Technologies For Exporting Electricity
of 100 kWh/T of Clean Cane
While Producing White Sugar

A SUCCESS STORY

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OBJECTIVE

To set up a **green field integrated sugar complex** with **eco-friendly plant** configuration and zero liquid discharge for sustainable socio-economic development of rural area for:

- Production of plantation white sugar with high process efficiencies
- Fuel grade ethanol with zero liquid discharge.
- High milling efficiency RME>96.5%,
- Low power consumption of i.e. <33.5 kW/T of cane, including sugar, co-gen, distillery.
- Minimum process steam consumption to achieve surplus power of minimum 100 kW/t cane for export.

CHALLENGES

- The Indian regulations require that a new sugar plant has minimum aerial distance of 15 kM. from any of the existing sugar plants.

- The land area available with us was on hill terrain and could not accommodate the entire complex on a single hillock. We had to spilt the plant on two adjacent hillocks with a elevation difference of 40 m and horizontal distance of 500 m.

- This was a challenge for us. But after discussion with our engineering team, it was decided to put Mill on lower hillock and rest of plant at the upper hillock.

PLANT VIEW


Process plant
Cogen plant
40 meter elevation difference
Mill section

OVERVIEW OF PROJECT

Project Promoter	Sar Senapati Santaji Ghorpade Sugar Factory
Sugar plant capacity	3500 tcd, expandable to 5000 tcd
Process	Double sulphitation
Process steam consumption	Less than 32% on cane
Co-gen plant capacity	• 120 t/h, 110 bar, 540°C boiler • 23 MW triple extraction cum condensing turbo generator
Distillery Plant	35 kL/day with Zero liquid Discharge
Distillery boiler	10 t/h, slop incineration boiler
Sugar Complex power cons.	33.5 kW/t of cane

METHODOLOGY : SELECTION OF MILL

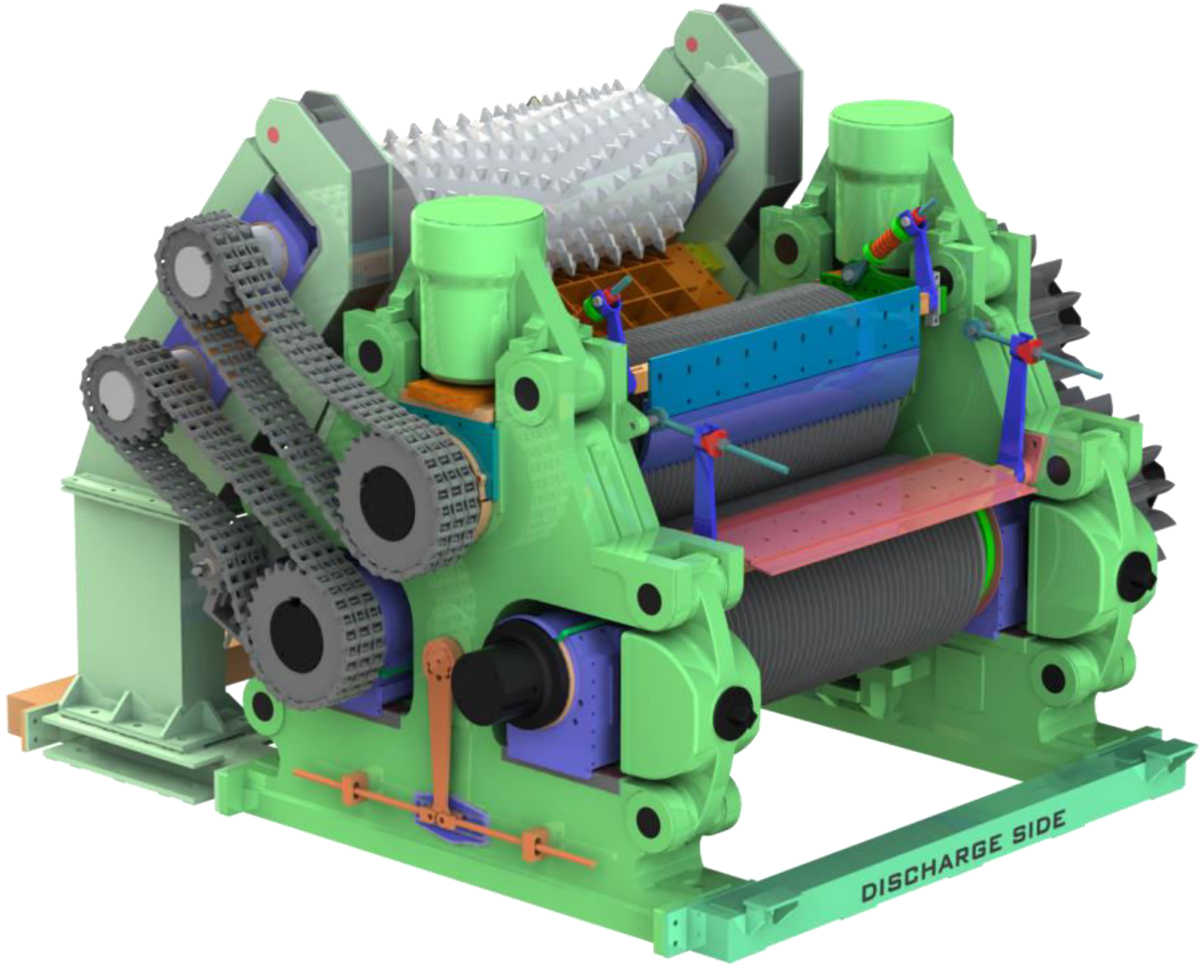
Higher efficiency with less power cons.

