PIC Date: DD MMM 2016

Project No. : E-GC1.1-2016/035 (e-MOC no.)

Project Title: Revamping Structure Packing of EO stripper column

Location: E-GC

Proposal for:

- ☐ **Gate 1 (+/-50%)**; Approval to develop and select conceptual design
- ☐ **Gate 2 (+/-30%)**; Approval to define and develop Basic Design and/or Front End Engineering & Design (FEED)
- ✓ **Gate 3 (+/-10%)**; Approval to perform Detailed Engineering, Procurement, and Construction
- ☐ **Revise Budget**; Approval for additional budget as scope and/or schedual change

Project Engineer: Mr. Thepchan Promtong <DEB-PLE-PEN/6706>
Process Engineer: Mr. Karn Phongprot <E-GC-TE/7141>

Objective of Today

Project request PIC to endorse **Gate 1 (±10%)**
Project budget: **47.5 MTHB**
Investment type: **Operational Excellence**

Benefit: **31.43** M THB/Year
IRR: **62.29** %
Payback: **1.51** Year
J-Factor: N/A

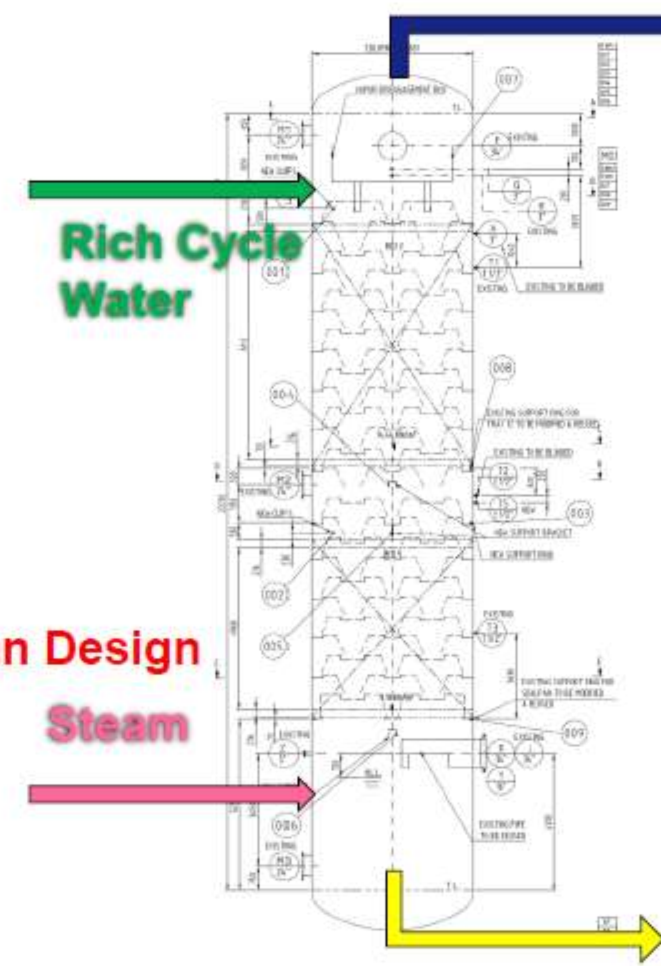
Project Schedule: 1 September 2016 – 30 April 2017 (EPC)

Propose to use budget by September 2016.

Agenda

1. Background
2. Proposal
3. Cost estimate
4. Benefit and Project justification
5. Project schedule
6. Project cash flow
7. Risk & Key success factor

EO stripper column | T-310

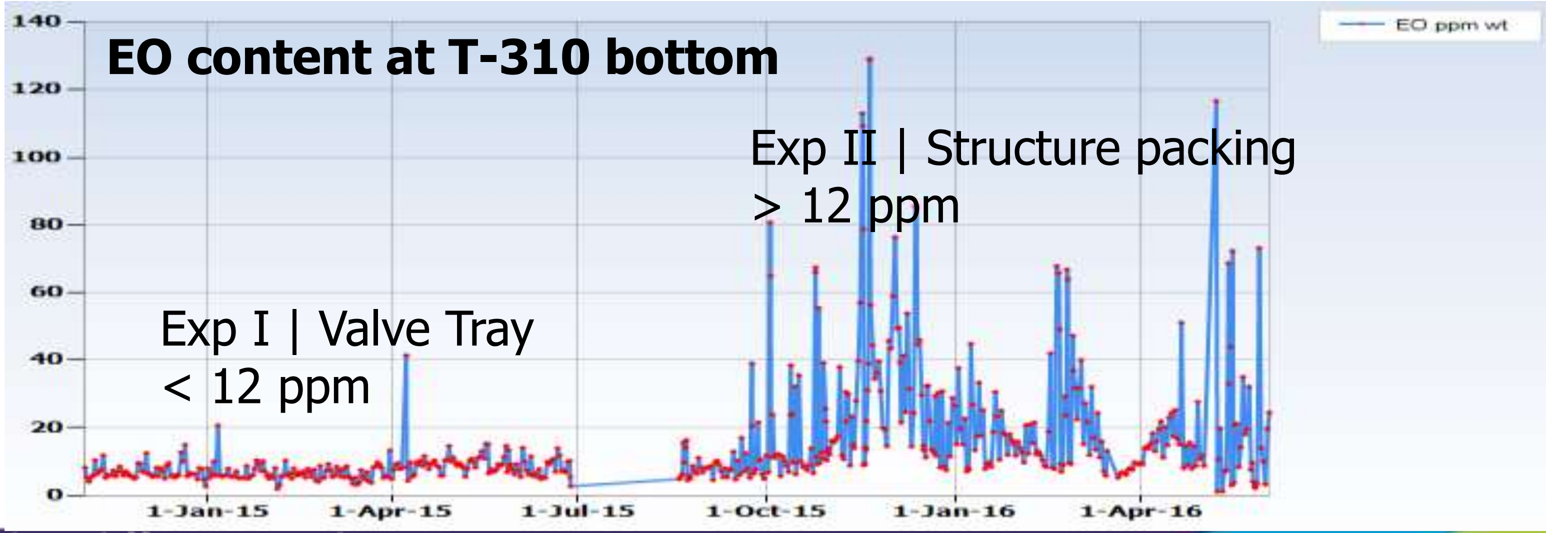


Objective:

