SIT Technical proceeding
May, 2016, New York, New York

50 years of progress in sugar technologies
From 1 G to 5th Generation --- a Benchmark

Dr. Chung Chi Chou,
drchouusa@gmail.com

President, Dr. Chou Technologies, Inc. USA.
www.esugartech.com

Chairman/Founder, Wellbrookfoundation, Inc.
www.wellbrookfoundation.com

Introduction

Last 25 years of digital science/technologies revolution has brought a quantum jump in productivities both in IT (Information Technologies) and in manufacturing sectors. Although the sugar industry has, in general, lagged behind in the utilization/application of digital advantages, significant progress has also been made, particularly in automation to reduce manning.

This paper will present the technologies progress from 1st Generation of 1960's to the 4th Generation of 2010's to achieve plant performances with respect to energy consumption, % sugar yield, manning reduction and value added products introduction.

5th Generation technologies together with achievable performance, a benchmark, will be proposed and discussed.

(l) Benchmark

1) Progress of Sugar Technology/Engineering – 1960 to 2015

	Steam on melt Ton/ton	Sucrose Yield %	Electricity Usage kW/ton sugar
Pre 1970	> 1.7	< 97%	>125
1970 -1980's (1G with good processing practices)	< 1.4	97 to 97.5%	100 to125
1980 -1990's (2G with VHP raw sugar)	<0.8	97.5 to 98%	75
1990-2000's (3G with low head vacuum pans, etc.)	<0.5	98 – 98.5%	50
2000-2010's (4G with thermal recompression)	<0.3	>99%	85
Future (5 G) 4 G plus no molasses produced	<0.3	>99.5%	80

.

2) Comparison of performance standard

Criteria	Conventional Refinery	Updated refinery
a) Sugar Yield	96 to 96.5%	98.5 to 99.2%
b) Energy	85 L #6 oil/ton raw sugar	55 to 60 L #6 oil/ton raw sugar
c) Electricity	80 kwh/ton raw sugar	50 to 55 kwh/ton raw sugar
d) Environment issue	yes	almost zero discharge
e) Labor cost	very high	few worker and lower salary
f) Value added products	Nil	up to 7 different types
g) Management	Bureaucratic	Motivated and progressive
h) Water usage	0.9 ton /raw sugar	0.4 ton/ton raw sugar
i) Energy loss to ambient	10 to 20 %	5 (south) to10 % (north)

3) refinery design criteria

a) Energy usage – 0.75 ton of steam per ton of raw sugar
b) Electricity – 50 KWH per ton of raw sugar
c) Water usage – 50% of raw sugar
d) Sucrose loss – 0.55% of raw sugar for carbonation process refineries and 0.75 % for phosphatation refineries.
e) Number of operators – 7 to 8 per shift
f) Capability to produce value-added products
g) Environmentally friendly

(II) Process and Engineering

(1) Keys to day to day operation efficiency

a) acquire and apply basic consistently
b) pay attention to detail
c) do it now
d) do it right the first time

2) Upgrade quality of Staff

a) training in process technologies and engineering principle;
b) Instill financial and business sense (profitability) to managers/department heads/staff for everything they do.

3) Stability and consistency in operating parameters is the key to process efficiency

4) Increase the plant capacity

a) Reduce the impurities input to the refineries, use VHP raw sugar, etc.,
a-1) minimize sugar carried to molasses;
a-2) avoid recycle
a-3) reduce chemical usage; a-4) increase sugar yield
b) capacity utilization at each unit operation

5) Simplify refining processes

a) NO carbonation;
b) Focus in clarifier design (air diffuser);
c) NO IER, use PAC,
d) NO Silo, except for storage purpose;
e) Need phosphatation and filter press
f) Alleviate environmental problem and save energy by using surface condenser

6) Value added product introduction

a) No Molasses-quantum jump in sugar yield;
b) sell non sugar
c) Molasses extract--antioxidants production

7) Function of a Refinery

(a) Separation of non sucrose from sucrose,

(b) Removal of microbs and heavy metals

8) The most effective way to reduce operating cost:

(a) Increase capacity of 45% by elimination of affination – Reduce impurities input by using VHP

(b) Simplify Refining process

(c) Less impurities input means less sucrose to molasses

(d) Sale non sucrose as value added product

(e) Control water usage to save evaporation cost and sucrose loss to sewer

9) Energy efficiency - Environment Assurance:

1) Minimize sweetwater generation

(a) Avoid process with need for regeneration such as GAC & IER

(b) Use Process to filter phosphatation scum instead of3 stages scum desweetening system