- Minimum no. of cane preparatory devices with high PI>89
- Low speed milling achieve high RME>96.5 @low power consume.
- Use of planetary gear boxes to minimise transmission losses

METHODOLOGY : SELECTION OF MILL

- Juice extraction section consumes 50% of total power and hence require greater attention for selection of mill configuration.
- Two stage cane preparation i.e. cane cutter & heavy duty fiberizor, with energy-efficient flux-compensated magnetic-amplifier rotor starters selected to achieve higher P.I. (89+) at lower power.
- Low-speed milling (12.0 m/min roller speed) comprising 4 mills of size 915 mm x 1980 mm (36”x78”), each mill with toothed roller pressure feeder, foot-mounted planetary gear box and AC VFD drive, selected to achieve higher Reduced mill extraction > 96.50% & at lower power consumption (12 kW/T of cane)

3D VIEW OF THE MILL AT OUR PLANT



SITE PHOTOGRAPH OF MILLING TANDEM

TREND: STEAM CONSUMPTION

Our Target
32% on cane

Present : 35-37% on cane

In 2000's : 50% on cane

In 1980's : 55% on cane

METHODOLOGY : STEAM SAVING IN PROCESS HOUSE

Eliminating the use of live steam

- Heat recovery of SO_2 gas for sulphur melting
- Use of high temperature condensate for sugar wash in high grade C/f
- Use of non condensable in online molasses conditioners

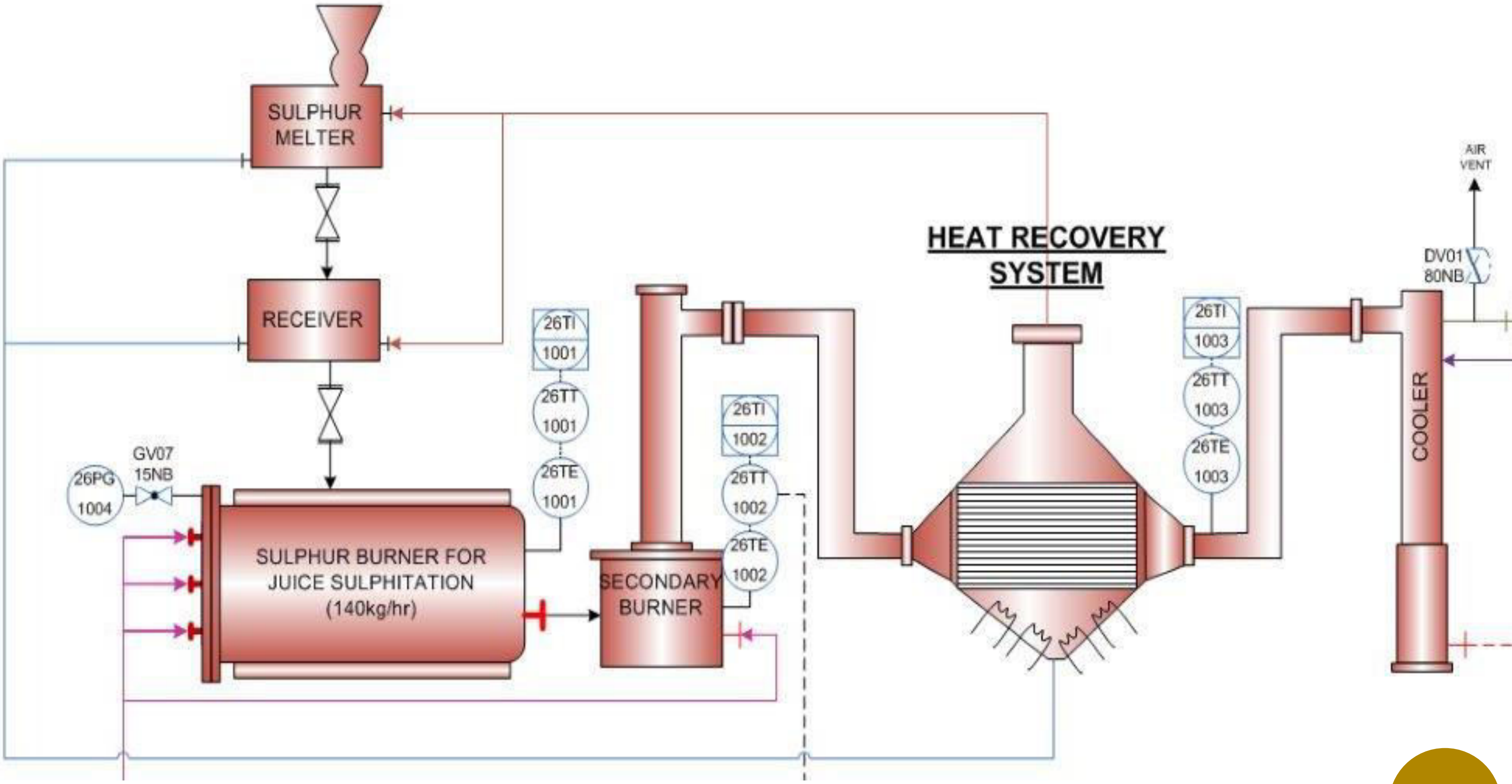
STEAM SAVING IN PROCESS HOUSE SULPHUR MELTING

- Sulphur got melted at 140°C temperature and about 0.3-0.5 % live steam (7 bar pressure) is used for sulphur melting

- Sulphur burning is exothermic reaction and liberate 9726 kJ/kg energy. This thermal energy is used in small re-boiler to generate steam, which is utilize for sulphur melting.