- Strip the EO out from Rich Cycle Water.
- Design Spec: EO content in Lean Cycle Water ≤ 12wt% ppm

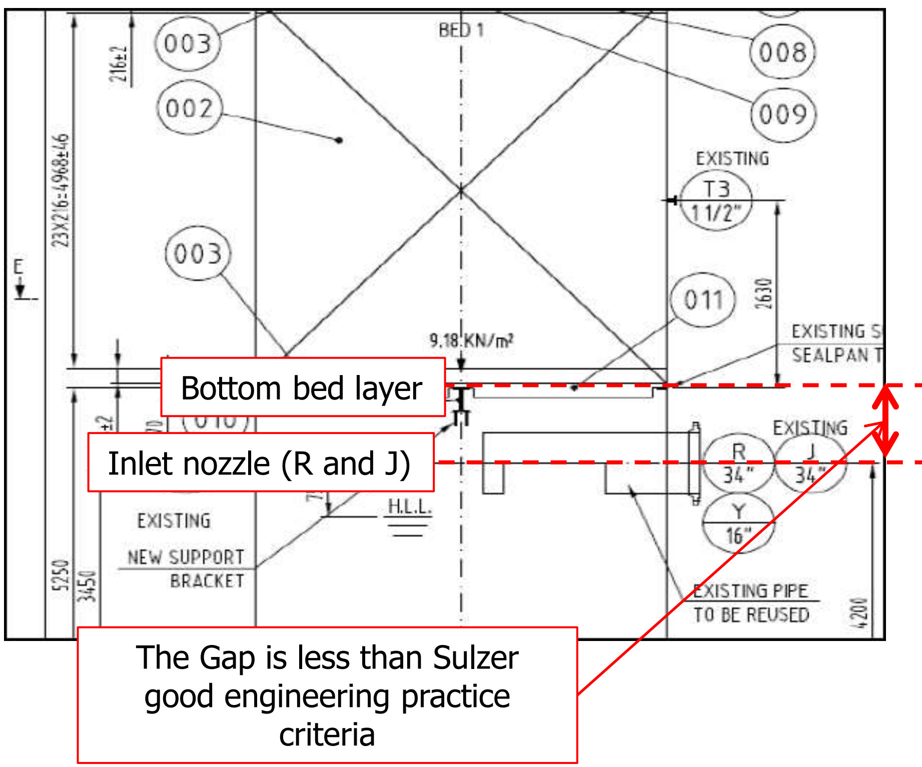
1.Background

- Y2006 – 2014, EO separation in EO stripper column had been achieved by valve tray.
- 2014, TOCGC had capacity expansion II project. Valve tray has been revamped by replacing structure packing (MellapakPlus252.Y) in order to improve capacity and separation efficiency.
- During the commissioning, it was found that the EO separation cannot be achieved as design as indicated from EO breakthrough at the column bottom while steam consumption for stripping was greater than design.

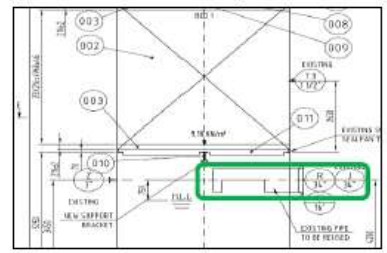


1.Background

- The most likely possible cause is **vapor maldistribution** in the bottom section which are suspected from a close distance between reboiler return inlet nozzle and bottom of structure packing bed. **Poor vapor distribution resulted in loss number of theoretical stage (NTS) and consequently loss separation efficiency. (Refer to MOM with Sulzer and SD on Jun 16th, 2016)**



3. Vapor Maldistribution
   - There are two huge 34" vapor inlet (R and J) below the bottom last bed.
   - Furthermore, these inlet nozzles are very close to the bottom of the bed.



   - Due to the 2 points above, vapor maldistribution might occur causing the packing efficiency to be poor.

6. Instead of using existing packing model of MellapakPlus 252.Y, SD proposed to use a denser packing type of MellapakPlus 352.Y for both Bed#2 and Bed#1 as the operating pressure drop across the column at this moment is lower that the design case. Denser packing can be considered.

   Actual operating pressure drop = 0.40 bar
   Design pressure drop (allowable) = 0.70 bar

   Benefit: By using a denser packing, it will compensate the loss of NTS of removing few layers of packing due to the installation of the chimney tray.

1.Background

SCIENTIFIC DESIGN COMPANY, INC.
A SABIC – Clariant Partnership Company

SD Project 80014-14
February 24, 2016

Action Item 5 – T-310 Process Simulation Study

We run process simulations of the operating and analytical data of December 22 2015 to evaluate the performance and determine the overall efficiency of the structured packing. We also compare the data and the results of the simulations against the process design conditions of the PFD. The results of the process simulation cases studies are summarized in the Table below.

