14th Chemical Process Safety Sharing (CPSS)

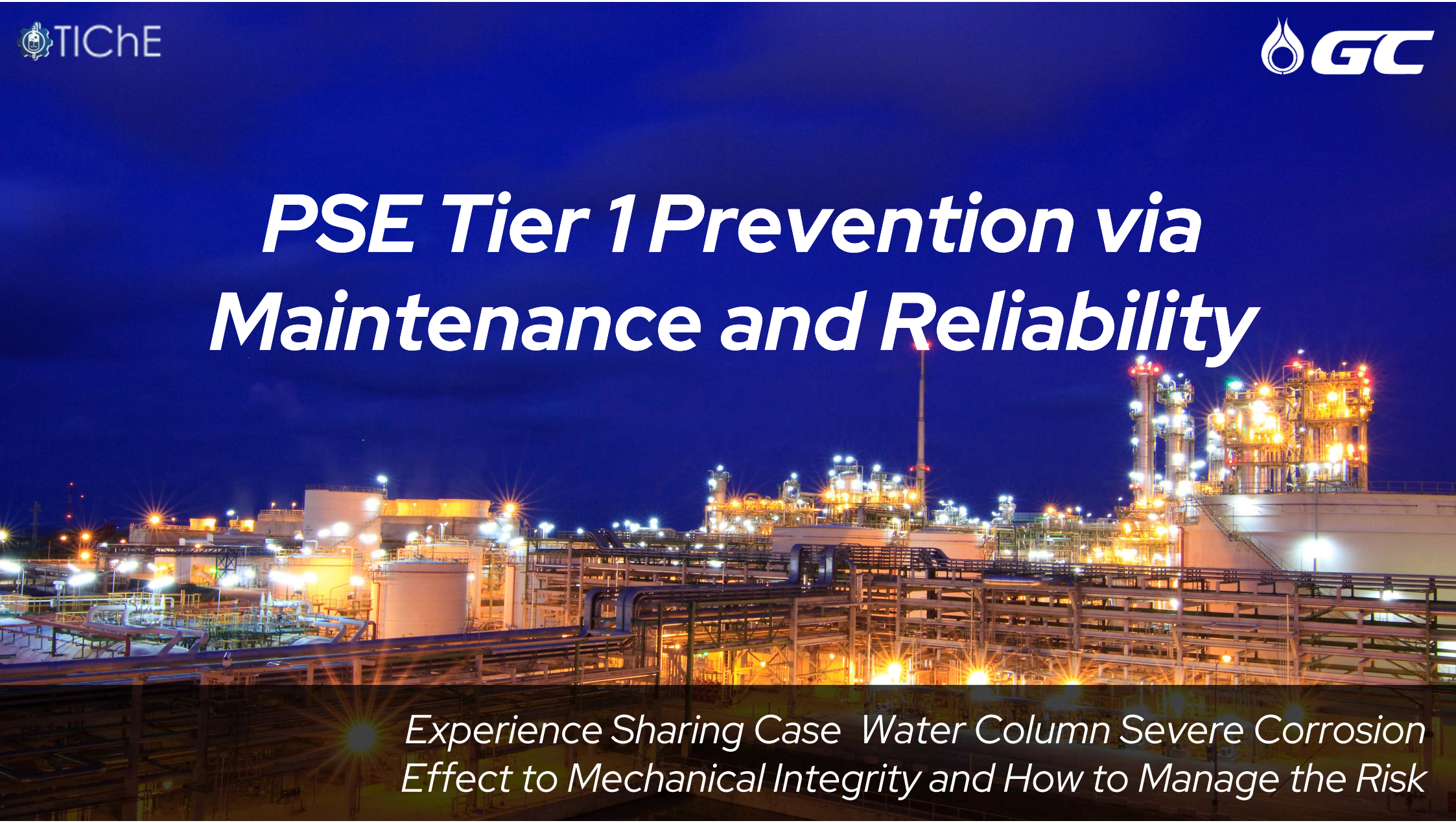
Topic: PSE Tier 1 Prevention via Maintenance and Reliability

Presenter Name: Mr. Prinya Keawdiau

e-mail: Prinya.k@pttgcgroup.com

Company: GC

PTT Global Chemical Public Company Limited



PSE Tier 1 Prevention via Maintenance and Reliability

Experience Sharing Case Water Column Severe Corrosion Effect to Mechanical Integrity and How to Manage the Risk

SPEAKER

Mr. Prinya Keawdiau
(Division Manager)
Reliability and Asset Integrity

Komkrish T
(Senior Mechanic Engineer)

Pakkapol N
(Inspection Engineer)

Matee P
(Inspection Engineer)

Peeradech T
(Division Manager
Process Engineer)

Papinol U
(Process Engineer)

Pijak T
(Corrosion Engineer)

Team Member

AGENDA

1. Background
2. Chronology
3. Finding & Correction
4. Root Cause Failure Analysis
5. Solution & Optional
6. Risk Monitoring
7. Fabrication & Construction
8. Conclusion & Key Takeaway