- About 1.3 kW/Ton of cane extra power can be generate, to avoid 0.5 % live steam for sulphur melting through waste heat recovery system.

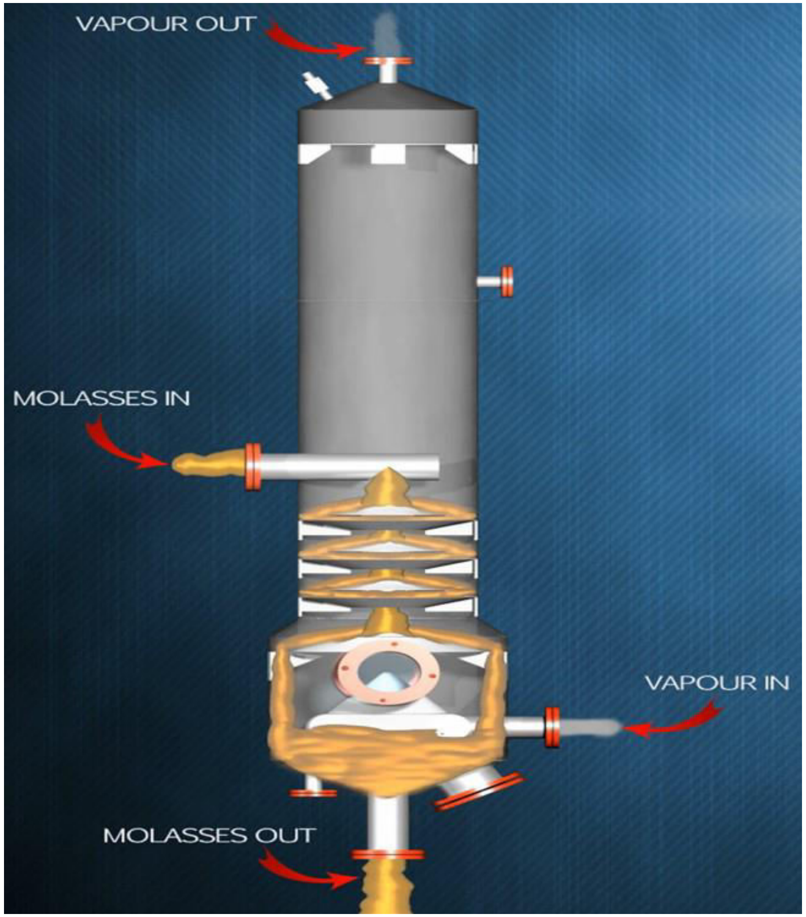
STEAM SAVING IN PROCESS HOUSE SULPHUR MELTING



STEAM SAVING IN PROCESS HOUSE: MOLASSES CONDITIONING

- Earlier Live steam at 150^{0}C was used for molasses conditioning, that lead to caramalisation of sugar and higher colour load in process house.

- Now 3rd effect vapour (100^{0}C) is used in specially designed on line conditioners, which eliminates live steam consumption.



METHODOLOGY : STEAM SAVING IN PROCESS HOUSE

Selection of equipment to suit Extensive vapour bleeding

- **Quintuple evaporator system**
- **Heat recovery of LP exhaust condensate**
- **Use of direct-contact juice heaters**
- **Use of a condensate flash heat recovery system**
- **Use of continuous pan**