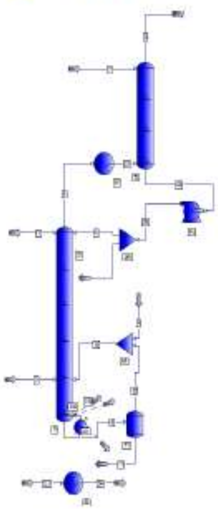
As shown in the Table the overall efficiency of the structured packing was calculated to be in the range of 79 - 90% of the design PFD efficiency. It is estimated that the lower efficiency is equivalent to about 8 tons/h additional steam consumption rate or about 115 - 116% of the expected steam of the design efficiency.

1.Background

SULZER

Simulation Result

- Sulzer try to do the match back simulation based on the operating data provided by Samsung.
- Found that in actual case, NTS is only 4.



Stream Name / Stream Description		1 Feed-109	3 LP steam	4 MP steam
Phase		Mixed	Vapor	Vapor
Liquid Weight Fraction		0.9638	0.0000	0.0000
Vapor Weight Fraction		0.0362	1.0000	1.0000
Temperature	C	100.400	143.263	170.502
Pressure	BAR	1.621	3.953	8.000
Pressure	bar	1.621	3.953	8.000
Total Mass Rate	KG/HR	1297500.000	57524.000	2340.600
Liquid Mass Rate	KG/HR	1250535.082	n/a	n/a
Vapor Mass Rate	KG/HR	46964.918	57524.000	2340.600
Vapor Std. Vol. Rate	km3/hr	0.0000	0.0001	0.0000
Vapor Act. Vol. Rate	M3/HR	32377.9787	27966.6144	599.0635
Vapor Act. Density	KG/M3	1.451	2.057	3.907
Total Std. Liq. Rate	M3/HR	1300.763	57.581	2.343
Liquid Std Rate (vol)	M3/HR	1249.9591	n/a	n/a
Liquid Act. Rate (vol)	M3/HR	1307.3649	n/a	n/a
Liquid Act. Density	KG/M3	956.538	n/a	n/a
Total Molar Comp. Percents				
ETHYLENE		0.0000	0.0000	0.0000
O2		0.0000	0.0000	0.0000
EOXIDE		3.3500	0.0000	0.0000
CO2		0.0000	0.0000	0.0000
H2O		93.7900	100.0000	100.0000
N2		0.0000	0.0000	0.0000
AR		0.0000	0.0000	0.0000
CH4		0.0000	0.0000	0.0000
C2		0.0000	0.0000	0.0000
EG		2.8600	0.0000	0.0000
Total Weight Comp. Percents	KG/HR			
ETHYLENE		0.0000	0.0000	0.0000
O2		0.0000	0.0000	0.0000
EOXIDE		43466.2500	0.0000	0.0000
CO2		0.0000	0.0000	0.0000
H2O		1216925.2500	57524.0000	2340.6000
N2		0.0000	0.0000	0.0000
AR		0.0000	0.0000	0.0000
CH4		0.0000	0.0000	0.0000
C2		0.0000	0.0000	0.0000
EG		37108.5000	0.0000	0.0000
Total Weight Comp. Rates				
ETHYLENE		0.0000	0.0000	0.0000
O2		0.0000	0.0000	0.0000
EOXIDE		1.4272	0.0000	0.0000
CO2		0.0000	0.0000	0.0000
H2O		97.7080	100.0000	100.0000
N2		0.0000	0.0000	0.0000
AR		0.0000	0.0000	0.0000
CH4		0.0000	0.0000	0.0000
C2		0.0000	0.0000	0.0000
EG		0.8648	0.0000	0.0000

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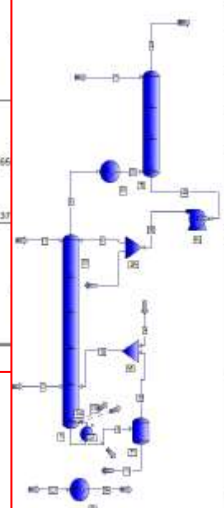
SULZER

Simulation Result

- In order to meet the design specification of ≤ 12wt% ppm of EO in the Lean Cycle Water, the NTS required will be 6.