AGENDA

1 Background

2 Chronology

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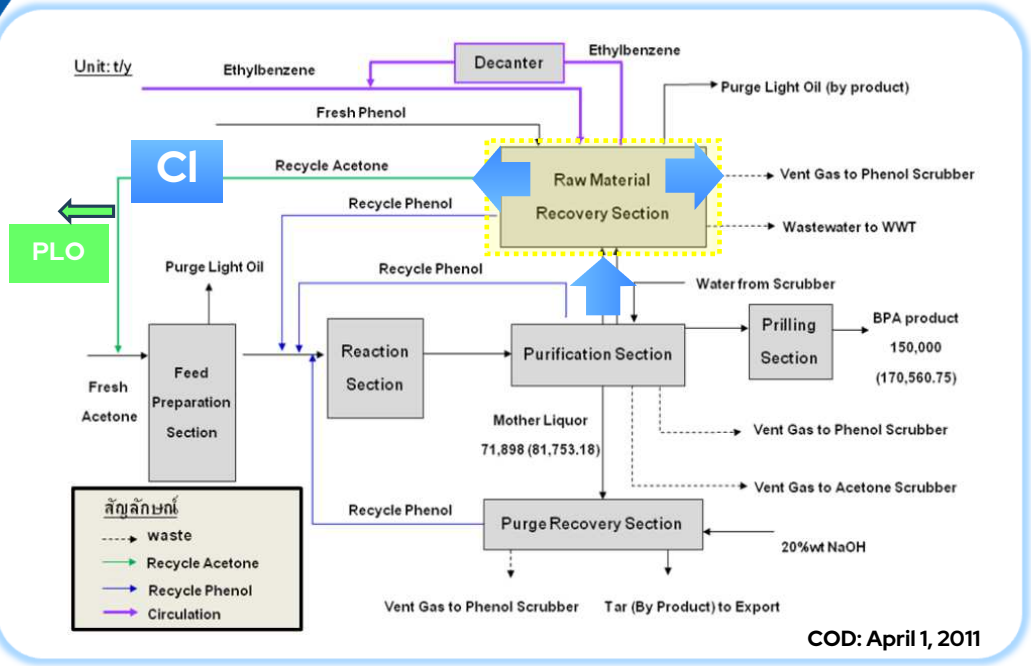
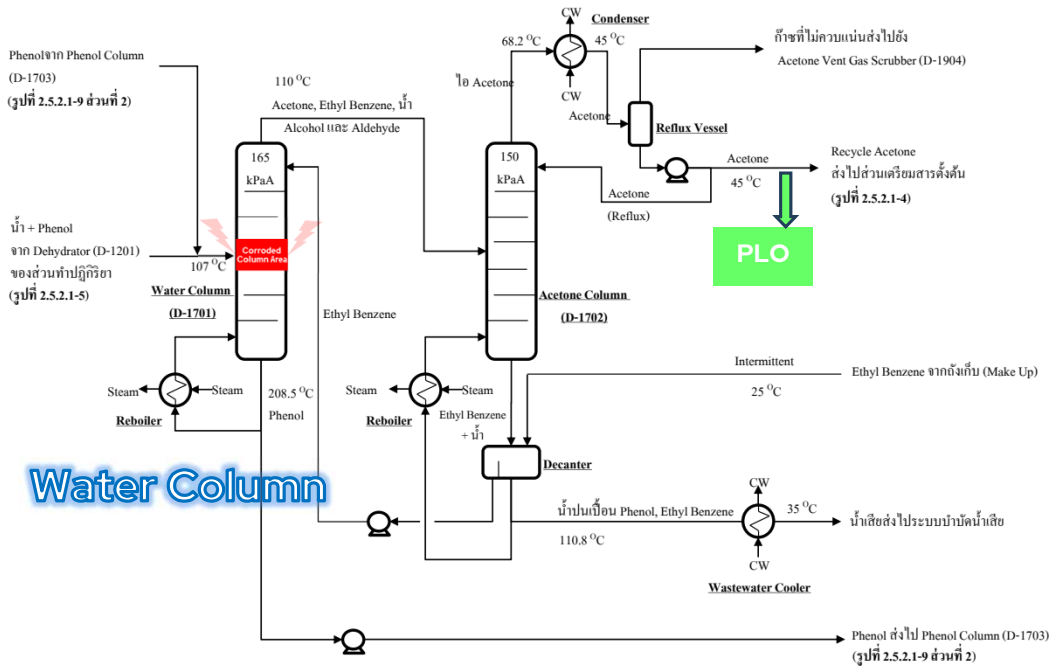
Process Overview





>> Mechanical Design

- *Water Column : Remove water & acetone from Phenol*

Equipment	DESIGN CODE	Design Pressure (kPaG)	Operate Pressure (kPaA)	Design Temperature (°C)	Operate Temperature (°C)	MATERIALS	Stress Relieved
Water Column	ASME SEC VIII DIV.1, 2024 ED	280 / F.V.	TOP : 165 BTM : 199	230	TOP : 110 BTM : 209	TOP : SUS 836L BTM : A240 316L	SHELL : NO HEAD : YES

AGENDA

1 Background

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Chronology

2022 (Aug)

Initial Findings and Actions

Problem Issues:
Severe corrosion and Cracks

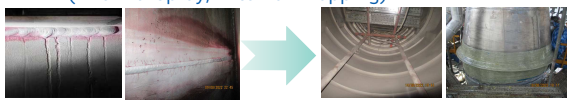
TA 22

Inspection history before TA2022

- **Finding :** Normal condition.

Inspection finding in TA2022

- **Finding :** Severe corrosion and Cracks
- **Repairs :** Replaced trays, applied corrosion protection, and marked cracks for monitoring. (Thermal Spray, External Wrapping)



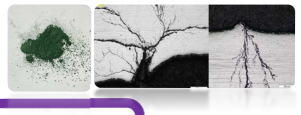
2022 (Sep)

Actions After Turnaround

Set-up
Mitigation Action and Way forward

AFTER TA 22

- **Root Cause Failure Analysis (RCFA) :** Chloride stress corrosion cracking due to reduced light oil purging.
- **Improvement :** Identified missing processes, recommended new column fabrication and upgrades.
- **Set-up Inspection Monitoring Plan :** Monthly Phased Array Ultrasonic Testing (PAUT) revealed crack growth.



Found Crack no. 5 depth Growth

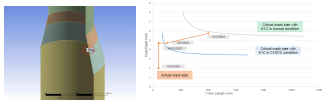
2023 (May)

Monitoring Findings and Actions

Crack Issues: Severe corrosion and cracks found in a column.

