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Sugar industry
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Steam power
...

WATER, STEAM, GAS AND ENERGY SUPPLY FOR A SUGAR FACTORY 1/

by

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SUMMARY

Attention is drawn to the self sufficient character of a sugar cane factory with respect to water and energy requirements. A beet factory or refinery requires an outside source of energy, but can be self sufficient with respect to water supply. The extent to which this is taken is an economic decision.

The inter-relationship of power and process usage of steam has been developed to a very high degree in the sugar industry.

The special place of sugar cane fibre as a source of replenishable energy is considered to be worthy of much more serios consideration. As a photo-synthesizer the sugar cane plant has many unique features each of which deserves full exploitation.

Primarily a sugar cane factory is concerned with the careful balance of materials in the form of fuel, steam and water as well as with the inter-related energy requirements for power generation and process heating. Of increasing importance is the need to make full use of available power potential by improved heat economy and efficiency of combustion. The extra power can be used outside the cane factory itself for pumping irrigation water or feeding into the national electricity grid.

General

A sugar cane factory is entirely self sufficient with respect to energy required for the process. Sugar beet on the other hand, is dependent entirely on outside sources of energy as the residual pulp is not really suitable as a fuel and does have significant value for animal fodder.

In a sugar cane factory there is a delicate balance between the fuel value of the residual bagasse, the steam requirements for power - both mechanical and electrical, and the steam required for process heating and evaporation. The amount of water available for imbibition is part of the carefully calculated energy balance involving, as it does, evaporation for its removal during concentration of juices.

The water employed in processing can be supplied from the juices themselves. Either the beet or cane is approximately two thirds water and only a small proportion of this leaves the system with the pulp or bagasse. The water used for diffusion or imbibition may be considered as being recycled by being returned as condensate from the multiple effect evaporators. There is also recycling of steam which is condensed in juice heaters, evaporators and vacuum pans to be returned as feed water to the steam generators. This condensate must be kept completely separate from the vapour condensate from the evaporators which is slightly contaminated with sugar carried over as entrainment from the boiling juices.

A. Condenser Water System

There is a loss of water from the system as vapour leaving the last effect of the evaporators and the vapour from the vacuum pans. As it is almost invariable practice in sugar factories to use condensers which absorb the condensed vapour into the condensing water stream this leaves the main factory water system. It does, however, afford useful make-up to the condenser cooling water system when this is used in closed circuit. Evaporative cooling is conventionally employed and this results in loss of vapour to the atmosphere in amount related to the psychrometry of the system.

The amount of water added in the form of condensed vapour closely approximates the evaporative cooling loss and is generally sufficient in a tower cooling circuit, with maybe some surplus, depending on local circumstances. In the case of spray pond cooling there can be also a significant windage loss depending on the effectiveness of protective screening, and this usually requires make-up from outside sources.

The vapour condensing in this cycle is invariably contaminated with some sugar carried over as droplets of syrup by entrainment, expecially from the last vessel of the multiple effect evaporators. This entrainment represents, on the one hand, a loss of sugar from the system which is usually worth recovering for its own value. There are various types of entrainment separators for this purpose. On the other hand the contaimination of the condenser water system is very undesirable for several reasons. The sugars oxidise to acids which are midly corrosive, the cumulative effect however is substantial. Malodorous substances are also generated which are probably more objectionable to the neighbourhood than to the factory workers themselves.

Bacteria associated with the decomposition of the entrained sugars are very much in need of inactivation. Various bactericidal techniques are useful for this purpose. Perhaps the simplest is ½ to 1 ppm. of copper sulphate maintained in the condenser water system. The author has found this to be very effective and the possible corrosion effects not to have been noticeable. There are also very effective organic bactericides but they are usually expensive.

Chlorine or hydrogen peroxide are perhaps intermediate in cost between the above two techniques but this will depend very largely on local circumstances. Either chlorine or hydrogen peroxide can be generated electrolytically at low cost by a sugar factory where electric power is in fact seldom actually costed at all.