Stream Name / Stream Description		1 Feed-109	3 LP steam	4 MP steam	5 Bottom	6 Top Vap	S1	7 Water	8 Reflux	S7	9 Off Gas
Phase		Mixed	Vapor	Vapor	Liquid	Mixed	Mixed	Liquid	Liquid	Liquid	Vapor
Liquid Weight Fraction		0.9638	0.0000	0.0000	1.0000	0.0009	0.5095	1.0000	1.0000	1.0000	0.0000
Vapor Weight Fraction		0.0362	1.0000	1.0000	0.0000	0.9991	0.4905	0.0000	0.0000	0.0000	1.0000
Temperature	C	100.400	143.263	170.502	111.315	100.322	60.000	45.000	61.567	61.567	61.483
Pressure	BAR	1.621	3.953	8.000	1.483	1.422	1.422	4.903	2.000	2.000	1.455
Pressure	bar	1.621	3.953	8.000	1.483	1.422	1.422	4.903	2.000	2.000	1.455
Total Mass Rate	KG/HR	1297500.000	57524.000	2340.600	1302599.586	94683.080	94683.080	500.000	39879.001	9819.533	45484.546
Liquid Mass Rate	KG/HR	1250535.082	n/a	n/a	1302599.586	88.943	48237.059	500.000	39879.001	9819.533	n/a
Vapor Mass Rate	KG/HR	46964.918	57524.000	2340.600	n/a	94594.137	46446.021	n/a	n/a	n/a	45484.546
Vapor Std. Vol. Rate	km3/hr	0.0000	0.0001	0.0000	n/a	0.0001	0.0000	n/a	n/a	n/a	0.0000
Vapor Act. Vol. Rate	M3/HR	32377.9787	27966.6144	599.0635	n/a	81014.6744	22339.5942	n/a	n/a	n/a	21554.8836
Vapor Act. Density	KG/M3	1.451	2.057	3.907	n/a	1.168	2.079	n/a	n/a	n/a	2.110
Total Std. Liq. Rate	M3/HR	1300.763	57.581	2.343	1299.967	101.145	101.149	0.500	40.391	9.946	51.313
Liquid Std Rate (vol)	M3/HR	1249.9591	n/a	n/a	1299.9673	0.0889	48.7352	0.5005	40.3909	9.9456	n/a
Liquid Act. Rate (vol)	M3/HR	1307.3649	n/a	n/a	1368.0058	0.0929	49.8815	0.5064	41.4331	10.2022	n/a
Liquid Act. Density	KG/M3	956.538	n/a	n/a	952.189	957.258	967.033	987.365	962.492	962.492	n/a
Total Molar Comp. Percents											
ETHYLENE		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
O2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EOXIDE		3.3500	0.0000	0.0000	0.0002	49.5919	49.5919	0.0000	8.7467	8.7467	93.6761
CO2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O		93.7900	100.0000	100.0000	97.1512	50.3955	50.3955	100.0000	91.2293	91.2293	6.3239
N2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH4		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EG		2.8600	0.0000	0.0000	2.8496	0.0126	0.0126	0.0000	0.0241	0.0241	0.0000
Total Weight Comp. Percents	KG/HR										
ETHYLENE		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
O2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EOXIDE		43466.2500	0.0000	0.0000	2.5600	46955.1311	46955.1311	0.0000	3488.0900	858.8835	42608.1574
CO2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O		1216925.2500	57524.0000	2340.6000	1265490.8806	47715.9898	47715.9898	500.0000	36381.3144	8958.2857	2876.3888
N2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH4		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EG		37108.5000	0.0000	0.0000	37106.1449	11.9590	11.9590	0.0000	9.5961	2.3629	0.0000
Total Weight Comp. Rates											
ETHYLENE		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
O2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EOXIDE		1.4272	0.0000	0.0000	0.0001	28.6934	28.6934	0.0000	3.7726	3.7726	85.8311
CO2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O		97.7080	100.0000	100.0000	99.1560	71.3015	71.3015	100.0000	96.2201	96.2201	14.1689
N2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH4		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EG		0.8648	0.0000	0.0000	0.8439	0.0052	0.0052	0.0000	0.0074	0.0074	0.0000

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T-310 Troubleshooting | June 16, 2016 |

1.Background

Sulzer recommendation

Quote:

"However in your case, the packed bed height for M352.Y shall be reduced due to the inclusion of chimney tray. The estimated NTS improvement is approx. 20% based on HETP comparison. Consequently, based on a theoretical basis, the estimated expected reduction in steam consumption is approx. 5% ~ 8% for every 10% improvement in NTS."

End quote:

SULZER NTS Calculation

NTS calculation	Original	Case I	Case II
	252Y	352Y + 452Y	352Y
Top Bed Height (352Y)	7242	7242	7242
Bottom Bed Height (452Y)	5400	4473	4473
Total Bed Hight	12.642	11.715	11.715
Chimney Tray	--	Applied	Applied
FF Top bed	1.17	1.17	1.17
FF Bottom bed	1.42	1.42	1.42
HETP/m Top bed	0.36	0.28	0.28
HETP/m BTM bed	0.38	0.24	0.29
NTS top bed	20.12	25.86	25.86
NTS btm bed	14.21	18.64	15.42
Total NTS	34.33	44.50	41.29
NTS increment	--	30%	20%

Column Liquid/Vapor data

Vout (kg/h)	65,700.00		Lin (kg/h)	1,334,430.00	
Temp	101		Temp	93	
Density	1.148	7.242 m	Density	958	
MW	24.45	Bed	Viscos	0.305	cP
		2	Seufac ten	59.3	dyne/cm
		352Y			
V	84,380.00		L	1,353,110.00	
Temp	111.00		Temp	110.00	
Density	0.85	4.473 m	Density	952	
MW	18.20	Bed	Viscos	0.258	cP
		1	Seufac ten	56.8	dyne/cm
		452Y			
Vin (kh/h)	86,900.00		Lout (kg/h)	1,355,630.00	
Temp	112		Temp	111	
Density	0.859		Density	952	
MW	18.03		Viscos	0.255	cP
			Seufac ten	56.5	dyne/cm

2.Proposal

Project Objective:

To improve separation efficiency of EO stripper column by replacing higher performance of structure packing and newly install chimney tray to improve vapor distribution.

Scope of Modification:

- Newly install a chimney tray above nozzle R and J (reboiler return nozzle and extraction steam nozzle)
- Revamp current structure packing model of MellapakPlus 252.Y by replacing MellapakPlus 352.Y which has higher NTS at the same height

Problem & Opportunity

Problem Statement:

Low separation efficiency in EO stripper column causes several disadvantages.

- Excessive steam usage by 15 – 16% of design (8 – 10 t/h) | See back-up slide
- Acid intermediate and impurities carryover to cause mechanical damage from corrosion in downstream section are suspected by plant licensor. In addition, improving packing efficiency is one of corrective action from RCA meeting.