2) Increase liquor Brix across the refining process

(a) A liquor of 75 brix minimum

(b) Melt liquor at 68 brix

(c) Avoid use of high pressure drop process such as GAC, IER

(d) Eliminate redundant process, such as phosphatation vs IER – remove same type of colorant

3) Reduce % recycle stream by introduction of value added product – Micro Crystalline Brown Sugar to increase yield by 2%

4) Do not remix separated non sucrose with sucrose

5) Use of surface condenser at pan

6) Vapor melting of raw sugar

7) 2nd vapor for sugar boiling using low head vacuum pan

8) Control of sweet water production

a) Sweet water from scum desweetening
b) Extend filter press cycle to reduce sweet water
c) Reduce carry over from phosphatation in order to extend IER liquor cycle time—laminar flow inside clarifier with sufficient depth
d) Optimize clarification process to avoid secondary floc which block IER columns.
e) Minimize back washing recycle liquor from deep bed filters
f) Use filter presses to replace Deep bed filter (which only remove particulates over 5 micron size) and IER
g) Control use of flocculent. Excessive use increase sweet water and may be in violation of governmental regulation (total 15 ppm, including use for scum desweetening) on sugar solid.
h) Reduce sweet water from floor washing (avoid spillages)

9) Minimize process water usage:
Any time you put process water into the refinery, you either have to evaporate it or it will carry sucrose with it to the sewer ()sucrose loss

10) Pan house control--Up to 65 % of energy is consumed in sugar boiling

a) Reduce recycle (5 % maximum)
b) Boil sugar with good CV

c) Increase brix of feed syrup
d) No water for boiling
e) Good pan scheduling-- no live steam make up
f) Smooth scheduling and good maintenance of centrifugal, massecuite mixer and pan operation --no downtime and pan waiting time.
g) Optimal boiling scheme to minimize boiling time
h) 100% of pan condensate to return to boiler house
i) Feed liquor brix of average 75 brix
j) **Elimination of affination step by using VHP raw sugar as input to the refinery. No IER is would be needed for decolorization**

10) No molasses produced in refineries (SIT 2014 paper)

All 4/5 syrup would be converted into value added brown sugar

1) Operating requirements for Molasses conversion

a) Massecuite purity minimum: 88
b) % invert maximum in massecuite: 7%
c) Massecuite temperature over 245 ^{o}F for high heat of crystallization
d) Massecuite brix minimum 94 brix
e) Agitation to create surface area for evaporation
f) Evaporated vapor must be carried away via vacuum or air

2) Four industrial processes for conversion of molasses

a) Micro crystallization—continuous process
b) Areado process
c) Muscavado process
d) Spray drying process

11) Boiler house operation

a) Minimize excess air

b) Recover heat from stack gases
c) Minimize boiler blowdown
d) Return condensate to boiler house
e) Boiler efficiency: 85% ---Good. New boiler may be 90 %
f) Feed water treatment to remove hardness, silica, and iron.

12) Optimizing Power generation

a) Produce high pressure steam
b) Maintain high turbine efficiency; Example

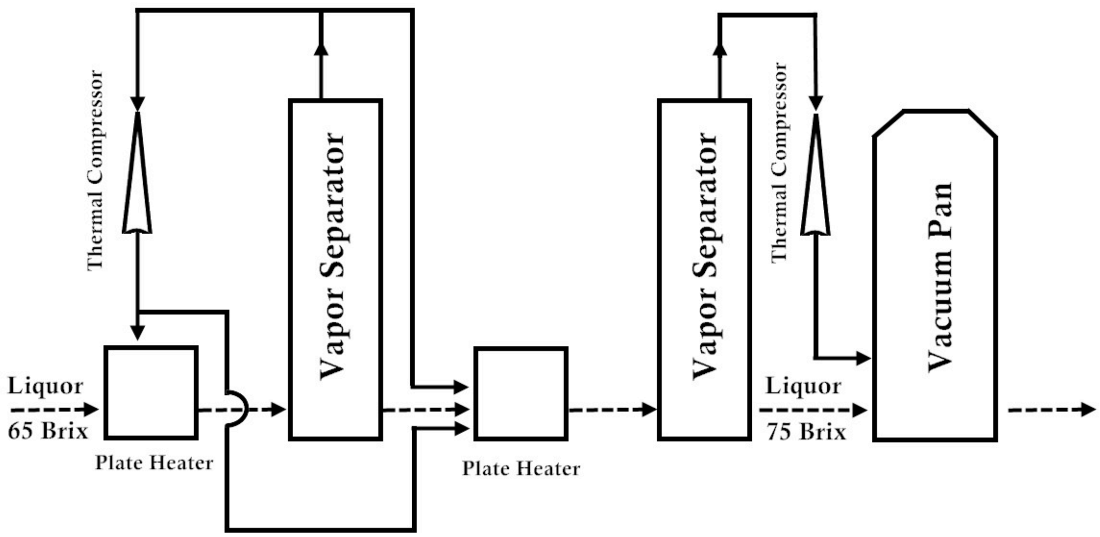
Steam inlet at 320 psia and 700^{o}F, H = 1365 btu/lb;
Steam outlet at 30 psig & 405^{o}F, H = 1238 btu/lb (actual)
Steam at 30 psig & saturated 250oF, H = 1140 btu/lb
Turbine efficiency = (1365 – 1238)/(1365-1140) = (127/225)x 100 = 56.4 %