ON-STREAM PERIOD 23

- **Risk Finding**
  Crack depth to nearly critical crack size.
- **Risk Assessment & Mitigation Action :**
  Evaluated cracks API RP 579, Part 9 Fitness-for-Service level 3.
- **On-going Monitoring :**
  Monthly PAUT revealed crack growth.



2023 (Aug)

Further Mitigation

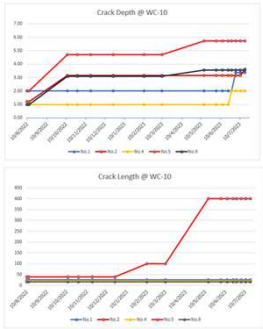
Mini-SD Aug 23
Additional Temporary Support

Mini -SD 23

- **Support Installation :** Added external temporary support, inspected coating, and wrapped cracks.
- **Crack Stability :** Monitored cracks, ensuring they remained within acceptable limits.

Continue PAUT for monitor the crack.

- **Crack status :** Cracks was stable after addition temporary support.



2024 (May)

Final Corrective Actions

New Column Replacement

SD 24

Column Replacement (2024) :

- **Site Preparation :** Addressed heavy lifting space constraints, soil tests, and scaffolding.
- **Objectives Achieved :** Successfully replaced the column with attention to safety, quality, cost, and scheduling.

Final Outcome :

- **Corrective Actions :** New column fabrication and upgrade from tray 28 to tray 41.
- **Result :** Ensured planned risk management and operational integrity, with the new column successfully installed by May 2024.

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1 Background

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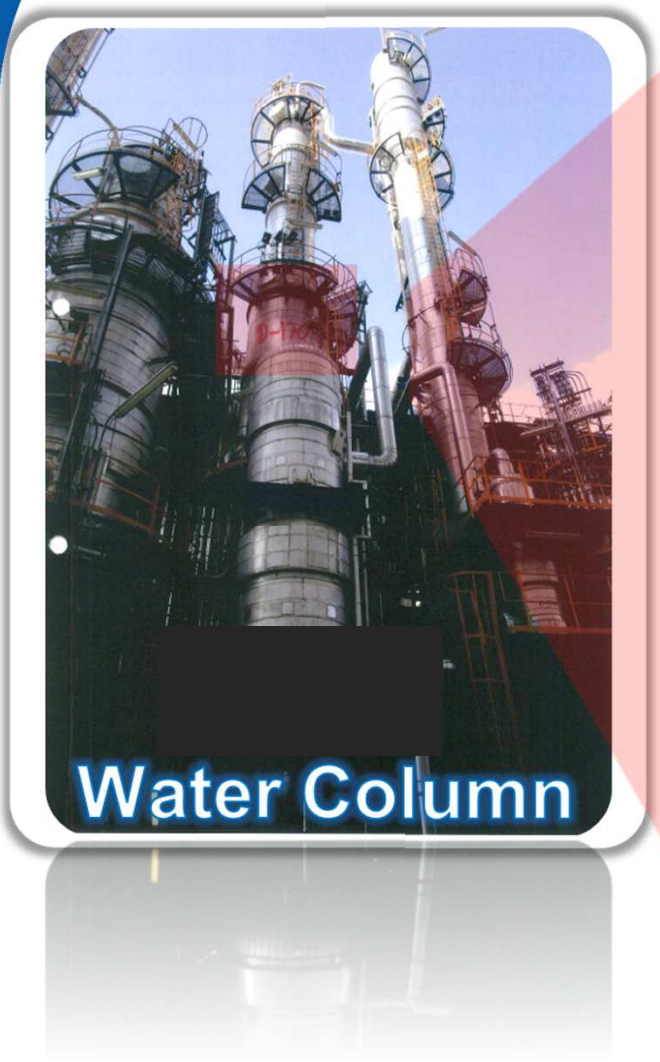
7 Fabrication & Construction

8 Conclusion & Key take a way

Column Damaged Appearance (during T/A 22)



>> Cl accumulation in system

High HCl (Acid) → corrosion → Column Corrosion

1 Tray corroded/damaged 2 Green corrosion product 3 Localized corrosion

Acid is suspected to be a cause

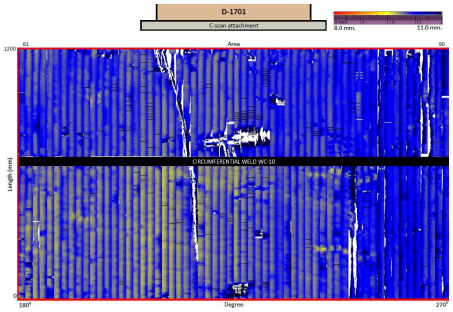
4 Pitting & Cracking *(SCC with branch)*

Chloride species are suspected to be a cause

Inspection Evaluation and Decision Making (during T/A 22)

Metal loss
Thickness measurement by Corrosion mapping

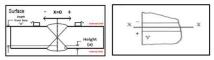
- Minimum thickness is 9.61 mm [10 mm]