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Recommendation to Prevent Recurrence

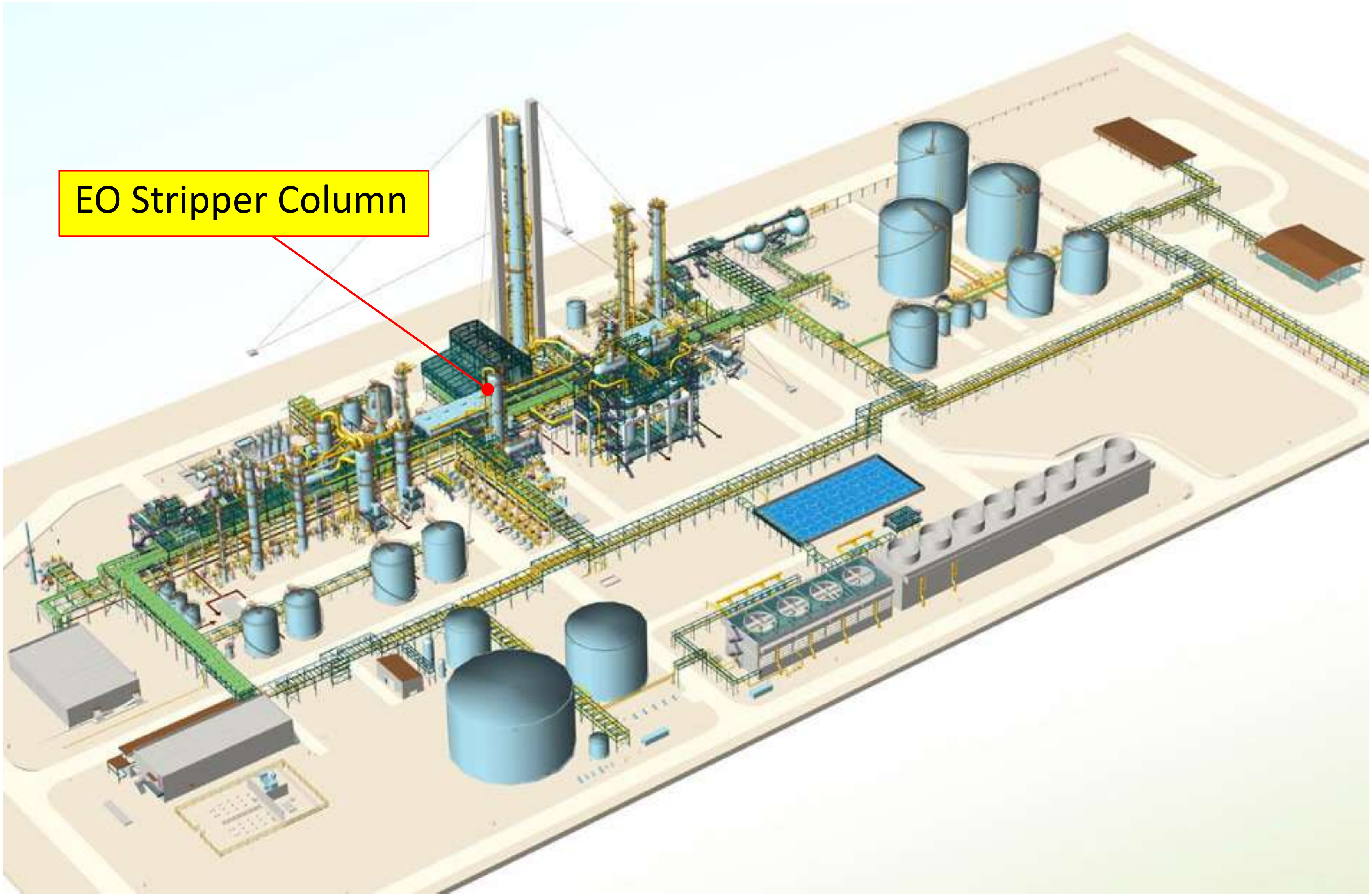
Actions	RP	Due date
7. Upgrade MEG post treatment resin unit (D-640) to handle higher acid and impurities from process.	E-GC-TE	T/A 2017
8. Material upgrade for Evaporator system from CS to SS by using the Corrosion review of Glycol Evaporation unit (IR.16.00036), section 4 Conclusion and Recommendation.	E-GC-AS	T/A 2017
9. Apply CFD simulation to identify potential location of erosion in Evaporator section which consider the Schoepentoeter for all evaporators to reduce the flow velocity for inlet column evaporators.	T-TE-PT	T/A 2017
10. Extend structure packing of T-310 from 12.54 m to 14 m to improve efficiency. (SD recommendation)	E-GC-TE	T/A 2017
11. Upgrade DI unit capacity to handle higher impurities in cycle water. (lower UV transmission less than 10%)	E-GC-TE	T/A 2017

- MEG product tends to off spec. as due to lower UV transmission | See back-up slide

Proposed Opportunity and Solution:

