of energy does not affect the mill's profitability in nearly the same proportion as many other opportunities. Therefore, the mill is likely to spend the energies of its personnel where the potential is greatest (and where it shows the most . . . energy is not really visible to the naked eye!).

3.2 Natural Gas

Much the same comments as above are applicable to natural energy conservation. However, in-mill evaluations have shown some means of energy savings that are simple and easy to achieve — and a lot of further analysis and design has not been necessary. This would indicate that even the dissemination of this report would help mills achieve savings with relatively small effort and cost and very large returns on investment.

However, as a general observation, the wood products manufacturing plants do need some help in determining where the energy savings are and what the amount of the savings are likely to be.

This help can be provided by the supplying utility or by outside consultants hired for the purpose.

3.3 Summary

An order of priority relating to the relative success of various programs is as follows (the most successful first):

- An example of the absolutely most successful program would be the high efficiency motor program in B.C. where, in future, it will be illegal to sell a motor of 200 horsepower or less that is not a high efficiency motor. With this legislation, the utility's rebate will end.

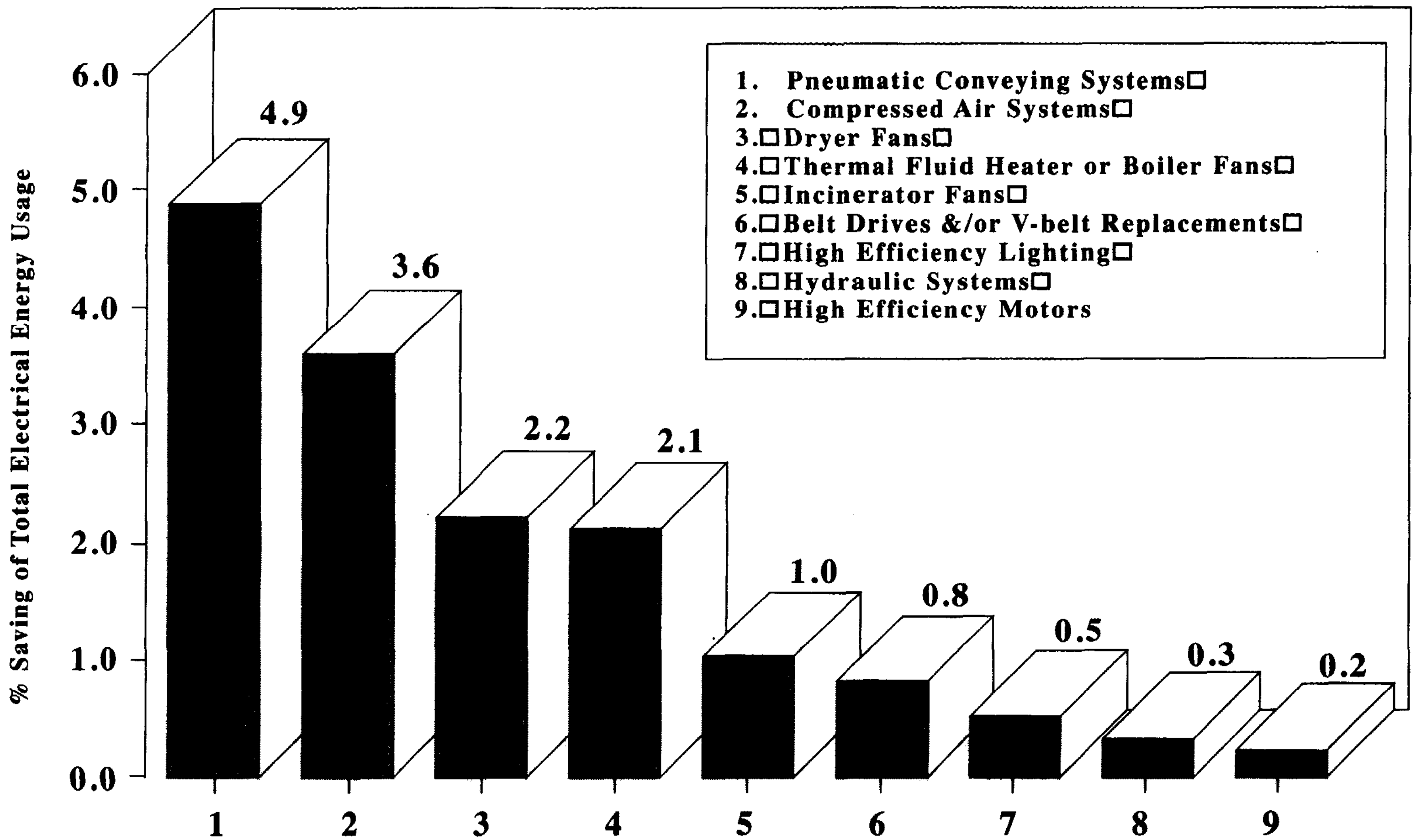
- The second most successful program, although it is much like the one described above, is where a "standard" is written for a particular product stating the minimum allowable energy efficiency — especially where the building code reflects this "standard".