Cracking
Crack size measurement by Phase array ultrasonic testing

- WC-10 was founded many cracks.
- Maximum crack depth is 4.71 mm

Joint No.	Thickness (mm.)	Cap Width (mm.)	Indication No.	Basis Offset (mm)	Type of Indication	Distance X-Line	Distance Y-Line	Details of inspection: Height (mm.) 18-Aug-2022	Length (mm.) 18-Aug-2022	Height (mm.) 13-Aug-2022	Length (mm.) 13-Aug-2022	Depth from face "AX" (DA.)	Height (mm.) 25-Oct-2022	Length (mm.) 25-Oct-2022	Growth status	Evaluation	Result
WC-10	10	15	1	Manual	Surface	-35	20	2.00	25.00	2.00	25.00	8.00	2.00	25.00	N	SCC	N/A
	10	15	2	Manual	Surface	-8	830	1.20	20.00	1.20	20.00	8.93	0.13	20.00	Y	SCCTDS	N/A
	10	15	3	Manual	Surface	-8	950	1.00	20.00	1.00	20.00	8.00	1.00	20.00	N	SCCTDS	N/A
	10	15	4	Manual	Surface	-8	1280	1.00	20.00	1.00	20.00	9.00	1.00	20.00	N	SCCTDS	N/A
	10	15	5	Manual	Surface	-8	1450	2.00	40.00	2.00	40.00	5.29	4.71	40.00	Y	SCC	N/A
	10	15	6	Manual	Surface	+25	2710	1.50	20.00	1.50	20.00	8.50	1.50	20.00	N	SCC	N/A
	10	15	7	Manual	Surface	+8	2570	1.00	10.00	1.00	10.00	9.00	1.00	10.00	N	SCC	N/A
	10	15	8	Manual	Surface	-8	2900	2.00	20.00	2.00	20.00	8.00	2.00	20.00	N	SCC	N/A
	10	15	9	Manual	Surface	+8	3040	1.00	15.00	1.00	15.00	8.89	0.11	15.00	Y	SCC	N/A
	10	15	10	Manual	Surface	+45	3190	1.50	15.00	1.50	15.00	8.50	1.50	15.00	N	SCC	N/A
	10	15	11	Manual	Surface	-325	3750	2.00	20.00	2.00	20.00	8.00	2.00	20.00	N	SCCTDS	N/A
	10	15	12	Manual	Surface	-328	4330	2.00	25.00	2.00	25.00	8.00	2.00	25.00	N	SCCTDS	N/A
	10	15	13	Manual	Surface	+8	4530	2.00	15.00	2.00	15.00	8.00	2.00	15.00	N	SCCTDS	N/A



Before TSA | After TSA | First monitoring

Cracks size comparison

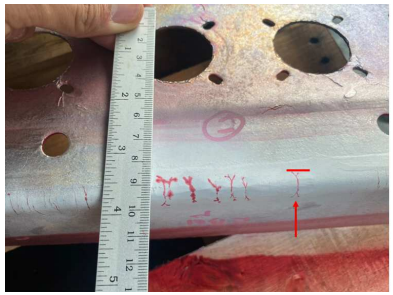
Repairing Method (Optional)

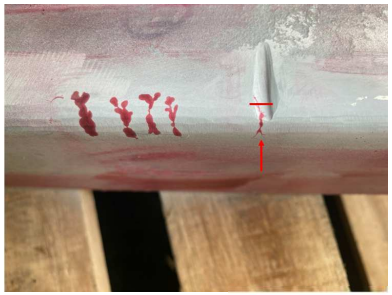
GC specialists had recommended method in repairing based on experience and confirm with simulation welding & griding on SCC sample work piece.

- Heat input from welding generate existing crack growth and small pitting.

Pitting & SCC	Grinding & PT before weld	PT After weld overlay
		

- Griding induced crack propagation.





Judgement Criteria

To operate

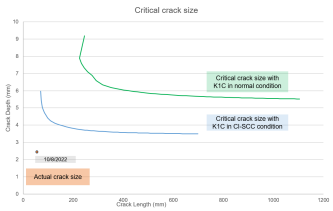
- **Metal loss**

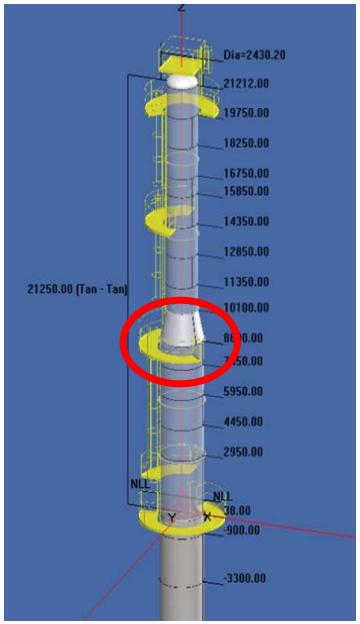
➢ The minimum shell section thickness requires **3.86 mm at the conical transition section**.

