TECHNOLOGY ABSORPTIONS IN RECENT TIMES

INNOVATIVE CHANGES IN EQUIPMENT DESIGN AND CONFIGURATION.

BY T.VENKATA RAMANA

VRL ENGINEERING AND PROJECTS PVT. LTD., BANGALORE

ABSTRACT: The evaporation of huge quantity of water from Sugar Cane juice in a Sugar Factory is a simple process but the concept & technology applied are unique and significant. Two aspects have been focused.

One being the quantity and quality of steam used, the other being accomplishing the desired evaporation same at minimum time. Over the years a number of developments have taken place keeping in mind the principle concerning the effect of time and temperature on the juice / syrup while concentrating. New design and configurations are developed to minimize the ill effects. In this regard the advantages of using the quintuple effect evaporator set with Falling Film Evaporator (FFE) are explained.

The pan boiling in a sugar mill is more important by the functional combination of crystallization with evaporation. Both the factors are again the function of Time, Temperature and Heat Transfer Co-efficient. The design and configuration of pan boiling have been developed to keep with a focus on optimizing various factors. The stress is on boiling the massecuite with low pressure vapors, maintaining good circulation, optimum growth rate of crystals, minimum color formation in crystals and steam economy. The advantages of continuous pan in general and Vertical Continuous Pan in particular (VCP) have been explained. The necessity of Automation and Instrumentation is stressed.

The authors have described the uniqueness of an innovative “Split Type Condenser” which is more efficient at the same time energy saving.

The stress is on Automation and Instrumentation.

1.0 INTRODUCTION

1.1 GENERAL

The honorable delegates may be aware that Sugar Industry was the first to put a steam driven engine for industrial use as a prime mover in the middle of 19th century. The power utilized was free as the steam in any way was required to process. One other notable event was that Sugar Industry was first to put into practice Multiple Effect Evaporator System around the same time. Steam driven prime movers together with Multiple Effect Evaporator System contributed tremendous advantages which needs no deliberation.

When steam turbines replaced the steam engines the necessity and scope for steam saving in process opened up. The more efficient turbines paved the way to go for in-house generation of electrical power for captive use. There existed no flair or necessity for steam saving at this stage which was around 60% on cane.

Consequent to the advent of cogeneration of power (surplus power) in sugar factories, the steam economy became the focus of any development or investment activity of a sugar mill. The sugar factories started working seriously on process steam economy. All feasible devices and technologies came into being explored and utilized to save steam, generate more power and sell more power. The scope for reducing the steam consumption in the process became opened up and expanded. Vapor bleeding intensified from all effects of evaporator set (Quintuple). Today, the authors have several examples of implementing projects with evaporator configuration of quintuple effects. The process house draws exhaust steam only into evaporator first effect. The evaporator station supplies the vapor to all other applications. The process steam consumption has been reduced to less than 30% on cane.

One may astonish how so much of vapour could be bled from the evaporation station? Where from the water comes to get evaporated? With so much of water removed from syrup how could the brix of syrup remain unsaturated!

1.2 TWO IMPORTANT PRINCIPALS

The authors picked up two important “Thermo Physical” principals which were practically irrelevant prior to advent of Co-generation.

a) Direct Contact Heating
b) Flashing vapor from hot water.

For Juice Heating when Direct Contact Heaters (DCHs) are used, the vapor gives away the entire latent heat to the extent that the approach temperature is practically zero. In this case the special advantage is that the available heat is fully absorbed. The juice is never over heated and the entire juice is uniformly heated.

The Juice gets diluted but the vapor required to evaporate this additional water is already compensated by heating the juice by vapour of one step lower pressure. Further there is more water in the juice which can be economically evaporated to bleed for Pan Boiling.

It is to be noted that the Sugar Cane brings abundant water in it which is removed during the process as hot water at various temperatures. It is further to be noticed that multiple effect evaporator works at multiple pressures meaning multiple temperatures. The hot water flashes between gradient of two pressures. In the multiple effect evaporator system the hot water in the form of condensate is generated in each calandria. In the condensate flashing system the various condensates from different calendria of the evaporation station are independently and systematically flashed to be utilized as vapor in the next calendria. As these vapors are not from boiling syrup this does not cause concentration of syrup, at the same time these vapors are multiplied in the evaporator system which are used for further evaporation.