METHODOLOGY: QUINTUPLE CONFIGURATION

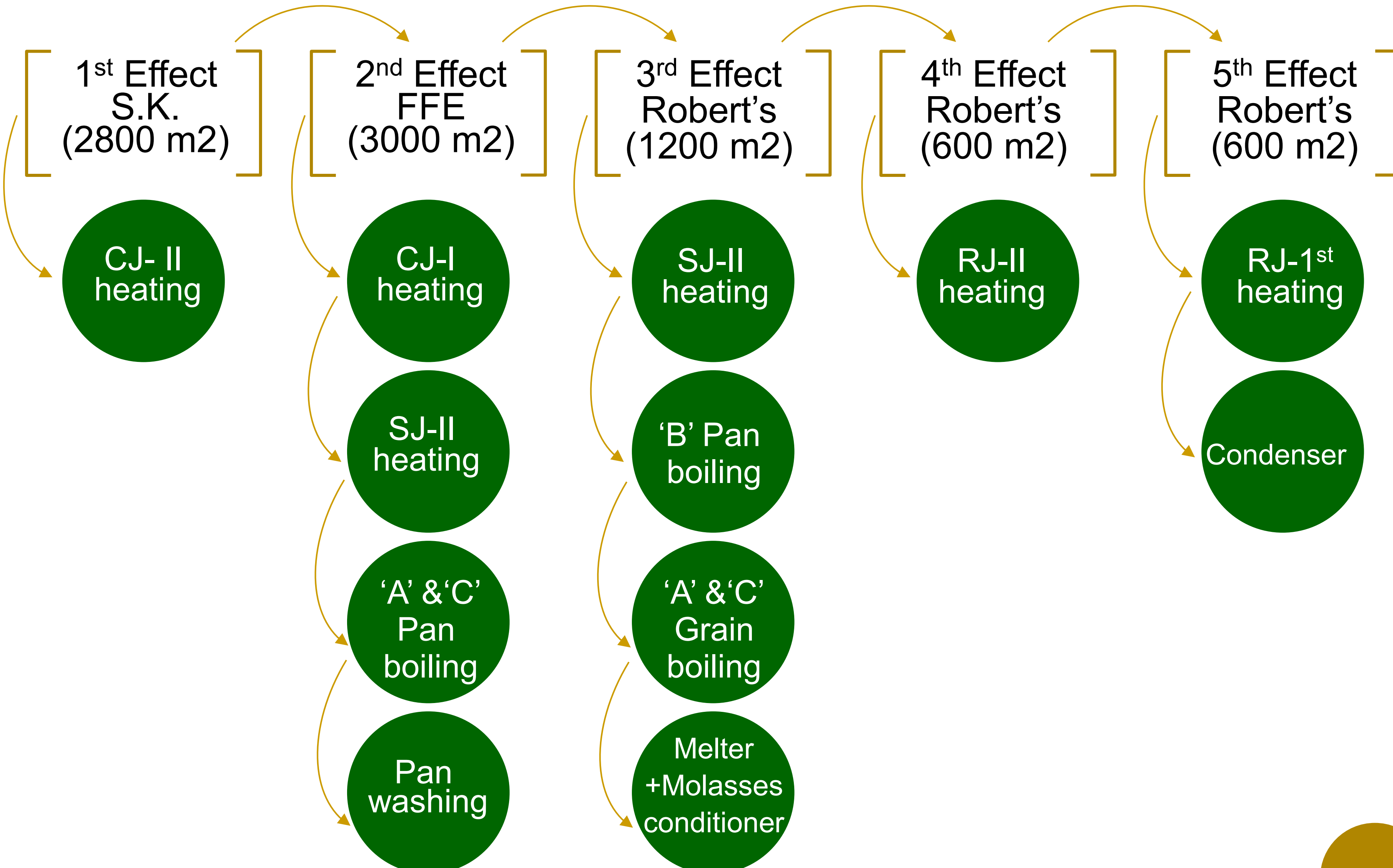
- Quintuple configuration evaporator is selected with 1st and 2nd effect as long tube evaporator and rest are down take less Robert's type evaporator.

- Maximum vapour bleeding from V2, V3 & V4 vapours, to reduce steam consumption at 1st effect.

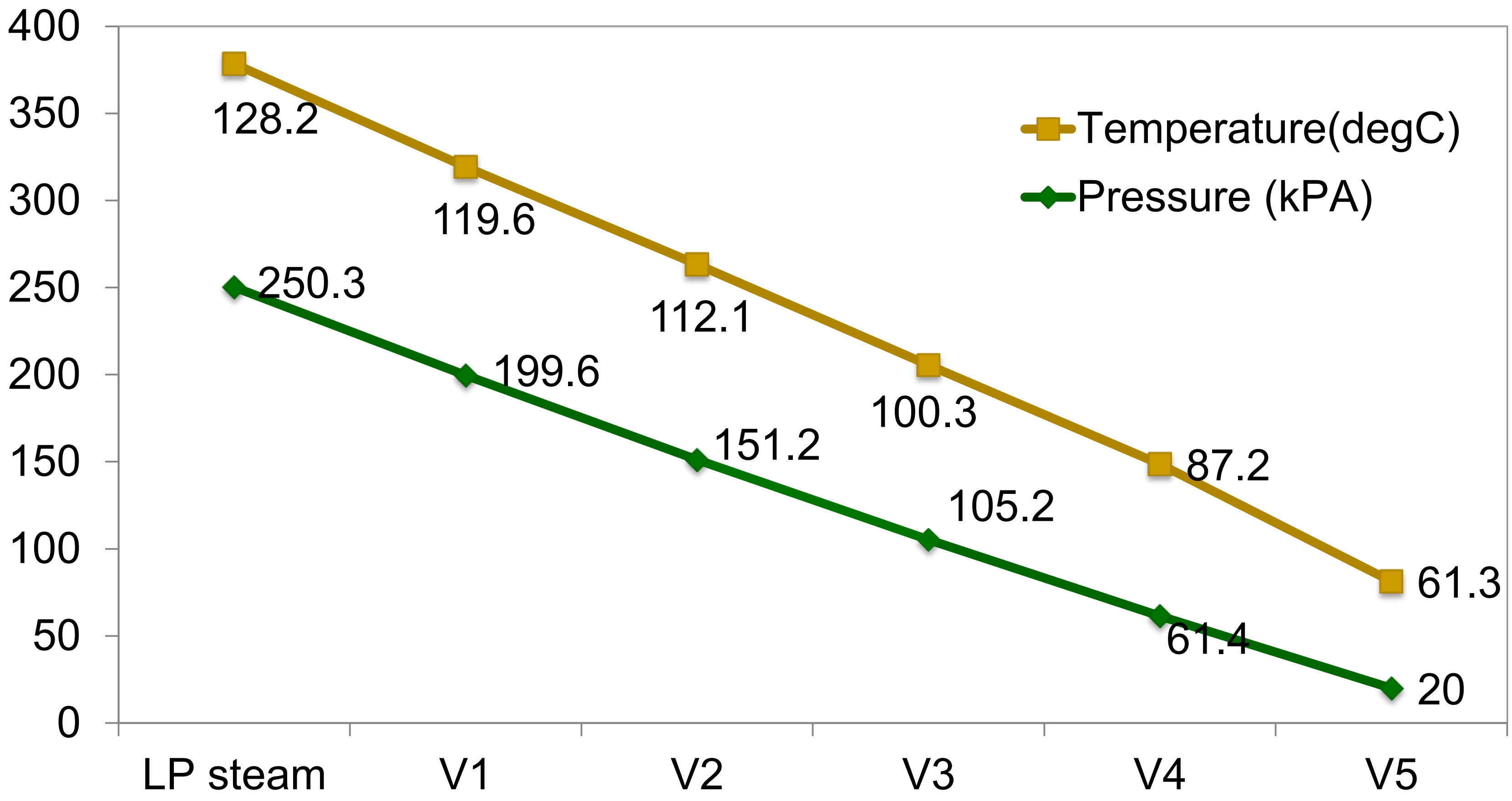
- Long tube evaporator for 1st and 2nd effect, to achieve lower Δ T so that higher vapour temperature of 2nd/3rd effect is maintained at more than 100^0C for pan boiling.