**** Included Internal pressure and wind load**

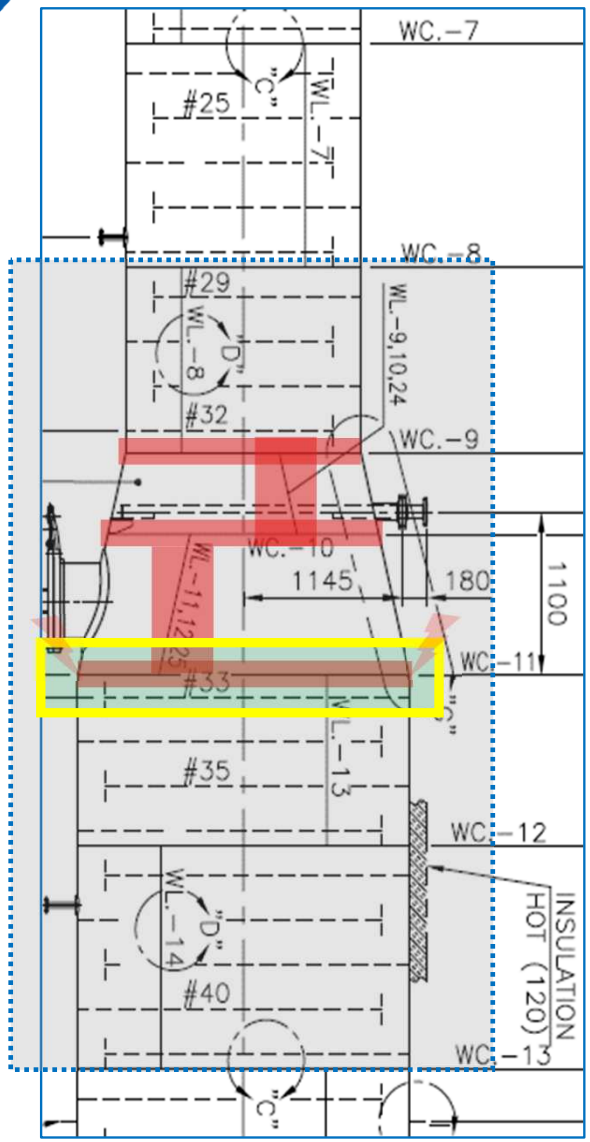
- **Cracking**

➢ The maximum crack **(depth)** shall be **less than Critical crack size**





Mitigation Actions (during BPA T/A 22)



1 Corrosion protection barrier → Internal Thermal spray

- Thermal spray with C276 on internal shell at WC-8 to WC-13

2 Double protection for personal safety → External Wrapping

- At WC-11 (contains cracks)

AGENDA

1 Background

2 Chronology

3 Finding & Correction

4 **Root Cause Failure Analysis**

5 Solution & Optional

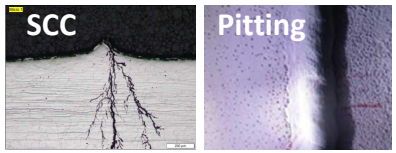
6 Risk Monitoring

7 Fabrication & Construction

8 Conclusion & Key Takeaway

Root Cause Failure Analysis

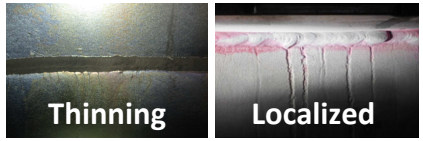
Chloride (Key factor for Cl cracking)



Physical | Significant Event | Human | Observation | System | Hypothesis

Tray and Column Damaged (By inspection in T/A Aug.22)

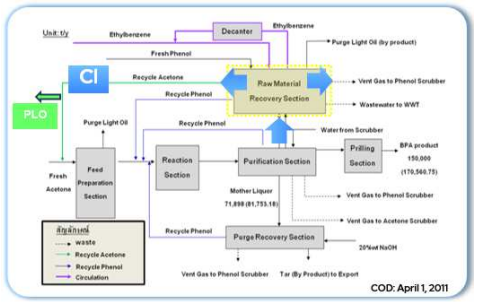
1. **S**tress **C**orrosion **C**racking and **P**itting **C**orrosion
2. **T**hinning and **L**ocalized **C**orrosion

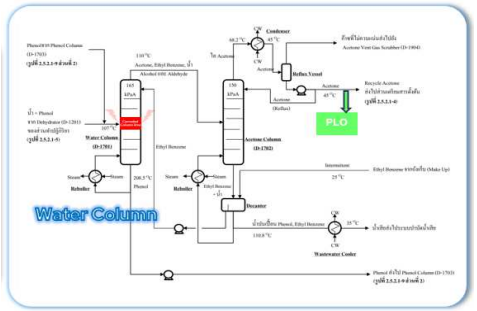


From Non-oxidizing acid (such as diluted sulfuric acid, HCl, sulfurous acid, etc.)

Process Operation

- Abnormal Operation ✗
- MOCs 2018-2022 ✗
- High Cl accumulation in reflux drums
  - HCl formation from high Cl content ✓
    - Action: Control Cl content in BPA process
  - Inadequate Cl purging from system ✓
    - Impact from PLO optimization project
      - Action:
        - TK-1251/TK-1351 pH monitoring during S/D & S/U
        - Monitor acid and balance acid purge to prevent accumulation
        - Confirm limitation of acidity conc [pH] to not impact D-1701 material
        - Lab Analysis on pH value for trend
      - Not aware about Chloride accumulation after reducing purge light oil.
        - Ineffectiveness of optimization system affects to equipment corrosion.





Strengthen Chloride Awareness

1 Operating Guideline: Control Methanol & Chloride content in process

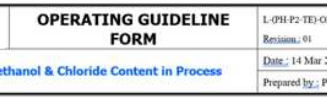
OPERATING GUIDELINE FORM	L-(PH-P2-TE)-OPG-ISBL-58
	Revision : 01
Control Methanol & Chloride Content in Process	Date : 14 Mar 2023
	Prepared by : Pakpoom P.

1)ที่มาและความสำคัญ (Background)

หนึ่งในสาเหตุที่ก่อให้เกิดปัญหาต่อง S/D BPA plant เร็วกว่าแผนที่วางไว้คือ catalyst performance ที่ main reactor R-1201A/B ลดลงเร็วกว่าที่คาดการณ์ไว้ ซึ่งสาเหตุหลักจะเกิดจาก catalyst poisoning จาก methanol content ที่เข้า reactor โดย methanol มาจากทั้ง Feed acetone ที่ TK-1111 รวมถึง recycle acetone ที่มาจาก TK-1701

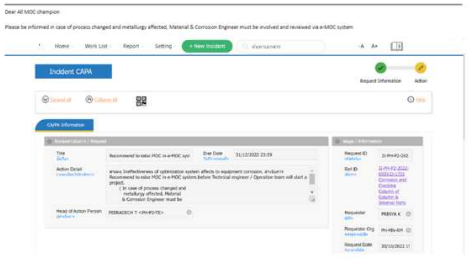
Poisoning

1. Methanol, Aldehydes and other alcohols in acetone



นอกจากนี้จากปัญหา equipment damage จาก corrosion ที่เกิดจากการสะสมของ Chloride ใน process และเริ่มพบความเสียหายของ material ที่ D-1702, D-1701, E-1705 จึงต้องมีการเพิ่ม purge Cl ที่ TK-1701 เพื่อป้องกันไม่ให้เกิดการสะสมของ Cl ในระบบ ซึ่งอาจนำไปสู่ equipment damage from corrosion