Steam required to generate 1 kw-hr:
127 btu/lb x 2.93 x 10^{-4} kw-hr/btu = 0.037 kw-hr/lb, 26.9 lb/kw-hr (actual)
225 btu/lb x 2.93 x 10^{-4} kw-hr/btu = 0.066 kw-hr/lb, 15.2 lb/kw-hr

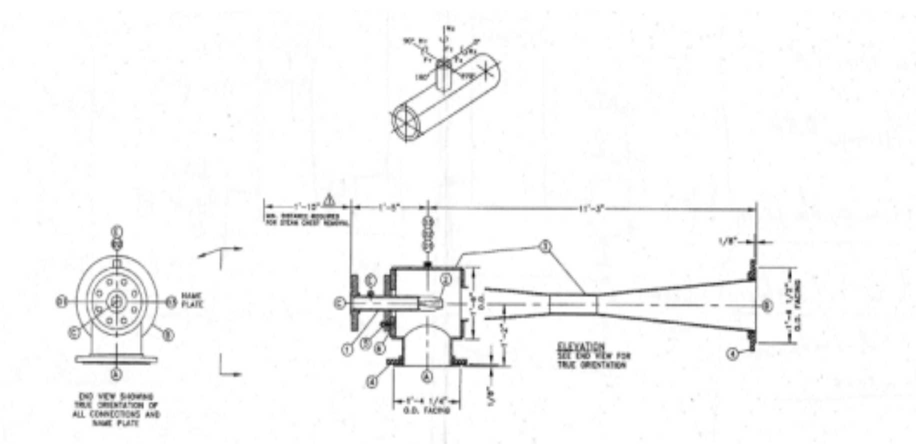
c) Back pressure control to maximize power generation
d) Minimize steam loss to the atmosphere via pan scheduling
e) Minimize demand charge via proper centrifugal sequencing and careful planning during start up
f) Power factor control; surcharge for low power factor

13) Thermal vapor recompression

Evaporators with Thermal compressors



a) require only 5 to 10% of energy necessary to generate the same steam in a boiler,
b) limited to inlet pressure of over 14.7 psia and compression ratio of about 2.



14) Mechanical vapor recompression

a) Commonly used in the China sugar industry

b) multistage needed to reduce the steam consumption to 0.2 tons/tons sugar steam (5^{th} Generation)

c) applicable where electricity is less expensive

15) Automation for high process efficiency, consistent product quality and labor cost

(III) Management

1} Organization/management

(a) Flattening management structure
(b) Restructuring/downsizing
(c) Re-engineering, automation, IT implementation

2) Management Operational Practices for the 21st century

a) Instill financial and business sense of urgency for enhanced profitability to managers/department heads, and staff for everything they do. The profit center in a refinery includes energy, material, labor (automation), product quality, safety program, environmental assurance, value added products, and intellectual asset.

b) Training program to elevate the quality of staff, both on technical/engineering competency and the management skills. To reduce the cost of training, in-house training should be considered.

c) Change the management approach from problem solving to problem prevention.

d) Change staff attitude from a traditional concept of: from "**my job is to fight fire**" to "**my job is to improve process and operations**." On daily basis.

e) Each Staff should justify his/her existing position by process improvement.

f) Performance evaluation of each employee/staff on an annual basis. The last ten percent performers should be trained or dismissed.

g) Send CEO and other upper level management to Executive programs (3 weeks to 2 months short courses) at US Ivy league universities (such as Stanford, and MIT) to prepare them for the challenges and opportunities of the 21st centuries.

h) Institute an annual technical and engineering audit by international sugar consultants a) to ensure continued high level of operational performance, b) to update technical and processing technologies, and c) use of best available technologies and sugar engineering principles.