METHODOLOGY: QUINTUPLE CONFIGURATION

QUINTUPLECONFIGURATION: VAPOUR BLEEDING PATTERN



PRESSURE AND TEMPERATURE PROFILE AT EVAPORATOR



STEAM SAVING IN PROCESS HEAT RECOVERY OF LP CONDENSATE

- Normally, LP exhaust condensate at 120^0C is pumped to boiler feed water tank where it flashes in atmosphere through a vent, thereby cooled down to 100°C.
- This condensate is again pumped to a de-aerator, where LP steam is used to heat the feed water to 118-120°C.
- Extra D.M. water is require to maintain vented out vapour deficiency.

STEAM SAVING IN PROCESS HEAT RECOVERY OF LP CONDENSATE

In this plant, New system is adopted: Pumping of LP exhaust condensate directly to a de-aerator at 120°C. The following are the major savings/benefits observed:

- Saving of D.M. water as vapour venting in feed tank is avoided so load on DM plant thereby raw water consumption & chemical load decreases.
- Steam saving: Negligible steam requirement in De-aerator as high temperature condensate directly pumped to De-aerator & less quantity of low temperature D.M. water.
- Avoids double pumping of condensate transfer.

STEAM SAVING IN PROCESS
DIRECT CONTACT JUICE HEATER

Can operate at lower Δ T 2-3^{0}C, so 2nd effect vapour is used for sulphited juice 2nd heating to heating up to 104^{0}C and clear juice heating.

Dilution due to water addition in direct contact heater, reduced Brix of sulphited juice so higher settling rate of mud is achieved in settler/clarifier. (The juice Brix are higher due to high sugar recovery)