2 Raise awareness about MOC system



F-(PH-P2-OP)-P-(PH-P2-OP)-001-015 :บันทึกการฝึกอบรมทบทวนและสื่อความภายใน

บันทึกการฝึกอบรม ทบทวน และสื่อความภายใน

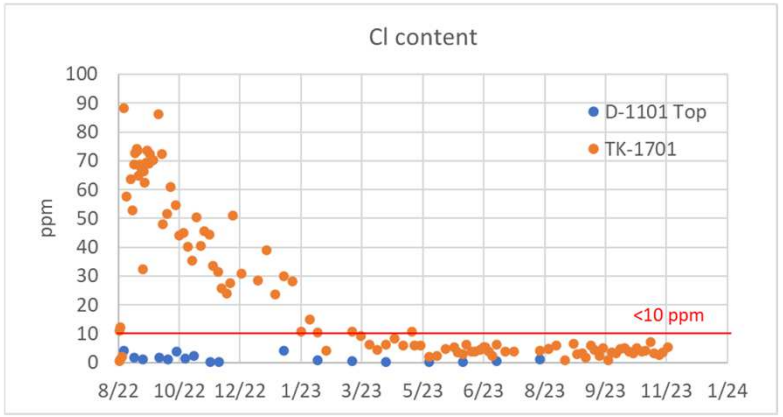
เรื่องที่อบรมและทบทวน : **[IIS , Notify] - Weekly Summary Table for Action of Incident (Plant : PH-P2)**

วัตถุประสงค์ : ให้ทราบถึงขั้นตอนการปฏิบัติงาน และให้เป็นไปในทิศทางเดียวกัน

Shift	ID.no	รายชื่อ	ครั้งที่ ..... ลายเซ็นต์	วันที่	หมายเหตุ
A					
B					

3 Training by T-II-MC about SCC and Corrosion

4 Parameters under condition monitoring : Cl Content



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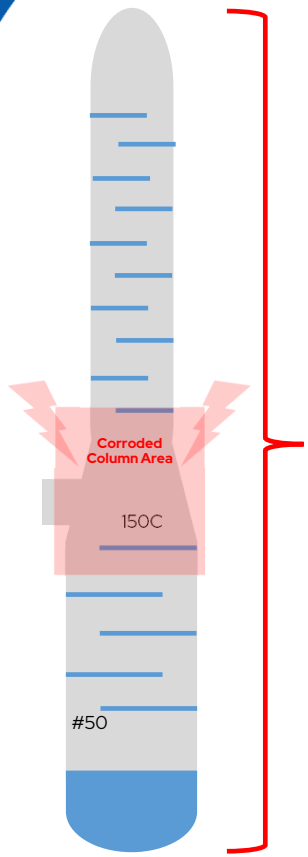
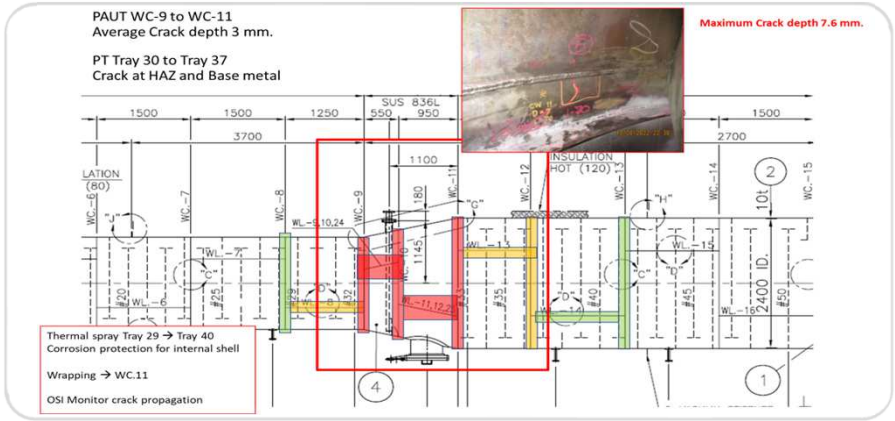
Alternative Solution for Water Column