Both the above principles are absorbed as part of the configuration of the multiple effect evaporator station by the author with Falling Film Evaporator bodies. The system is aided by Instrumentation and Automation. The system brings in external water to provide more water for bleeding and at the same time brings in external vapor to evaporate the additional water. Both principles are to be applied together.

1.3 POWER GENERATION

The authors have implemented a number of such projects through VRL in stages between 2007 and 2017. During the last 10 years VRL has been steadily working on energy saving theme in sugar factories accomplishing excellent results.

The factories which took cogeneration seriously went ahead with high pressure boilers from 45 ata to 67 ata to 85ata and in a short span the factories invested on 125 ata boiler with matching Turbo Alternator. (Condensing cum extraction type.) The power generated works out to about 140 kvh per ton of cane with process steam consumption of 30 % on cane.(About 35 % condensing) The surplus power salable would be about 110 kvh/ton cane.

2.0 DISCUSSION AND DESCRIPTION

2.1 PROCESS HOUSE CONFIGURATION

To correspond this the process side needed substantial changes in the configuration of process house equipment and machinery. The above indicates that every investment was oriented over higher power generation in terms of kvh/ton cane, and on the process side it is on equipment, devices and process changes to decrease process steam consumption in terms of tons steam per ton cane. VRL and the author have been actively involved in a number of projects both small and big. A number of such projects are successfully implemented on turnkey including design, fabrication, supply, erection and commissioning. Such process houses (often combined with expansion) are transformed into Energy Efficient Process house. It is not just energy saving but it a comprehensive program and project that makes the plant operate on automation, trouble free, with high degree of productivity and discipline. There would be less inversion, less color formation, minimizing human error.

The author would like to elaborate the two stations namely Evaporator station and Pan Boiling (Crystallisation) station.

2.1.1 FALLING FILM EVAPORATORS (FFE)

Falling Film Evaporator system with Quintuple effects, in combination with all other process house equipment is configured in such a way that the provision of exhaust steam is restricted to only the first effect of evaporator.

Falling film evaporator bodies (FFEs) are preferred to be used for all the effects of a multiple effect evaporator set. It is also possible and technically feasible to install them in part in combination with Robert bodies successfully under given conditions

The noteworthy advantages of FFE over raising film evaporators (Robert and Kestner) are listed below