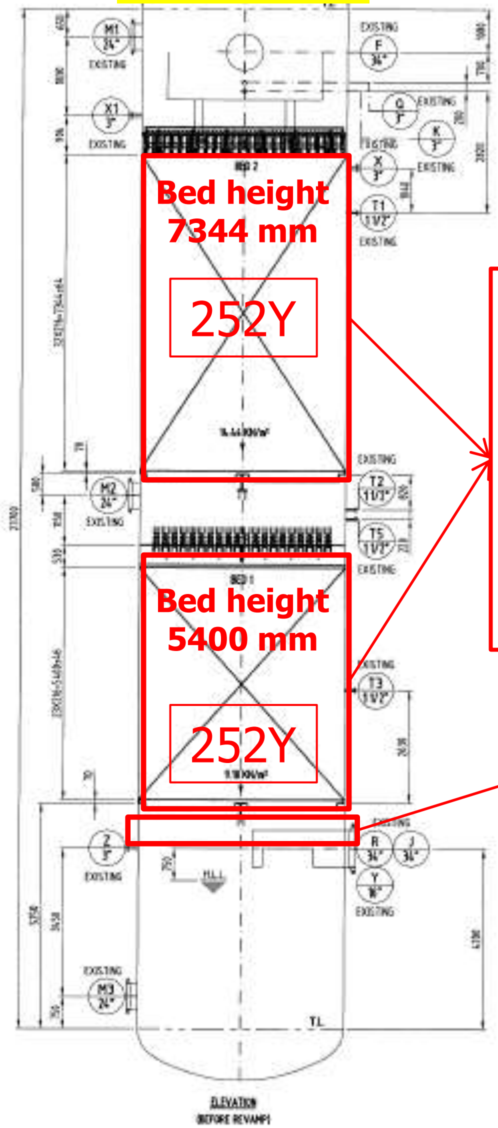
- Newly install a chimney tray above nozzle R and J (reboiler return nozzle and extraction steam nozzle)
- Revamp current structure packing model of MellapakPlus 252.Y by replacing MellapakPlus **352.Y** which has higher NTS at the same height

Simplify diagram / Plot plan / Drawing



Simplify diagram / Plot plan / Drawing

Before

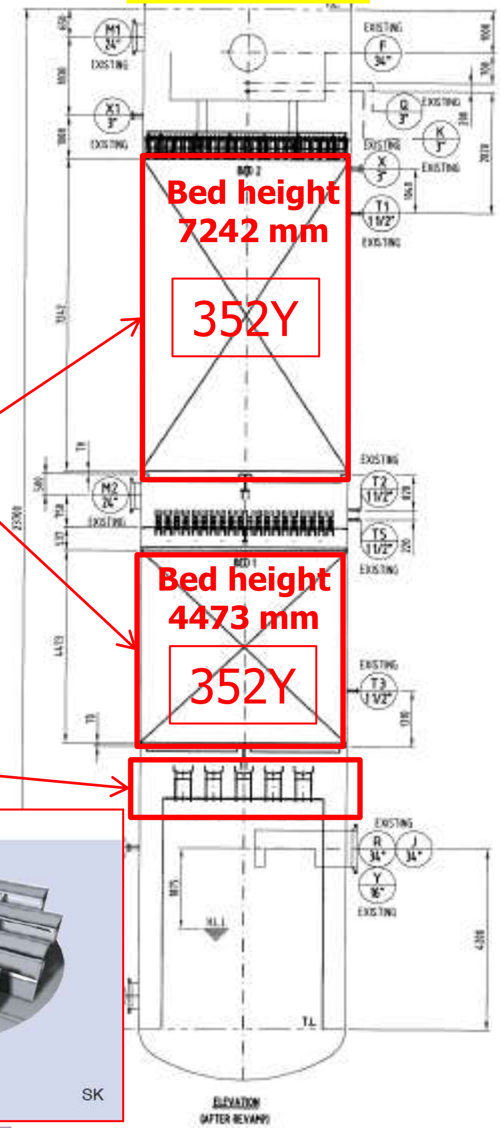


Replace packing
Mellapak 252.Y to 352.Y

Bottom bed height become shorter after revamping due to chimney tray but separation efficiency has been recovered by replacing with higher packing performance