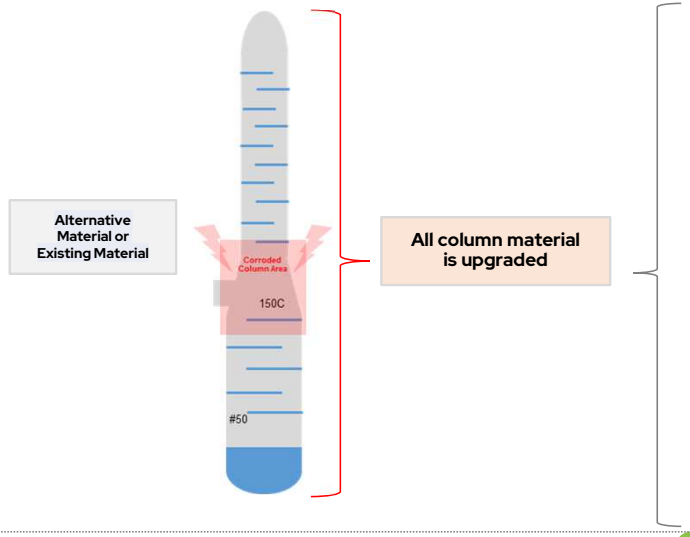


Priority Option	Upgrade Material	Material	Chloride stress corrosion cracking resistance	Pitting Resistance	Corrosion resistance in HCl service	Corrosion resistance in H_2SO_4	Remark
1	Hastelloy C-2000 *(Nickel base alloy)*	Hastelloy C-2000 (Nickel base alloy)	**Nearly immune (Ni > 45 %)	Best *PREN No. = ~ 80 (Superior to Hastelloy C-276)	Better (At concentration < 15 %, CR is five times less than Hastelloy C-276)	Better (CR is five times less than Hastelloy C-276)	Nickel base alloy offer much better resistance over a wide range of acid concentrations and temperature. However even these may be subjected to localized attack under certain conditions.
2	Hastelloy C-276 *(Nickel base alloy)*	Hastelloy C-276 (Nickel base alloy)	**Nearly immune (Ni > 45 %)	Better *PREN No. = ~ 75 (Superior to Inconel 625)	Good (At concentration < 20 %, CR is five times less than Inconel 625)	Good (At concentration > 50%, CR is five times less than Inconel 625)	
3	Inconel 625 *(Nickel base alloy)*	Inconel 625 (Nickel base alloy)	**Nearly immune (Ni > 45 %)	Good *PREN No. = ~ 51 (Superior to Alloy 836L)	Moderate	Moderate	Inconel 625 = existing weldment of D-1701 (ERNiCrMo-3). Corrosion was found at some area of weldment.
4 *Original Design*	Alloy 836L *(Super Austenitic stainless steel)*	Alloy 836L (Super Austenitic stainless steel)	Susceptible (Ni = 24 %)	*PREN No. = ~ 47	Corrosion resistance of super austenitic stainless steel is lower than nickel base alloy		
5 *Optimize*	**Alloy 836L + C-276** *(Upgrade Area : Tray 28 – 41 & WC8 – WC13)*						

- **Selection Column material upgraded**
- **Alternative Material or Existing Material**

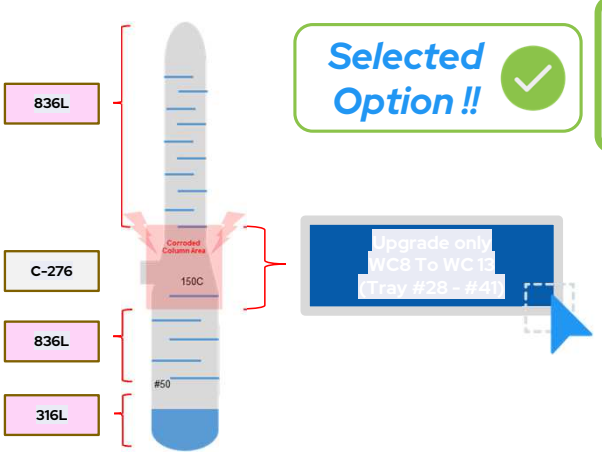


Alternative Solution for Water Column



Priority Option	Upgrade Material	Estimated Cost- Column + Tray & Internal Parts (Price MB)	Delivery Time(Months)
1	**Hastelloy C-2000** *(Nickel base alloy)*	(1)	17 Months (Material 12 Months) — Procurement 5 months (Nov22 – Mar23) → Engineering & Fabrication 17 months (Apr23 – Sep24) → Construction 21 Days (Oct24)
2	**Hastelloy C-276** *(Nickel base alloy)*	(2)	17 Months (Material 12 Months) — Procurement 5 months (Nov22 – Mar23) → Engineering & Fabrication 17 months (Apr23 – Sep24) → Construction 21 Days (Oct24)
3	**Inconel 625** *(Nickel base alloy)*	(3)	14 Months (Material 9 Months) — Procurement 5 months (Nov22 – Mar23) → Engineering & Fabrication 14 months (Apr23 – Jun24) → Construction 21 Days (Jul24)
4 *Original Design*	**Alloy 836L** *(Super Austenitic stainless steel)*	(4)	13 Months (Material 8 Months) — Procurement 5 months (Nov22 – Mar23) → Engineering & Fabrication 13 months (Apr23 – May24) → Construction 21 Days (Jun24)
5 *Optimize*	**Alloy 836L + C-276** *(Upgrade Area : Tray 28 – 41 & WC8 – WC13)*	(5)	17 Months (Material 12 Months) — Procurement 5 months (Nov22 – Mar23) → Engineering & Fabrication 17 months (Apr23 – Sep24) → Construction 21 Days (Oct24)

(1) – (5)
Minimum 100 MB up !



Selected Option !!

Upgrade only WC8 To WC 13 (Tray #28 - #41)