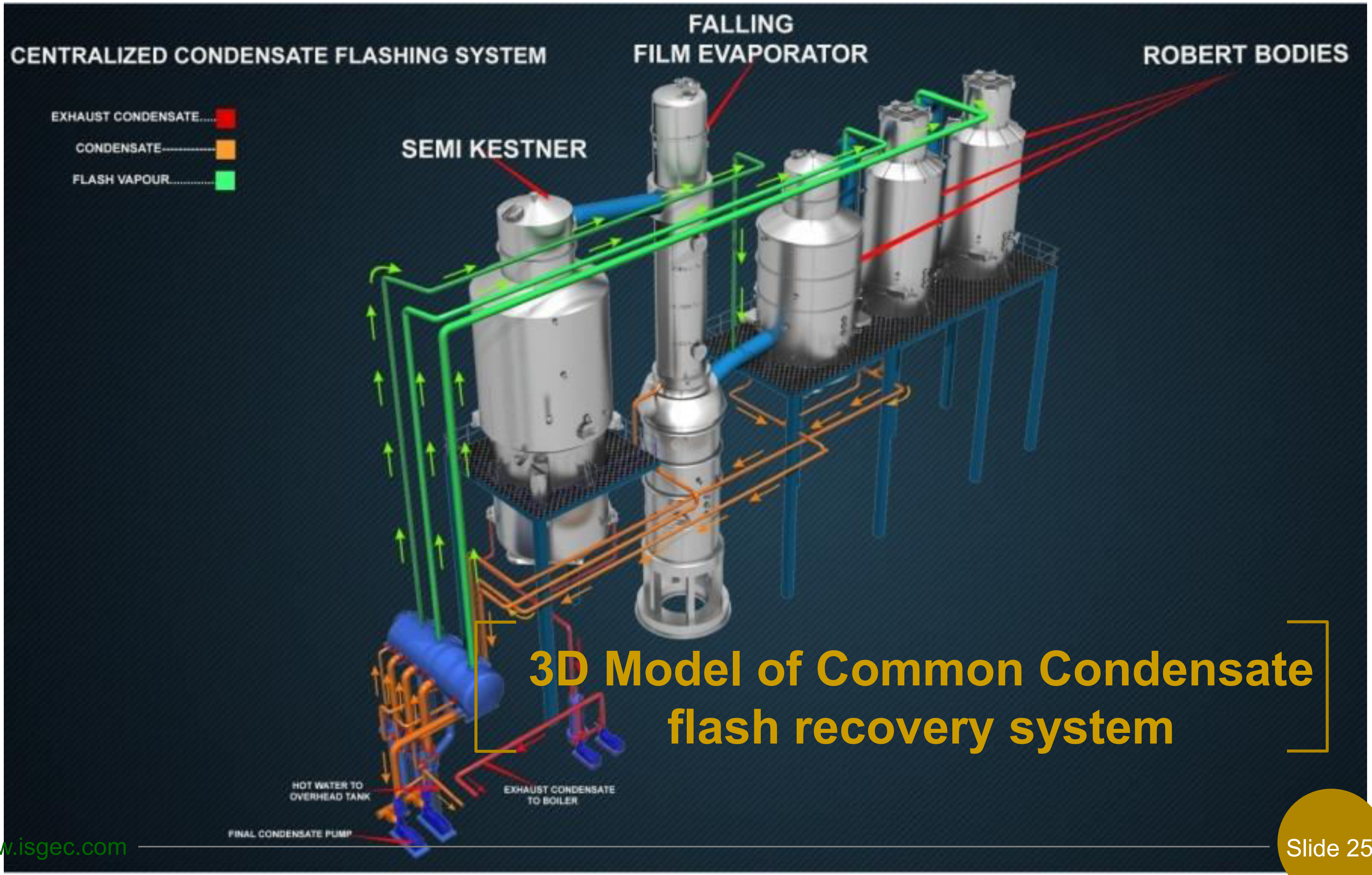
STEAM SAVING IN PROCESS
COND. FLASH HEAT RECOVERY

- Normally hot condensate is vented out to atmosphere from over head tank, which is loss of water as well as loss of energy.

- Hot condensate of different temperature recovered from evaporation, juice heating and pan boiling is sent to common condensate flash recovery system and flash vapour is used in evaporator bodies corresponding to their vapour/temperature.

- About 2.0-2.5 % steam reduction due to utilisation of flash vapour at evaporator.

STEAM SAVING IN PROCESS
COND. FLASH HEAT RECOVERY

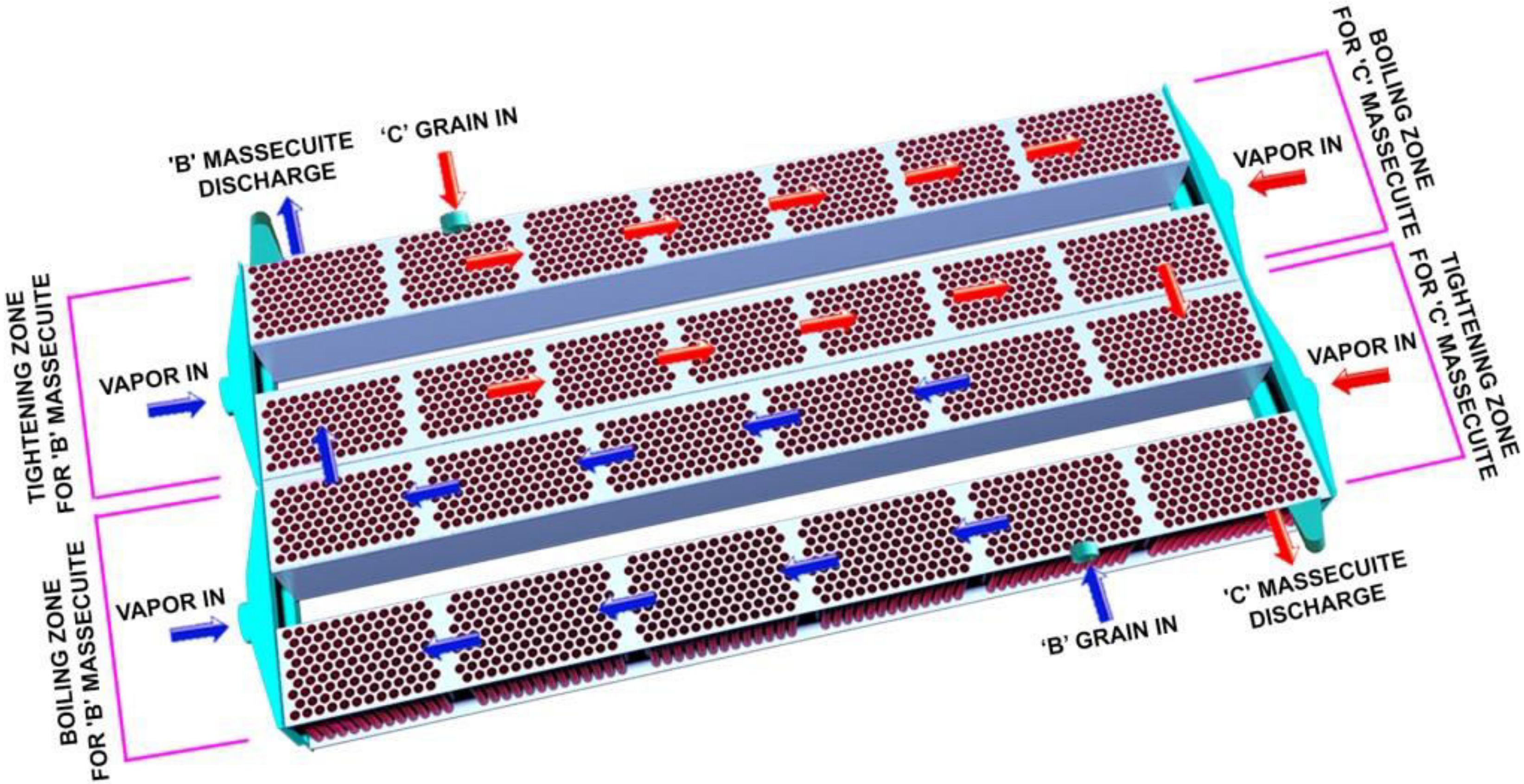


STEAM SAVING IN PROCESS CONTINUOUS VACUUM PAN

- Vapour requirement at pan station has been reduced to 18 % on cane by introducing a specially designed continuous pan, common for B & C massecuite boiling. This pan has multiple vapour entry so that same vapour pressure can be maintained throughout the calandria.