- Those programs such as "lighting" which are simple and do not require any expenditure before purchasing and installing the equipment.

- Those programs where the utility funds the analysis required to determine the savings and how the savings will be achieved. An example of the approach would be the Power Smart Compressed Air Program where the utility actually bought and provided the air flow rate gauge to the mill and also provided in-mill analysis and personnel training at no cost to the mill operator.

- The least effective programs have been those which required external analysis and design work before the magnitude and value of the savings could be determined. The problem is that this category has biggest savings available (see Figure 5).

FIGURE 5: POTENTIAL ELECTRICAL SAVINGS FOR A TYPICAL SAWMILL



4.0 ACTION PLAN

The purpose of the information in this section is to help the Canadian Industry Program For Energy Conservation (CIPEC) Wood Products Task Force develop a strategy to ensure the adoption of the energy efficiency opportunities identified in this report.

4.1 Electrical Energy Savings

Since almost all Canadian utilities have joined "Power Smart Inc." all the Guides to Energy Management (GEM's) are available to them. CIPEC could organize the dissemination of this extremely valuable information to each wood products plant. These GEM's are available in a loose leaf binder with dividers for each subject (e.g. flexible drives, power factor, wood hogs, etc.).

CIPEC could also assist for each utility to provide informative in-plant seminars to help the mill personnel relate the information in the GEM's to potential savings in the plant.

It would be possible to create a questionnaire for each type of mill (sawmill, plywood plant, MDF plant, etc.) which could be filled in by the plant personnel and, when analyzed, would be a "rough cut" of where potential savings would likely be and in what order of priority. In fact, these could be prepared in Windows software format (on disk) for each type of plant which the plant personnel could load, fill in the blanks and the calculations would be performed and then a prioritized list calculated and printed out.

A generalized program, much like the one described above, was created by B.C. Hydro - Power Smart in the Windows format. However, it does require a fairly knowledgable person at the mill to determine the appropriate data required and to enter the data correctly. B.C. Hydro - Power Smart organized a hands-on workshop (each person sitting at a computer terminal) to lead mill people through this program. Many of the mills, whose personnel attended the workshop, did purchase the program.

Carroll-Hatch (International) Ltd. prepared the typical problems, the input data and solutions for the program and thereafter helped present the workshop at various centres around the province. If this type of program was tailored to each type of mill (sawmill, plywood plant, MDF plant, OSB plant, etc.) then it would be much easier for mill personnel to operate.

Since the subject of energy conservation is extremely important to the whole society, it would be valuable for CIPEC to help organize extension courses to be offered at community colleges all across the country. These extension courses would be prepared specifically for the type of wood products operations in the vicinity, and would train people on how to determine the amount and value of energy savings that can be achieved. This program would logically fall under the Canadian Energy Management and Environmental Training Program (CEMET). However, this approach is slow. In other words, the energy savings will take a long time to be achieved by this process.

However, the whole subject of energy conservation is extremely important to society because almost every unit of energy used has an environmental "cost", e.g. a valley has been flooded behind a dam, or a unit of coal or natural gas has been combusted with resulting stack gas and particulate entering the atmosphere, or a unit of a non-renewable fuel has been burned up — never to be utilizable again. It would seem logical and would provide a very satisfactory return on investment to take a more intensive approach.

In contrast to the above training approach, a much quicker approach would be to provide funds for energy conservation consultants to undertake a thorough evaluation of each plant and to prepare a prioritized plan for each mill's energy conservation program. This plan would include the potential savings in energy from each location in the mill, the annual dollar savings, the estimated capital cost, the return on investment (after taking into account any utility rebates available) and the recommended changes to operating strategy, where required. Part of this activity would be the follow up with each mill to ensure that the energy efficiency programs were included in the mill's capital plans and were thereafter instituted and the energy savings measured.

One specialized area of energy conservation is the more widespread use of wood residues. Many plants presently use wood residues very effectively for fuel. However, in many plants these residues of the wood products manufacturing process are disposed in very sub-optimal methods - often by incineration or by land fill.

