Conservation of energy is not a high priority for Australian raw sugar factories. This is partly due to the ready availability of cheap coal in the sugar growing regions and partly because those regions are relatively remote from the centers of population which would form the initial market for any by-products. Hence, it is energy management rather than energy conservation that is the concern of most factory managers. This paper discusses the current energy management policies applied to the majority of Australian raw sugar factories and the reasons why those policies apply. However, energy conservation is not ignored. A few factories have additional demands on their available energy and the industry lives in hope a viable market will soon be found for an energy related by-product. The paper discusses some of the work that has been undertaken to prepare Australian factories for that eventuality.

INTRODUCTION

One major factor affecting the energy environment in which a sugar factory is operated is the general energy environment of the country or state in which that factory is located. The Australian raw sugar industry operates in a region in which there are vast resources of coal. Several major coal export ports are situated along the coastline that the sugar industry occupies. As a consequence the demand for electrical power export from sugar factories is minimal.

Another factor that affects a sugar factory’s attitude to energy conservation and management is the presence or absence of by-product operations such as refineries, distilleries, paper pulp plants or fiber board factories. The size of the Australian subcontinent and the large distance between much of the Australian raw sugar industry and the main centers of population are factors that have had a significant effect on the development (or lack of development) of sugar related by-product operations in Australia. The distance between the major population centers and much of the sugarcane growing areas is typically between 1000 km and 3000 km. Thus an export type operation has to be mounted even for marketing within Australia. This has placed and will continue to place a major disincen-
tive on the development of by-product operations in Australia. Only four of the 29 factories currently operating in Australia have associated by-product operations (two distilleries (one quite small), one refinery and one combined refinery/distillery). Hence only in those four factories do the energy conservation practices that are normal in many overseas factories have to apply. In the remaining factories the main concerns of the energy managers are to ensure that enough energy is available to run the factory and that there is the very minimum of spare energy in the form of bagasse left over for disposal.

The small distillery and the refinery have only been installed in the last few years following the easing of governmental constraints on industry operations. Until recently nearly all sugar refining was undertaken in the State capitals with the majority of the raw sugar being transported to those refineries by sea. The relaxation in governmental constraints has already resulted in the closure of one capital city refinery and may yet result in the closure of another and the construction of a large refinery in North Queensland. In addition there continues to be interest in exporting cane fiber based paper pulp and generation of electricity from bagasse, the latter being prompted by increased concern about the environment and the need to use renewable resources more effectively.

A final factor associated with investment for energy conservation or management is the cost of capital. In Australia, capital investment money is very expensive because of high interest rates and because the taxation regulations are not particularly favorable. Hence the economic benefit from any proposed change has to be very substantial before capital can be committed to a project.

CURRENT ENERGY MANAGEMENT POLICIES IN AUSTRALIAN FACTORIES

As the introduction indicates, there is in general no incentive for Australian raw sugar factories to practice energy conservation to any great extent. Rather the emphasis is on energy management with the following factors being important.

- The need to consume all bagasse;
- The need to supply enough steam energy for factory operations irrespective of the level of fiber (and incombustibles such as dirt) in the cane;
- The need to constrain steam use to within the steaming capacity of existing steam generation equipment;
- The need for a reasonable balance between high and low pressure steam requirements;
- The cost of alternative fuels.

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The relative importance of these factors varies from factory but all play some part in energy management in one way or another.

**Total Bagasse Consumption**

With no market for excess bagasse in most Australian factories, a high priority is placed on the consumption of all bagasse. Dumping of excess bagasse is a very expensive operation because bagasse is so light that the dumping operation is labor intensive. Even if this were not so, finding an acceptable place to dump is very awkward. The unsightly nature of the waste heap, the potential fire hazard and the risk of biologically active run-off all result in much attention being paid to the dump site by State and local government authorities. Hence the boiler station is always designed (at least initially) and operated (if at all possible) to ensure that all bagasse can be burnt. This condition generally defines the minimum efficiency required from the boiler station based on the highest planned cane fiber level.