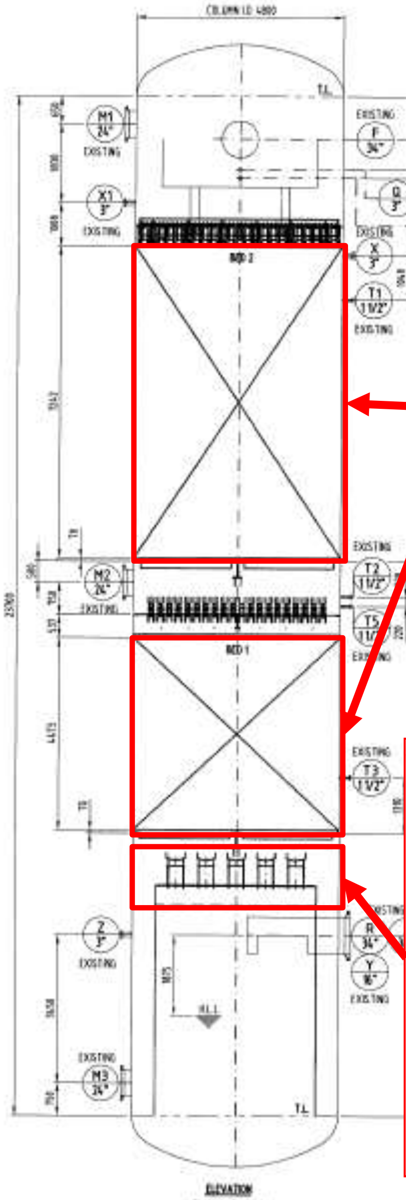
New Chimney Tray

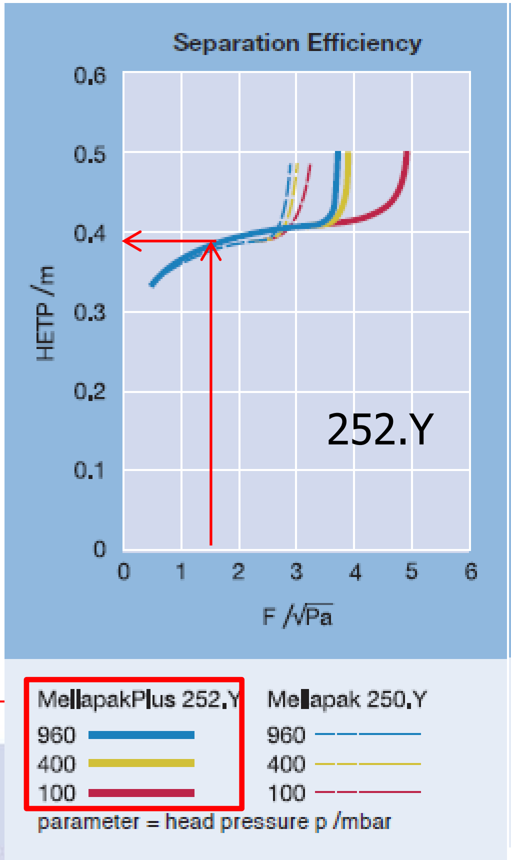
After

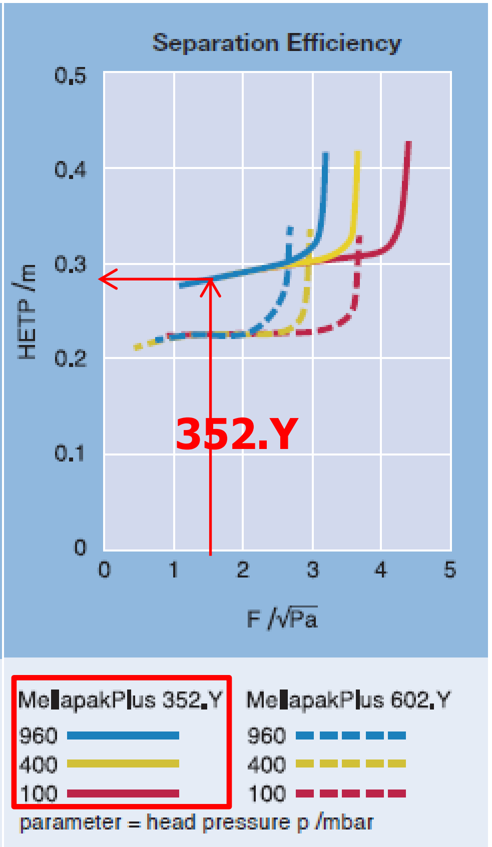


Simplify diagram / Plot plan / Drawing

Change from 252.Y → 352.Y







352.Y required less NTS to achieve the same flow capacity. NTS improvement is about 20%

Note:
HETP = height equivalent to a theoretical plate

3.Cost estimate

Request budget Gate 3 : +/-10%

COST ITEM	DESCRIPTION	TOTAL (THB)	REMARKS
1	**ENGINEERING**	**2,500,000**	Licensor process design fee
2	**PROCUREMENT**	**21,190,400**	
2.1	EQUIPMENT	**21,190,400**	Structure Packing INCL. TAX DUTY 10%
2.1.1	MECHANICAL	0	
2.1.2	ELECTRICAL	0	
2.1.3	INSTRUMENT	0	
2.2	BULK MATERIALS	0	
2.2.1	PIPING	0	
2.2.2	ELECTRICAL	0	
2.2.3	INSTRUMENT	0	
3	**CONSTRUCTION**	**19,000,000**	Lump sum price for installation and mobilization work
3.1	CIVIL WORK	0	
3.2	PIPING WORK	0	
3.3	ELECTRICAL WORK	0	
3.4	INSTRUMENT WORK	0	
3.5	PROJECT MANAGEMENT , SUPERVISION AND TAX DUTY	**0**	
4	**COMMISSIONING / RUN-IN & START-UP / WARRANTY**	**0**	
5	**OWNER COST**	**500,000**	FAT/Inspection
6	**CONTINGENCY (10%)**	**4,319,040**	INCL. FORWARD ESCALATION
	OVERALL PROJECT COST	**47,509,440**	

Benefit Calculation & Assumption

Basic Assumptions		
Price Assumption:		
Feed/Product	-	THB/Unit
Utility (steam)	*980*	THB/Unit
Others (i.e. Land Cost)	-	THB/Unit
Financial:		
Project Life Time / Depreciation	*20*	Years
Terminal Value @Year 20	*5 Time of EBITDA*	
Equity	*XXX*	%
Interest Loan Rate*	*5.5*	%
WACC	*9.39*	%
FX Rate	*Corporate Assumption*	THB/$
Tax	*20*	%
CPI	*Corporate Assumption*	%
Contingency Cost	*10*	%
Others:		
Operating Days	*330*	Days/Year
Maintenance	*2*	% of Investment Cost
Insurance	*1*	% of Investment Cost

* Include Interest During Construction / Working Capital Interest /Short term Loan

Benefit Calculation & Assumption

**Benefit are calculated from steam saving by 4.05 ton/h after revamping.
Steam cost 980 THB/ton, base on 330 operating days, Steam saving cost is 31.43 MTHB/year |** See back-up slide

Benefit Calculation		
Investment	47,509,440	THB
Benefit	31.43	MTHB/Year
IRR @ 20 Years	62.29	%
NPV@ WACC %	178,001,671	MTHB
Simple Payback	1.51	Years
EBITDA (Avg.)	N/A	MTHB
J-Factor:	N/A	

4.Benefit and Project justification

2.2) Growth or Core uplift or Business As Usual (Energy & Reliability) Project Categorization	
Total Investment Cost (฿)	47,509,440
Project Starting Year	2016
Project Completion Year	2017
Residual Value (฿)	-
Utilities (฿/year)	
Labour (฿/year)	
Maintenance (% of total investment cost)	0.0%
Catalyst & Chemicals (฿/year)	-
Benefits (฿/year)	31,434,480
Profit (฿/year)	**31,434,480**
Simple Payback (Year)	**1.51**
IRR	**62.29%**
NPV	**178,001,671**