These residues can be used to generate electricity, as heat sources for drying wood products, to make fertilizer and some residues can be used as decorative ground cover, etc. However, in most instances, there simply is no adequate return on investment for these endeavours. If more attractive tax incentives than "Class 34" were introduced to help make these endeavours at least break-even, then electrical energy would be saved and natural gas would be conserved.

4.2 Natural Gas

This report, if distributed to the many Canadian wood products plants, would help direct the plant personnel to look at those areas where potential savings are most likely to be found. Workshops could be organized to be held in appropriate centres. The workshops could take the attendees through typical areas of potential savings, calculate the heat savings, the annual dollar savings likely and the probable capital cost to make the necessary changes.

Another approach would be the organization by the natural gas utilities to have their service representatives trained in the methodology of energy savings in the wood products manufacturing sector. Thereafter helping their customers find potential areas of energy savings and provide assistance in achieving the savings.

Many of the suggestions made above in Section 4.1 - Electrical Energy Savings are equally valid for natural gas. Where the program could involve the dissemination of information, it would be logical to include information both on electrical conservation and on natural gas conservation. This would be true for training programs as well.

APPENDIX A:
OPPORTUNITIES FOR ENERGY SAVINGS (SAWMILLS) & PLANER MILLS: COMPRESSED AIR

ITEM	AREA		MINOR CHANGES		MAJOR CHANGES	Ref.
1	**Air Production**		**Operational**		**Modifications**	
	Compressor(s)	1	Check and Clean Air Intake Filters	1	Add Compressor sequencer if multiple compressors	
		2	Check and Adjust Compressor Pressure Setting	2	Convert Modulating Control to Load/Unload**	
		3	Check and Adjust Compressor Modulating Controls			
		4	Check and Adjust Sequencer (If present)			
		5	Check and Adjust Compressor Capacity			
2	**Air Production**		**Operational**		**Modifications**	
	Air Drying	1	Check Condition of filters and replace if necessary	1	Add Dryer Purge Control System	
	Pre/After Filters	2	Check and replace dessicant if required	2	Add Dryer Humidity Control	
		3	Check for Internal Bypass leaks in dryer switching Valves	3	Replace Heatless Dryers with Heat Regenerative type or Heat of Regeneration type	
3	**Sytm/Stor. Capacity**		**Operational**		**Modifications**	
	General	1	Check for and Reduce Air Leaks	1	Add Demand Control Air Management System (eg. ConservAir Intermediate Control (I/C))	
	Receiver/Reservoir	1	Check Safety relief setting if installed	1	Add Receiver/Reservoir Capacity	
	Pressure Settings	1	Adjust Receiver Discharge S/O valve to Control Flow**	1	Install High performance Pressure Regulator on Outlet	
	Header/Line Setting			1	Provide Adequate line Sizing	
				2	Modify to Loop system	
4	**Air Utilzn: Prodctn**		**Operational**		**Modifications**	
	End Use:	1	Adjust End Use pressures if Regulators installed	1	Add Pressure Regulators at Significant Users	
	Pressures	2	Adjust End Use Speeds to only what is required	2	Convert Appropriate Applications to Dual Pressures	
		3	Replace Flow restricting Undersized Hoses & fittings			
	Secondary Preparation	1	Check and Clean dirty filter elements			
	(Filter/Lubricators/	2	Check, Clean/Replace Leaking Filter Bowl Drain Plugs			
	Regulators)	3	Check and Repair Leaking Regulator Diaphragms			
	End Use: Miscellaneous	1	Add pressure regulators to air jets	1	Use More efficient Air Nozzle Technology for Air Jets (Photo eye cleaning, Belt Cleaning, Dust Blowing)	
		2	Add timed solenoid valve to air jets	2	Convert Apprpriate Users to Single Acting Cylinders	
	End Use: Alternatives			1	Replace Air User with Alternative Energy Sources: i.e. Hydraulics	
5	**Air Utlztn: Non Prod**		**Operational**		**Modifications**	
		1	Turn Off All Unnecessary Compressors	1	Install High Efficient air nozzle for clean up	
6	**Air Utlztn: Off Shfts**		**Operational**		**Modifications**	
		1	Turn Off All Unnecessary Compressors	1	Machine Center Isolation Valves Interlocked to Control Power	
				2	Isolate Fire Protection Air Supply For Dry Pipe Valves to its own dedicated small compressor(s)	