**Fiber Level Constraints**

In comparison, the maximum efficiency required from the boiler station is determined from the lowest anticipated cane fiber level and is associated with the need to supply enough steam for factory operations irrespective of the cane fiber level. To satisfy this requirement with reasonable certainty, the quality of the bagasse should be known with reasonable precision. Not only is the bagasse moisture important, it is equally important to know the amount of incombustible "ash" in the fiber and the actual amount of fiber that reaches the boiler station. The main "loss" of fiber as far as the boiler station is concerned is to the filter station in the form of bagacillo. In Australian factories, typically about 3% of the fiber is used as bagacillo. Dirt levels vary greatly depending both on the location of the factory and on weather conditions. In some areas, season average ash levels in bagasse as a proportion of dry fiber can be as high as 20%, dropping to somewhere in the region of 5% under better conditions. Once all these effects are allowed for, the amount of clean fiber actually available at the boiler station can be several units lower than the "fiber" level (defined as dry insoluble solids) measured when the cane enters the factory. These "few units" make a very significant difference to the actual amount of steam that can be raised when cane fiber levels are low and dirt levels are high.

The result of the requirement to not only burn all the bagasse when cane fiber levels are high but also to be able to generate enough steam when fiber levels are low requires variable efficiency boilers and careful selection of the limits to the efficiency range. All boilers built during the last two decades have some type of
variable efficiency system incorporated. On earlier boilers the change in efficiency was built into the boiler itself using some means of dumping heat or reducing combustion efficiency. More recent boilers have tended to have fixed efficiency and the capability of generating more steam that the factory requires. The excess steam is then condensed in a separate air cooled dump condenser to obtain an effective variation in efficiency (Levy).)

**Boiler Steaming Capacity**

All this discussion is quite pertinent if a new boiler station is being designed or if the station has plenty of capacity. However boilers are very expensive items of equipment and economics (expressed as installation cost per ton of steam generated) dictate that they be installed in relatively large units. That also implies a reluctance to spend money on increasing boiler station capacity because small incremental increases in steaming rate are uneconomically expensive. Hence as factories increase their processing rate for whatever reason, there comes a time when steam generating capacity is a primary limitation of factory operations. Such a limitation is in some ways only an inconvenience and provides only a loss of operational flexibility. It generally means that water use in the factory has to be controlled and limited. More seriously under Australian conditions it often implies an inability to burn all the bagasse during periods when cane fiber levels are high so that the factory has to resort to bagasse dumping with all the attendant problems outlined above.

The cost of boiler installations is of considerable concern to Australian raw sugar factories. It would be preferable to have available a cost effective means of either installing small increments of steaming rate increase or a cost effective means of using existing steam generating equipment to generate more steam. In addition it is desirable that combustion stability be improved as well as fuel quality (moisture) changes occur. Sugar Research Institute has spent considerable resources investigating this problem. The result is the development of the swirl burner combustion system for bagasse (Dixon, Dixon and Steindl). This system is an extension and modification of the swirl burner system used in coal fired utility boilers and has been developed to the stage where it is operating on a relatively small boiler. The system provides improved combustion stability and an increase in steaming rate from an existing furnace retro-fitted with the swirl burner system. Such retrofitting appears to be more cost effective than the installation of a new furnace and can provide incremental increases in generating capacity. The swirl burner requires dried bagasse to operate effectively. The drying process uses furnace gases (rather than flue gases). It achieves the increased steaming capacity because the moisture from the dried bagasse bypasses the main tube bank of the boiler, thus enabling an increased firing rate within the furnace itself. There is generally only a small change in overall boiler efficiency.
High and Low Pressure System Balance

The last energy management factor mentioned at the start of this section is the generally perceived need to maintain a reasonable balance between high and low pressure steam use. If there is any bias, there tends to be slightly more low pressure steam used than high pressure steam because this means that control of the pressure of the low pressure steam can be obtained by varying the make-up of low pressure steam from the high pressure system. This avoids the loss of steam and condensate associated with control of low pressure steam by venting to atmosphere.

Australian raw sugar factories as a group are not static in terms of throughput. There is a general trend towards higher capacity. Hence there is a surprisingly frequent need to review and modify steam use efficiency.