- Vapour at two different pressure (1.55 and 1.05 bar) is used for low grade massecuite boiling without effecting crystal growth.

STEAM SAVING IN PROCESS CONTINUOUS VACUUM PAN



MASSECUITE FLOW INDICATIVE DRAWING FOR COMMON CONTI. PAN.

STEAM SAVING IN PROCESS CONTINUOUS VACUUM PAN

WORKING RESULTS OF 2014-15 & 2015-16

Week	Cane crushed (t)		Bagasse moisture (%)		Process steam % cane	
	Feb-15	Jan-16	Feb-15	Jan-16	Feb-15	Jan-16
Week-1	4522	5568	48.9	49.57	33.03	31.60
Week-2	4678	5700	48.8	49.72	31.46	30.42
Week-3	4655	5476	48.9	49.57	31.54	32.15
Week-4	4459	5756	48.9	49.65	31.97	30.91
Week-5	–	5710	–	49.65	–	30.59
Average	4578	5718*	48.9	49.62	31.99	30.95

WORKING RESULTS OF 2014-15 & 2015-16

After successful trial season 2014-15, few balancing equipment we added only in the process house, to enhance crush rate to 5500 TCD

Plant achieved season average Reduced mill extraction of 96.89% in 2014-15 and 96.6 % in 2015-16, which is the one of the best efficiency from a 4 mill tandem. Power consumption of the mill section was only 11.5-11.8 kW/T of cane.

CO-GENERATION PLANT: SELECTION OF POWER CYCLE

- Thermodynamically, the energy recovery from the Rankin cycle depends upon the steam temperature, but any increase in steam temperature must be accompanied by an increase in steam pressure to ensure optimum extraction of useful energy from the working medium

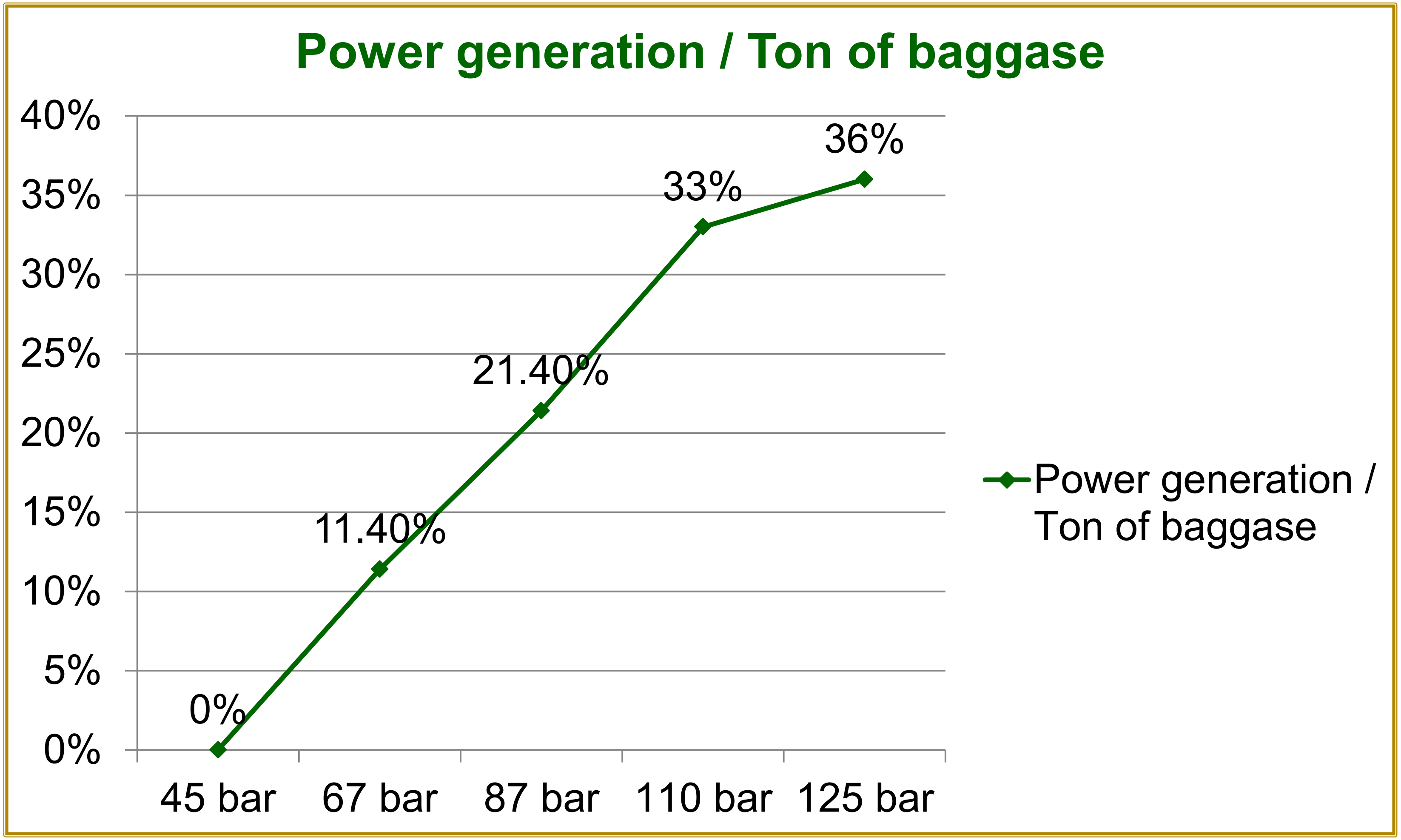
- We selected 110 bar cycle as its power generation potential is about 33% more than 45 bar cycle.