B. Steam Generator Feed Water System

The purity of the water cycled in this system is of paramount importance, and the higher the pressure of the generated steam the greater is this importance because of the correspondingly high temperatures in the tubes where the generation takes place.

It would be ideal if a completely closed system could be maintained in which all of the steam is condensed and recycled as feed water. Even this however would need careful chemical monitoring to maintain the required standards of purity.

Reciprocating steam engines are still employed to drive the mills in many cane sugar factories. Modern installations of course are steam turbines, but reciprocating engines take a long time to wear out and many reliable units are still operating. Unfortunately the lubrication requirements of these engines results in oil being carried through into the exhaust steam.

Oil in exhaust steam has two quite serious effects in a sugar cane factory which may initially be small but are cumulative. In the first place a film of oil will form on the outside of the tubes of the heating surfaces of evaporators, juice heaters and pans. This is the usual order of the effect. It requires only a very thin film of oil to significantly reduce the rate of heat transfer at the evaporators and juice heaters. The influence at the pans is much less because the rate of heat transfer is more significantly controlled by the film on the massecuite side.

The oil does not entirely deposit on the tubes, in fact probably only a very small fraction does so,but enough to be troublesome. It is only by a specific analysis of heat transfer coefficient and film coefficient studies that the effect of the oil film can be identified. On the other hand it is not difficult to see the oil film if a visual inspection is made, the off-season shut-down period being a convenient opportunity. Oil does appear with the condensate A significant proportion can be separated by gravity or centrifugal separators but there will always be a few ppm going through to the steam generators with the feed water. In the days of fire tube units when reciprocating steam engines were simultaneously introduced any oil in the feed water had very little effect on operation. Water tube units, however, especially when operating at higher temperatures and pressure are much more susceptible to damage resulting from oil in the feed water. The thinnest of films reduces the over-all heat transfer coefficient and the only way to maintain the desired rate of heat transfer is to increase the temperature on the flame side of the tube. This temperature can, and frequently does, rise to values at which tube failure takes place usually in the form of quite fine perforations - often referred to as pin-holes but more like nail-holes in size, with a surrounding bubble.

If there are scale forming components also in the water this aggravates the problem.

The best way to deal with the problem is to modernise the prime movers at the same time as the steam generators, or simultaneously instal the appropriate combination in new factories. Treatment of water with chemicals for the removal of oil is very expensive and filtration incompletely effective. The author has had success in changing the source of factory water for the steam generator to take vapour condensates from the first and second effects of the evaporators. There is sufficient water available from these two sources to enable make-up water to be eliminated. This also eliminated the need for a chemical treatment plant for the make-up water and the possibility of scale problems. The thermal content of either of the two water mixtures are approximately the same. The vapour condensates do have the disadvantage of a trace of sugar entrained from the boiling juices which can be minimised but never completely eliminated. The sugar decomposes to acid which must be neutralized to avoid corrosion. This can be done with sodium hydroxide or carbonate with a pH monitoring of the water in the drums of the steam generator aiming usually to maintain the value between 10 and 11.

Replacing reciprocating engines with turbines does not solve all problems. The exhaust from turbines is invariably superheated and superheated steam is not very satisfactory as a heat transfer medium and should be desuperheated before use for this purpose.

C. Process Water

Most of this is used for diffusion or imbibition, being obtained from the evaporator units. If the steam generators are being supplied with water from the first and second units of the evaporators then the process water may be obtained from the exhaust steam condensate cooled by mixing with vapour condensate from the later effects of the evaporators.

Water is also required for washing at the centrifugals, for dilution of liquors being recycled for further boiling at the pan stage and for movement water employed at the pans themselves to aid in the sugar boiling operations.

Washing down of floors and water used for maintaining cleanliness standards in the factory are also provided for from this source.