In practice high pressure steam use cannot be modified much. Of all the factory turbines, the only flexibility lies with the turbo-alternator. In many factories it is possible to generate a small amount of excess electrical power and export this to the electricity grid. The financial rewards for such casual and uncontrolled export are very poor and cannot possibly justify the installation of generating capacity just to export power. (Payment for such export is less than $0.02 per kWh compared to a cost of about $0.10 per kWh for imported power). Nevertheless boiler station control can be improved considerably if export power can be readily varied to compensate for variations in demand, particularly from the batch operations at the back end of the factory. This form of control is practiced in several Australian factories.

Apart from this, factories generally accept whatever efficiency is associated with the high pressure turbines and adjust back end efficiency to suit. The techniques available for the variation in efficiency of the operation of the back end of the factory are much greater than on the high pressure side. When the need to adjust low pressure steam use is seen to be long term, Australian factories generally find it possible to justify equipment changes. The techniques for deciding on these changes are well defined although the constraints on the decision making process tend to be factory specific so that the final decisions on factory configuration are variable. Even without major changes to equipment, significant variation in the efficiency with which low pressure steam can be used is available (McDougall, Moir and Wright).

Alternative Fuels

Another very important factor in determining energy management and conservation policy is the relative cost of the various sources of energy. Table 1 gives an approximate indication of the relative cost of electricity, oil, coal and bagasse in
Queensland. Electricity is by far the most expensive so the import of electricity is always tightly controlled.

**TABLE 1. Approximate cost of energy from various sources.**

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Purchase cost</th>
<th>Energy cost ($/GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity import</td>
<td>$0.10/kWh</td>
<td>28</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>$ 300/t</td>
<td>9</td>
</tr>
<tr>
<td>Coal</td>
<td>$ 40/t</td>
<td>2</td>
</tr>
<tr>
<td>Bagasse</td>
<td>$ 10/t</td>
<td>2</td>
</tr>
</tbody>
</table>

Oil is also relatively expensive and so its use too is minimized. The cost of oil soared during the oil crisis in the early 1980s. (At one stage there was a risk that there would be no fuel oil available in North Queensland). Prior to this, oil was significantly cheaper. Consequently it was the designated auxiliary fuel for all suspension fired boilers installed before that time and was used quite liberally during the crushing season whenever it was convenient for the boiler station operators to use it. It was also used as the primary energy source for the preseason steaming trials. That situation has now changed. Most boilers still have oil burners fitted for emergency use, so nearly every factory uses some oil but restrictions have been placed on the use of oil by factory management. In recent years the total consumption by the Australian industry has averaged about 6500 tons (about 220 tons per factory). In the late 1970s, oil consumption was typically six times greater than this level.

As oil use decreased, the use of coal has increased. The price of coal is very dependent on the distance the coal has to be transported and the cost indicated in Table 1 is towards the bottom end of the landed price range. Unfortunately, compared to oil, coal is not as easy to use as an auxiliary fuel in a bagasse-fired boiler. Only two factories have boilers with dedicated coal spreaders. All other boilers using coal mix and fire it with bagasse with varying degrees of sophistication in the mechanisms used to combine the coal with the bagasse. The annual tonnage of coal used in recent years is about the same as that for oil although fewer mills use coal, so the average use per user is higher.

A significant amount of “wood” is also used in factory boilers as an auxiliary fuel (a current annual average total of about 16,000 tons). This wood consists
mostly of wood chips plus waste wood and sawdust from timber yards. There would also be some peanut shells and small logs in the total. This “wood” is generally only used when a suitable source is available close to the factory so that transport costs are not prohibitive. Consequently relatively few mills (about one third) use wood. In every case the wood is used mixed with bagasse. Because the source of the wood is so varied it is not possible to indicate a typical price. In some cases it is available free of charge as a waste product if the factory is prepared to arrange transport to the factory.

The final energy source covered in Table 1 is bagasse. The $10 per ton cost is a nominal value used for the sake of comparison although generally the cost of bagasse is less than this to a mill owner who has surplus bagasse. Thus bagasse is the cheapest available “auxiliary” fuel and is used in that capacity by many factories. In particular, many factories store bagasse from the end of one season to provide the energy source for the steaming trials before the start of the next season. It is not possible to say how much bagasse is used in this auxiliary fuel role because bagasse use records fail to distinguish this.