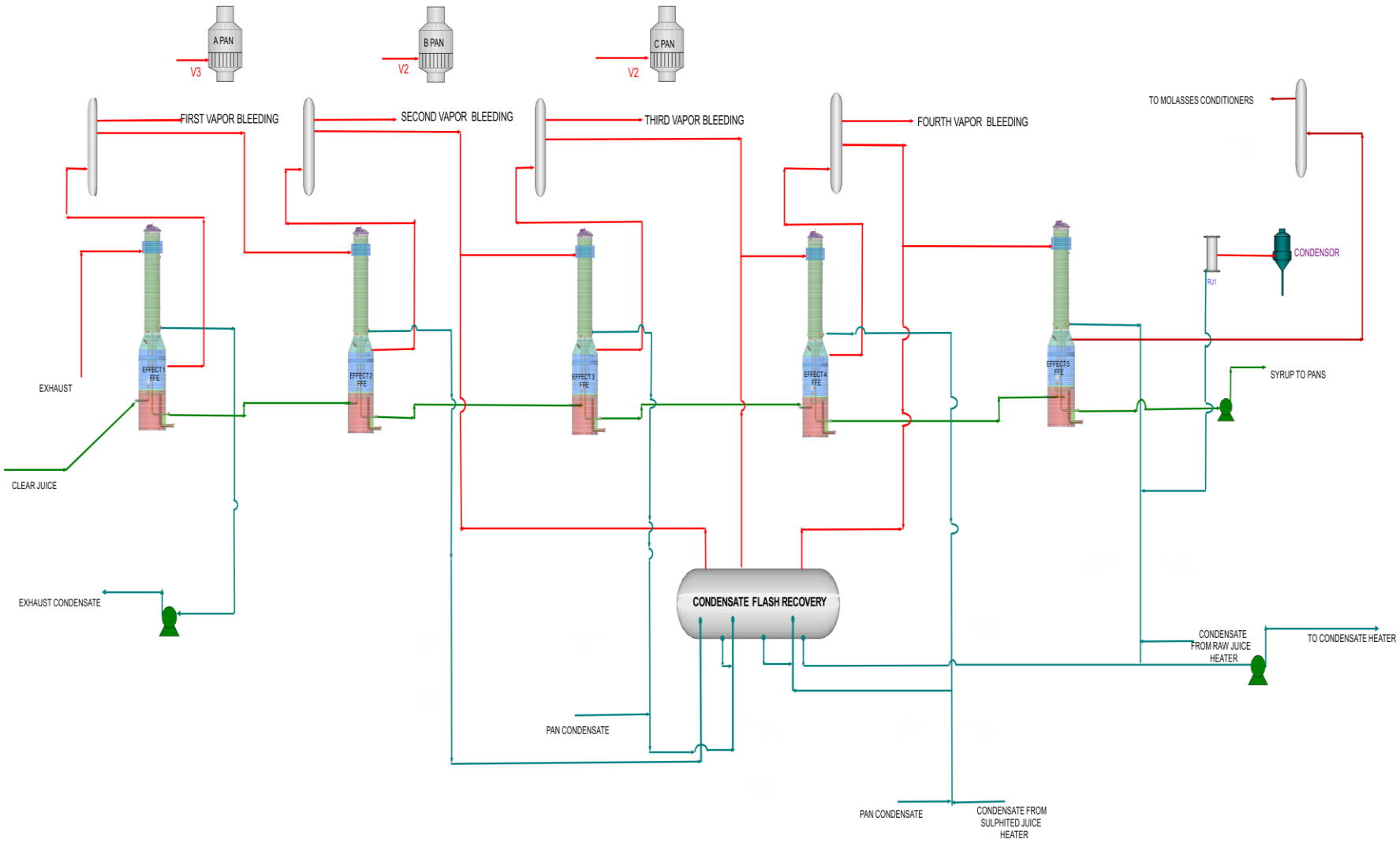
- In FFE the Juice flows, continuously and uniformly as a thin layer along the inner decimeter of the tubes from top to bottom. Only a thin layer of the juice is in contact with heating surface and the heat transfer is effective.
- The temperatures inside & outside the tube are always uniform. While the temperature outside is same as the heating steam /vapor, the temperature inside is equivalent to the vapor generated. There is no question of the juice getting heated beyond the respective vapor temperature at any part of the tube.

- The FFE bodies do work efficiently with lower temperature gradient there by enabling more extensive and intensive bleeding of vapors
- Because of the steady state of temperature and boiling rate, the generation and flow of vapors would be consistent thereby stabilizing the entire vapour bleeding system.
- The process of juice heating and pan boiling are run under uninterrupted and identical conditions. It is found feasible technically that the vacuum pans are boiled comfortably on third vapor and even on forth vapor.
- The FFE is an enabler to bleed III vapour and even fourth vapor to pans by virtue of working on low temperature gradient. The Pans when boiled on low temperature vapors there is an added advantage of reduced thermal damage on the crystal thereby recording lower IU on sugar analyses.
- The working of the FFE bodies are very comfortable, user friendly and effectively brought under instrumentation and automation as compared to rising film evaporators
- Heating surfaces could be cleaned very fast and without opening the bodies by chemical cleaning. It makes feasible to run the evaporator set nonstop just by having one or two additional bodies for rotating.
- Contrary to this the following are the major drawbacks in the rising film bodies (Robert & Kestner)

    a. There is always a retention of juice at the bottom to the extent of 30 to 35% of the tube length. This needs a driving force in the form of higher temperature to set the juice in circulation and boiling.
    b. The higher temperature results in lessening the temperature gradient. More harmful is the increased temperature coupled with increased retention time of juice which causes thermal damage to sugar in the juice enhancing color formation.
    c. Further, the retention of the juice in the bottom portion of tubes on a continuous basis enhances the scale formation thereby affecting evaporator performance.

All other applications like juice heating, Pan boiling, Molasses conditioning, Melting, Centrifugal washing, Sugar drying etc. are done by vapors generated from different effects of evaporator set. Vapors at ideal temperatures are bled from each effect selectively calculated to result in maximum economy and minimum thermal damage (Refer attached diagram-1 distribution of vapors from Evaporator System).