OPPORTUNITIES FOR ENERGY SAVINGS (PLYWOOD & COMPOSITE BOARD PLANTS): COMPRESSED AIR

ITEM	AREA		MINOR CHANGES		MAJOR CHANGES	Ref.
1	**Air Production**		**Operational**		**Modifications**	
	Compressor(s)	1	Check and Clean Air Intake Filters	1	Add Compressor sequencer if multiple compressors	
		2	Check and Adjust Compressor Pressure Setting	2	Convert Modulating Control to Load/Unload**	
		3	Check and Adjust Compressor Modulating Controls			
		4	Check and Adjust Sequencer (If present)			
		5	Check and Adjust Compressor Capacity			
2	**Air Production**		**Operational**		**Modifications**	
	Air Drying	1	Check Condition of filters and replace if necessary	1	Add Dryer Purge Control System	
	Pre/After Filters	2	Check and replace dessicant if required	2	Add Dryer Humidity Control	
		3	Check for Internal Bypass leaks in dryer switching Valves	3	Replace Heatless Dryers with Heat Regenerative type or Heat of Regeneration type	
3	**Sytm/Stor. Capacity**		**Operational**		**Modifications**	
	General	1	Check for and Reduce Air Leaks	1	Add Demand Control Air Management System (eg. ConservAir Intermediate Control (I/C))	
	Receiver/Reservoir	1	Check Safety relief setting if installed	1	Add Receiver/Reservoir Capacity	
	Pressure Settings	1	Adjust Receiver Discharge S/O valve to Control Flow**	1	Install High performance Pressure Regulator on Outlet	
	Header/Line Setting			1	Provide Adequate line Sizing	
				2	Modify to Loop system	
4	**Air Utlzn: Prodctn**		**Operational**		**Modifications**	
	End Use:	1	Adjust End Use pressures if Regulators installed	1	Add Pressure Regulators at Significant Users	
	Pressures	2	Adjust End Use Speeds to only what is required	2	Convert Appropriate Applications to Dual Pressures	
		3	Replace Flow restricting Undersized Hoses & fittings			
	Secondary Preparation	1	Check and Clean dirty filter elements			
		2	Check, Clean/Replace Leaking Filter Bowl Drain Plugs			
		3	Check and Repair Leaking Regulator Diaphragms			
	End Use Miscellaneous	1	Add pressure regulators to air jets	1	Use More Efficient Air Nozzle Technology for Air Jets (Photo eye cleaning, Belt Cleaning, Dust Blowing)	
		2	Add timed solenoid valve to air jets	2	Convert Appropriate Users to Single Acting Cylinders	
	End Use: Alternatives			3	Modify Baghouse to Low Air use Type	
				1	Replace air user with alternative energy source: i.e. Hydraulics	
5	**Air Utlztn: Non Prod**		**Operational**		**Modifications**	
		1	Turn Off All Unnecessary Compressors	1	Install High Efficient air nozzle for clean up	
6	**Air Utlztn: Off Shfts**		**Operational**		**Modifications**	
		1	Turn Off All Unnecessary Compressors	1	Machine Center Isolation Valves Interlocked to Control Power	
				2	Isolate Fire Protection Air Supply For Dry Pipe Valves to its own dedicated small compressor(s)	

APPENDIX B: OPPORTUNITIES FOR ENERGY SAVINGS IN FLEXIBLE DRIVES AND GEAR REDUCERS

ITEM	AREA		MINOR CHANGES		MAJOR CHANGES
1	Flat Belt	1	Check and adjust alignment	1	Upgrade to newer belt using synthetic materials
		2	Check belt condition and replace if required	2	Replace with timing belt
		3	Check and adjust tension		
2	V-belt	1	Check and adjust alignment	1	Increase sheave size
		2	Check belt condition and replace if required	2	Replace with timing belt
		3	Check and adjust tension		
3	Timing Belt	1	Check and adjust alignment		
		2	Check belt condition and replace if required		
		3	Check and adjust tension		
4	Roller chain	1	Check and adjust alignment		
		2	Check for wear and replace if required		
		3	Check and adjust tension		
		4	Check for lubrication		
5	Worm Gear	1	Check oil level	1	Replace with smaller unit if greatly oversized
		2	Remove dust and debris for proper heat dissipation	2	Increase input speed
				3	Decrease reduction ratio
				4	Replace with a more efficient gear unit
6	Cycloidal	1	Check oil level	1	Increase input speed
		2	Remove dust and debris for proper heat dissipation	2	Replace with a more efficient gear unit
7	Planetary	1	Check oil level	1	Increase input speed
		2	Remove dust and debris for proper heat dissipation	2	Replace with a more efficient gear unit
8	Helical	1	Check oil level	1	Replace with unit having fewer reduction stages
		2	Remove dust and debris for proper heat dissipation	2	Increase input speed

NOTES

Prepared by:
Carroll-Hatch (International) Ltd
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