**OTHER ASPECTS OF ENERGY CONSERVATION**

Although the need for very careful energy conservation in Australia is not widespread, a few factories have to pay attention to this area and the industry in general still feels that one day a market for some form of “spare” energy will develop. Hence studies have been undertaken and the implications of increased energy condensation considered in some detail. It is interesting to consider both where the energy is used at present and how much energy is available.

Table 2 illustrates where most of the energy is used in a factory. In the boiler station, typically 45% of the energy in the fuel is lost to atmosphere because it is not converted to steam. Clearly the optimization of boiler operations must figure largely in any energy conservation operation since so much energy is lost in that area. Of the energy that is converted to steam, roughly one tenth is used for prime mover power via turbines (with about half that amount used to generate electricity). About nine tenths of the steam energy is used as low pressure steam with about two thirds of that going to heating and evaporation with the remainder to the pans. Although the evaporator station uses so much energy, there is little the operator of that station can do to change the amount of energy used. That is predetermined by the configuration of the station (e.g. whether quad or quin and what vapor bleeding takes place) and by the amount of water added on the extraction train and filters. The pan stage use is to some extent also predetermined by factors such as syrup brix and cane quality. However, the pan stage operator can adjust the amount of added water that is used and affect energy use by this means.
TABLE 2. Approximate energy consumption of major users within a factory.

<table>
<thead>
<tr>
<th>Energy user</th>
<th>Total energy use (%) of total</th>
<th>Steam energy use (%) of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler losses</td>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>High pressure steam</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Evaporators and heaters</td>
<td>33</td>
<td>60</td>
</tr>
<tr>
<td>Pan stage</td>
<td>17</td>
<td>30</td>
</tr>
</tbody>
</table>

It is also very interesting to contemplate the total amount of energy available from bagasse in Australia. The figures are so large as to be difficult to comprehend (Edwards). The total energy available in all Australian bagasse is in the region of $70 \times 10^{15}$ J per year. This is equivalent to about 2000 MW years of energy. Of course all of this is not available for use. If all was to be converted to steam, boiler inefficiencies would imply a loss of the order of 30%. If the factories still had to draw power to operate from that source, much more would not be available.

Australian factories currently use an average of about 1200 MJ per ton of cane in the form of steam energy (equivalent to about 550 kg steam for each ton of cane processed). Allowing for boiler inefficiencies (some of which are designed into the boiler so that all bagasse can be consumed), total energy consumption is in the range 2100 to 2900 MJ per ton of cane. These figures can be compared to the energy use in beet factories (Edwards). For example the average energy use in French beet factories in 1988 was about 880 MJ per ton of beets (excluding beet pulp drying) and the best factory uses only 660 MJ per ton (Anon.). There is also a published design for a beet factory using less than 400 MJ per ton (Schlephake and Ekelhoft). Based on this, one would assume that in Australia half the current energy used could be made available if the price paid for that energy was sufficient to cover the associated cost of new capital equipment.

The process of changing from the current position of thermodynamically inefficient use of energy to a much more efficient operation is technically quite interesting. (It becomes even more interesting if the capital cost constraints are added). The process varies depending on whether the extra energy is required as low pressure steam (e.g. as for a refinery), for electricity generation or for the production of excess bagasse but in each case there will be impact on all parts of the factory (Edwards). For the moment these conditions are relatively academic in
Australia but within the sugar industry consideration has been given to various options and the industry feels it is ready to respond should the need arise.

**CONCLUDING COMMENTS**

The preceding discussion has indicated that energy conservation in the true sense of the phrase is not of great importance to the Australian raw sugar industry in general. The incentives for very efficient use of energy are just not present in the Australian environment. Conservation has taken place to the extent that the use of expensive extraneous fuels such as fuel oil is minimized and the use of cheap and readily available bagasse maximized. The Australian industry lives in hope that a viable large scale use of the plentiful energy available to it will one day be found because at present the cheapest option is to use all available energy within each factory and in particular to avoid having any excess bagasse.

**REFERENCES**