VAPOR BLEEDING ARRANGEMENT



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BANGALORE

2.2 VERTICAL CONTINUOUS PAN (VCP)

2.2.1 A REVOLUTION IN PAN BOILING AND STEAM ECONOMY.

The advancement of vacuum pan for manufacture of crystal sugar is an historical and revolutionary step in sugar processing industry. The commercial sugar was first made possible only after development of vacuum pan. The noteworthy significance of vacuum pan is that it made it possible to produce crystal sugar under reduced boiling temperature and with reduced boiling time. The color formation as well loss of sugar due to inversion is minimized. The sugar is crystallized from the concentrated sugar syrup obtained from cane/beet juice. The syrup carries substantial impurities generally identified as 'non sugars' in solution.

2.2.2 AUTOMATION

The presence of non-sugars complicates the process of crystallization. They cause changes in solubility coefficient of the mother liquor. The crystallization process is slowed down due to higher viscosity. Some of the non-sugar would block the crystallization sites. All these negative effects are specific to individual non sugar component and are found to vary from region to region, from variety to variety, from season to season and at different time of the same season. They are generally difficult to be measured and their effects on the crystallization process are even more difficult to assess.

The crystallization traditionally called as "Pan boiling "remained to a large extent as a batch process and remained human skill dependent. The process had been in need of skilled labour. Owing to these complicities the pan boiling process for crystallization of sugar had been considered as an art world over. Only by virtue of long experience coupled with talent and aptitude one could accomplish satisfactory work in the pan floor of sugar factories. Over the years by constant study of research workers the pan boiling process was brought under controllable mechanism. Application of automation and instrumentation is becoming workable which helped the operators to get an insight into the pan boiling and crystallization process.

2.2.3 EVAPORATION V/S CRYSTALLISATION

When a supersaturated sugar solution held with in a boiling massecuite is further concentrated by evaporating water from the solution, crystallization starts and continues. If the evaporation rate is increased the crystallization rate increases. The existing crystals provide site for sugar molecules and grow in size. It is possible that new crystals are also

formed which situation deserves to be called uncontrolled and not desirable. The intended situation in vacuum pan is establishment of equilibrium between rate of evaporation and rate of crystallization. The essential prerequisite is to provide adequate site for crystallization meaning the surface area of the crystals. While heat transfer causes evaporation the degree of super saturation decides crystallization. The total area put together, of the existing crystals, results in the growth of crystal size. The purpose of boiling a massecuite is to develop crystals to the targeted size. The time taken to accomplish the target depends upon the other three factors mentioned above. When the other three factors are ideally matched, the time taken to achieve the target (boil a massecuite) is minimum

The vacuum pan conceptually did not find changes over the years. But there had been design changes in stages bringing improvements in overall performance. But most of the improvements and changes are focused on better heat transfer coefficient and greater evaporation rates. The crystallization process is often looked as' simple evaporation and concentration.' The more important and more significant aspects of crystal development and the rate of crystallization in terms of crystal growth are not given prominence. The focus had been on speeding up evaporation but not so much on crystal surface and crystal growth. The results of experimental works on crystallization in laboratories could not always be scaled up to factory level operations because of non identical and dissimilar conditions.

2.2.4 CONTINUOUS PAN BOILING

As afore said three factors are to be synchronized to yield the desired result (size and uniformity of crystals) the operation has to be on automation and instrumentation. If the instrumentation has to be successfully implemented and operated the process has to be made continuous and uninterrupted instead of batch by batch with interruptions. So the crystallization process (Pan Boiling Process whether A, B or C massecuites) is to be on auto mode with controlled operations. This is what the authors have attempted at VRL (INDIA). The VRL has designed, fabricated and supplied several of such units called 'VERTICAL CONTINUOUS VACUUM PAN (VCP)'.

2.2.5 VERTICAL CONTINUOUS VACCUUM PAN

One of the recent advances of pan floor in the sugar processing house is development of Vertical Continuous Pan (VCP). Quite a number of VCPs are already in different parts of the world. Many of them are for capacity additions. Some of them are for replacements of existing batch pans. VCPs coupled with automation are found to be yielding excellent

results. With introduction of Vertical Continuous Pan especially for A Massecuite the entire process house operations in the Sugar plant would become truly continuous.

2.2.6 MECHANICAL CIRCULATOR

It is well known that greater circulation with in the pan improves heat transfer coefficient and therefore improves evaporation rate to that extent under given Delta T. Increasing the Delta T increases evaporation rate in direct relation. The same increases circulation also. But in this case the crystal mass within the tube is not undergoing the same pattern of movement uniformly.Heat transfer for boiling (Evaporation) is an intrinsically unsteady process characterized by intermittent nucleation and Fluctuating generation of vapour. The bubbles in general display random behavior being influenced by a number of factors.