There should always be adequate water for all requirements but stoichiometric estimates of the balance of water within the factory should be the subject of regular calculations.

D. Steam Cycle

In the sugar beet factory and in the separate refinery steam is a very expensive commodity as it must be generated by the burning of fuel specially purchased for this purpose. The sugar cane factory, on the other hand, is likely to be somewhat careless in the use of steam because of the amount of fuel available from the fibre in the cane.

There is in fact an important balance between fuel available in bagasse and steam used in the factory.

The sugar industry is probably a better example than any other industry of the substantial employment of steam for both its power potential and its heating quality. The power potential used to drive prime mover for the generation of electric power and in the case of sugar cane factories for the driving of the mill engines needs to be balanced against the heat requirements for evaporation and the small proportion of miscellaneous extras. Ideally a perfect balance would be sought by appropriate adjustments of pressure systems. In practice it is more simple to design for a small deficiency of steam for process requirements and to make this up by passing high pressure steam simply through an exhaust valve. An amount of about 5 to 10% of the total steam requirement is sufficient for this purpose.

Over the years the fibre content of sugar cane has gradually increased to values which are now more than adequate for fuel requirements. This has resulted in a depreciation of the efficiency of steam generator units, possibly an increase in the moisture content and hence reduction in fuel value of the bagasse and a greater laxity in the usage of steam for its various purposes.

With attention being focussed on the critical situation of world energy supplies it is pertinent to draw attention to the real energy potential of sugar cane fibre. When full advantage is taken of this potential, especially in high fibre situations, it is possible to produce useful amounts of electrical energy over and above that required by the sugar factory itself and to use it for other purposes such as driving irrigation pumps for the cane fields or simply feeding into the national power grid to augment general supplies.

As well as being a supplier of electrical energy a sugar factory can also be a supplier of potable water. If the vapour from the evaporators and pans was to be condensed in surface condensers rather than the torricellian leg type then the condensate could be recovered for other uses. This could be of advantage in a separate refinery which otherwise has to draw heavily on outside supplies for melting or dissolving of its raw sugar.

It is a matter of costing and of assessing the relative quality and availability of water from the various sources available.

Beet and cane factories should be self sufficient with condensate from the evaporators but there could well be circumstances when there would be merit in recovering the additional water for supply to a neighbouring town or village. The cane season is likely to last longer than the beet season and to be associated with more isolated communities.

Some treatment would be necessary (oxidation and neutralisation) to deal with the small amounts of sugar entrained in vapours but this should be no more costly, and probably less so, than treatment of raw water from natural sources.

E. Gas Reticulation

Gas, understood as being the fuel value as an energy source is only used in situations where this is naturally available at satisfactory cost. A sugar beet factory or refinery can profit from such situations but a sugar cane factory could do so only if it is desired to use the bagasse for chemurgic purposes. Such possibilities are not to be overlooked, but the relative chemurgic properties of the gas and the bagasse should first be evaluated.

Gas in the form of producer gas can be produced as a by-product of a cane factory where such is available. This has advantage where a sugar cane factory complex is endeavouring to make all possible use of its resources to make the area self-sufficient as far as possible. In this case it is more likely to produce water gas for its hydrogen value to be used in the synthesis of ammonia.

A cane sugar factory can be eminently situated for this purpose in that the main requirement for ammonia production other than hydrogen is electric power. With problems arising over production of ammonia from petrochemical sources and the great importance of nitrogenous fertiliser in the cane growing areas the possibilities of becoming self-sufficient develop increasing importance.

Questions:

1. What is meant by self-sufficiency with respect to process water requirements in

   (a) a sugar cane factory?

   (b) a sugar beet factory?

   (c) a separate sugar refinery?

2. What is required for a sugar factory to become self-sufficient with respect to condenser cooling water?

3. Is surplus bagasse better used for steam and power generation or for its chemurgic properties? Why?

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