Expected benefit calculation

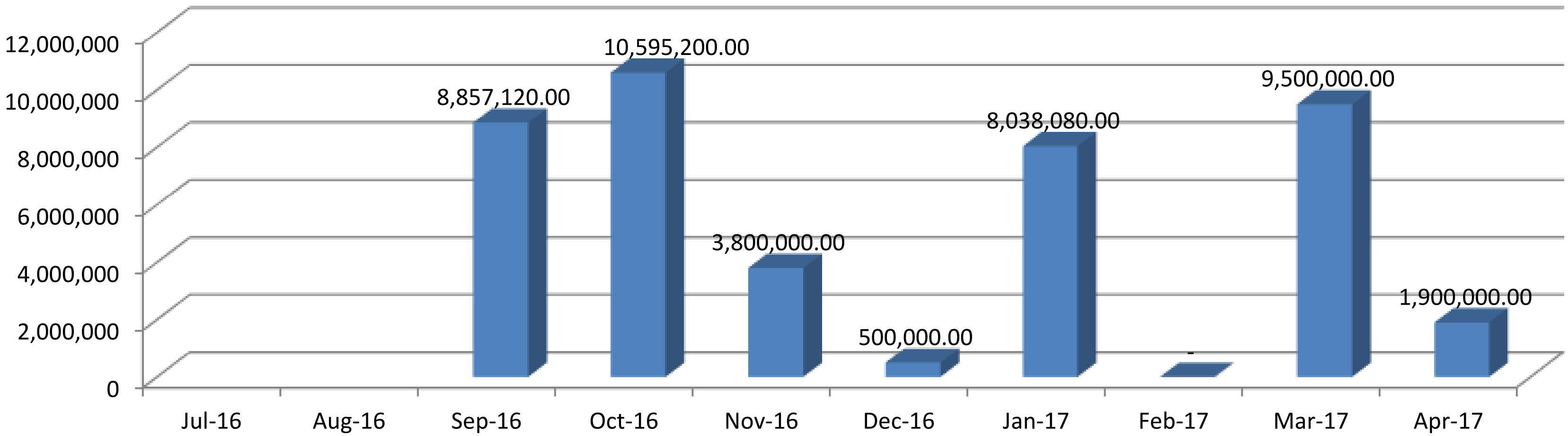
Current basline steam consumption @100% plant rate	81	ton/h
NTS improvement by	20%	(Refer to Sulzer estimation)
Average steam reduction per 10% NTS improvement	5.00%	(5% - 8% of steam reduction per 10% NTS improvement)
Theoritical Steam reduction after improvement	10%	
Theoritical Steam reduction after improvement	8.1	ton/h
Success factor	**50%**	
Steam reduction @ success factor 50%	**4.05**	**ton/h**
Steam cost	980	THB/t
Operating day	330	day/year
Operating hour	7920	hr/year
Annual steam saving	32076	ton/h
Realized steam cost saving	31,434,480.00	THB/y

5.Project schedule

Activity	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 17	Feb 17	Mar 17	Apr 17
Conclusion of budgetary from Sulzer +-50%	24/6/2016									
Sulzer provide detail engineering drawing	4/7/2016									
SD confirm simulation and issued revised datasheet	11/7/2016									
Sulzer give firm price based on SD revised datasheet	18/7/2016									
PIC gate 1	11/7/2016									
HAZOP Review										
Request budget from TOCGC BOD	6/7/2016									
Firm budget ±10% to proposed in PIC gate 3			Clarify technical issue and waiting firm quotation from Sulzer							
PIC gate 3		30/8/2016								
Procurement Committee approval			2 weeks							
Issue PO (Critical milestone)			15/9/2016							
Final drawing from Sulzer			1 month after PO	15/10/2016						
Drawing approval by client				5 days 20/10/2016						
Material Production and delivery (CIF LC port)					3.5 month			No later than 1st week of Feb,2017		
Turnaround Project (Mar 1 – April 15, 2017)									45 day	
Dismantle/Installation									24 day	
Mechanical complete									31/3/2017	
Performance Test										April 17

6.Project cash flow

Total Budget 47.5 MTHB



Month		Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17
Project Cash Flow				8,857,120.00	10,595,200.00	3,800,000.00	500,000.00	8,038,080.00	-	9,500,000.00	1,900,000.00
SD Design Fee	**2,500,000.00**			2,500,000.00							
Material cost (include Tax 10%)	**21,190,400.00**										
Upon order, payment by T/T latest 30 days from date of invoice.	30%			6,357,120.00							
Upon first submission of engineering drawings for approval. L/C to be issued within 4 weeks after order confirmation.	50%				10,595,200.00						
upon readiness of goods. L/C to be issued 2 months before contractual delivery date.	20%							4,238,080.00			
FAT and Inspection	**500,000.00**						500,000.00				
Installation cost	**19,000,000.00**										
Payable after award	20%					3,800,000.00					
Payable after mobilization&training	20%							3,800,000.00			
Payable after construction work finish	50%									9,500,000.00	
Payble after submission of document	10%										1,900,000.00
Contingency (10%)	**4,269,040.00**										
Total Budgetary	**47,459,440.00**				19,452,320.00			19,438,080.00			
					(19,452,320.00)	-	-	(19,438,080.00)			

7. Risk & Key Success factor

1. Fast-track for budgetary approval before mid of July 2016
2. Process performance guarantee from Licensor
3. On time delivery of material due to tight schedule

Thank you