The crystal mass is poor conductor of heat where as it is the mother liquor that gets heated. Even the liquor nearer to the surface of the tube is heated faster than that in the centre of the tube. However the average temperature of the massecuite increases and rises up due to pressure gradient as well as buoyancy. The circulation rate of the crystal portion of the massecuite is not the same as that of mother liquor.

In the case of a mechanical circulator the entire mass physically moves and circulates. The effect of natural forces is augmented amply that it becomes less significant. Hence in the interest of faster crystallization rate, uniformity and reduced color of the crystals it is advantageous to install mechanical circulator. Even in recovery strikes the mechanical circulator aids faster and better exhaustion of mother liquor. The aided circulation improves further the heat transfer coefficient with corresponding benefits. Mechanical circulator thus aids faster boiling, faster crystallization, supports use of low pressures, improves steam economy and improves sugar quality in terms of color and crystal uniformity.

2.2.7 HORIZONTAL CONTINUOUS PAN (HCP)

The first generation HCP though found to be having certain shortfall, was received well by the technologists as well as by the industry for its advantages over the batch type vacuum pans specially for low grade boiling. The pans are working on auto modes almost unattended. In fact the extra water boiled is found be reduced and steam consumption is noted to be lower as compared to batch pans The design as well the process (being continuous) enabled automation to a reasonable extent with instrumentation controls to optimize the process. But the shortfalls observed were that the final brix obtained was not enough and not consistent. Secondly, formation of incrustations and dead pockets

disturbing normal circulation and heat transfer needing stoppage of the pan for cleaning periodically.

However recently the authors at VRL have introduced an innovative design of HCP which has removed all the shortfalls of earlier designs. In addition to certain other modifications in the design feutures, the authors have introduced an innovative circular compartment with calandria called “Finishing Compartment” with exclusive vapor connection. The chamber is also equipped with an aided mechanical circulator. This chamber exclusively takes care of tightening the massecuite to the limit.

Further the pan is provided with jigger steam arrangement to avoid incrustation, stagnation and possible cholking. The circulation is greatly improved. The new generation Continuous Pan (HCP) especially for low grades are working very well.

2.3 VAPOR CONDENSER:

The split type condenser is unique & differs from conventional Multi Jet Condensers. The water mist created will cover entire cross section of Vapor space, without any idle pockets.

In split type condenser, as it receives water exclusively for condensing the vapor, we can reduce approach temperature between Vapor and tail pipe water. This leads to higher Delta T between Cold & Hot Water channel temperatures.

The water demand at Condenser & Ejector is not the same at any point of time, the average water requirement in split type condenser will always be less compared to Multi jet / Single Entry Condenser.
The Non-Condensable Gases are handled by the water Ejector attached to the outer shell of condenser.

There is considerable Energy Saving in this System, as water going to Spray Pond or Cooling Tower is reduced by about 40%, when compared to Multi Jet / Single Entry Condensers.

Power reduction at injection water, due to reduced water consumption on account of effective spraying to create water mist for intimate contact with vapors. It facilitates the use of low head pumps for injection, thereby reducing power requirement for pumping.

- There is Power reduction by economizing Injection water and cooling water
- Power reduction at cooling station

It is maintenance free and user friendly

2.4 OPERATION

Under the given set of equipment and process followed, the operational efficiency makes substantial difference. The actual steam consumption varies, even under similar equipment configuration. Quite often it is experienced that the actual steam consumption is higher than the designed/calculated figures. This could be due to operational errors, operational contingencies and compulsions also. Instrumentation and automation will to a great extent bring down the manual errors. “What happens” will be nearer to “what should happen”

2.5 AUTOMATION

Besides the conventional automation system for juice heating, clarification, Centrifuging and some level controlling etc. the authors have found that the following areas need précised instrumentation system and accordingly designed the systems apt to the process conditions and process needs.

- Mass flow meter and juice flow stabilization.
- Exhaust steam flow, pressure and temperature stabilization
- Vapor Pressure and Temperature controls for all Vapors.
- Vapor pressure stabilization at the Pan floor.
- Condensate Flash system.
- Seed melting, Molasses Conditioning
- Pan Boiling – Crystallization Process
- Condensers
- Transient Heaters.