CO-GENERATION PLANT: SELECTION OF POWER CYCLE

Parameter	Unit	45bar/ 440°C	66bar/ 485°C	87bar/ 515°C	110 bar/ 540°C	125bar/ 548°C
Feed water temperature	°C	105 (without HP heater)	150 (with 1 HP heater)	170 (with 1 HP heater)	220 (with 2 HP heater)	240 (with 3 HP heater)
Steam/fuel ratio	**-**	**2.29**	**2.39**	**2.42**	**2.59**	**2.68**
Steam parameters at turbine inlet	bar /°C	42 / 435	63 / 480	84 / 510	107 / 535	122 / 543
Gross power output *	**MW**	**22.3**	**23.2**	**25.6**	**27.0**	**27.8**
Specific steam consumption	kg/kW	4.5	4.3	3.9	3.7	3.6
Plant efficiency	%	19.4	21.0	23.5	26.5	28.3

*For 100 TPH steam and 0.1 bar 100 % condensing turbine

CO-GENERATION PLANT: SELECTION OF POWER CYCLE



CO-GENERATION PLANT: SELECTION OF BOILER DESIGN

- Travelling grate boiler has much better results on burning of bagasse as well as variety of biomass fuels and fossil fuels.
- The boiler is equipped with environmentally friendly electrostatic precipitators for limiting particulate emission, and a closed and energy-efficient dense-phase fly-ash handling system.
- Adoption of lower flue gas velocities across heating surfaces reduces draft losses, hence reduce ID, FD & SA fan power consumption.

CO-GENERATION PLANT: HEAT & MASS BALANCE

Condition	Steam Gen.	Extraction to process	To distillery	To feed water heating	To condenser	Power generation
	t/h	t/h	t/h	t/h	t/h	MW
Designed	120	64	8.0	27	21	23
Season 2014-15	113	57	--	26	30	23
Season 2015-16	120	73	--	27	20	23

In year 2015-16, the sugar plant operated for 158 days and the co-generation plant operated for a further period of 50 days using saved bagasse as fuel.

STEAM GENERATION PLANT

POWER TURBINE

POWER SAVING: USE OF VARIABLE FREQUENCY DRIVE

Variable frequency drives installed in mill, process & co-gen plant)	53 nos.
Load for operating motors	6056 kW
Load for standby motors	1120 kW
Total Load	7176 kW
Running load of motor without VFD	4481 kW
% consumption of connected load	**75%**
Actual running load of motor with VFD	4056 kW
% consumption of connected load	**67%**
Power saving	**425 kW**

RESULTS: POWER EXPORT

Description	Unit	Value	
		2014-15	2015-16
Cane crushed	t	477,000	8,00,057
Bagasse % cane	%	28	28.5
Steam consumption	**%**	**32**	**31**
Moisture of bagasse	%	48-49	48-49
Feed water temperature	°C	210-220	210-220
Steam temperature	°C	540	540
Steam pressure	bar	110	110
Season days		122	158
Bagasse saved (during harvest)	**t**	**7000**	**39,850**

RESULTS: POWER EXPORT

POWER EXPORT IN THE HARVEST			
Parameters	**Unit**	**2014-15**	**2015-16**
Power generation in the harvest	kWh	61,900,000	81,886,960
Power required for sugar + co-gen plant & other facilities	kWh	16,529,000	24,375,250
Power export to Grid	kWh	45,371,000	57,511,710
POWER EXPORT IN THE OFF–SEASON			
		2015	**2016**
No of days	days	7	50
Power generation in the off- season	kWh	3,445,000	27,600,000
Auxiliary power consumption	kWh	310,000	2,208,000
Power export in the off-season	kWh	3,135,000	25,392,000

RESULTS: POWER EXPORT

POWER EXPORT PER TONNE OF CANE			
		2014-15	**2015-16**
Total power export (during the harvest + off-season)	kWh	48,506,000	82,903,700
Total cane crushed	tonne	477,000	8,00,507
Power export	**kWh/t**	**101.60**	**103.57**

CONCLUSION

- Higher efficiencies (RME > 96.5%) with low speed milling cane be achieved with proper integration and selection of equipment.
- Steam consumption less than 31% on cane while maintaining high process efficiency (RBHR > 91%).
- 29% on cane steam consumption is also achieved for many days during the crop 2015-16.
- More than 100 kW per tonne of cane, power export has been achieved along with high efficiency and throughput from well designed sugar complex.

ACKNOWLEDGEMENT

We are sincerely thankful to Isgec Heavy Engineering Limited and its team for whole-hearted support during the establishment of the project and the operation of the plant.

We are also thankful to our technical team for their dedication to operate plant with highest efficiencies.

Thank You