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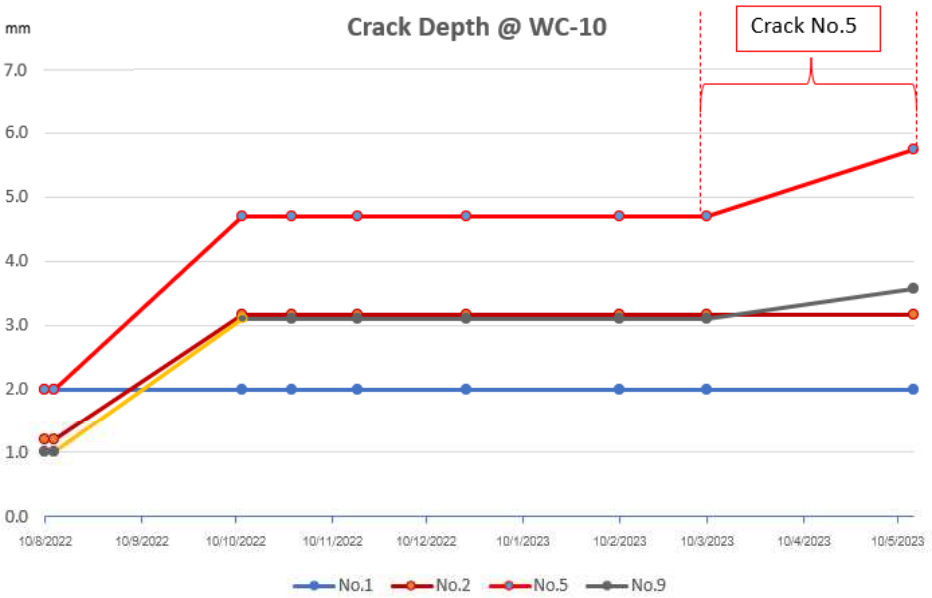
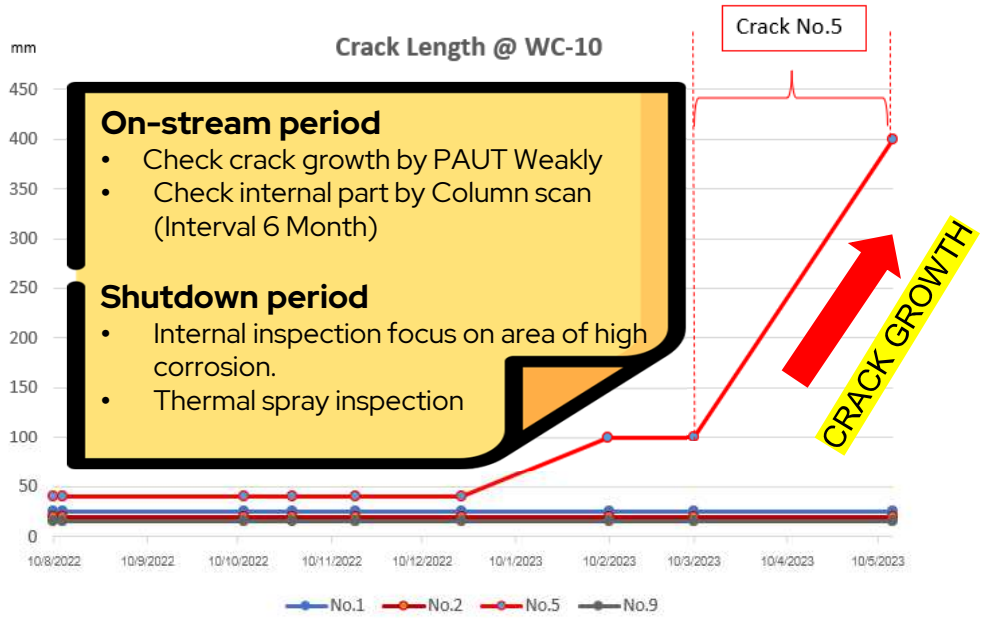
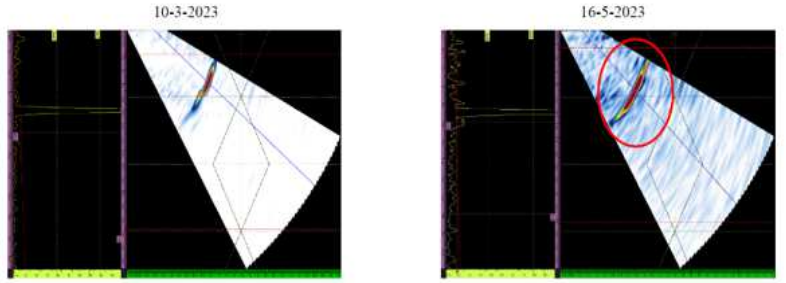
Risk Monitoring & Crack depth growth

Inspection Monitor during OSI 2023 for D-1701

Updated on 23-May-23







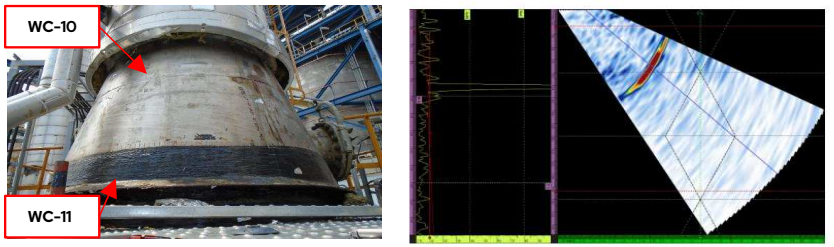
PHASED ARRAY ULTRASONIC TESTING SIGNAL OF WC-10 INDICATION NO.5

Phased Array Ultrasonic Testing Report on WC-09, 10

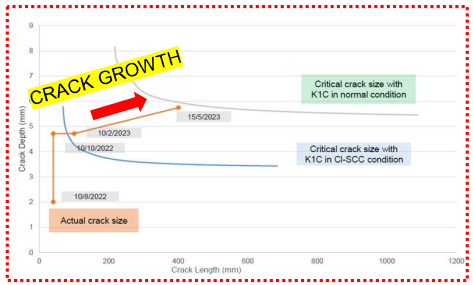
Risk Monitoring & Risk Mitigation

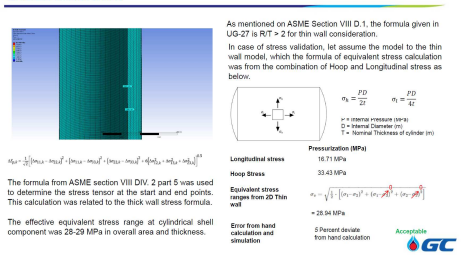
After 1 year of operating the distillation tower D-1701, it was found that the crack size at WC-10 exceeded the critical crack size based on the Fitness-for-Service (FFS) assessment.

-> **Risk Mitigation** by applying & installation the temporary support, external wrapping.

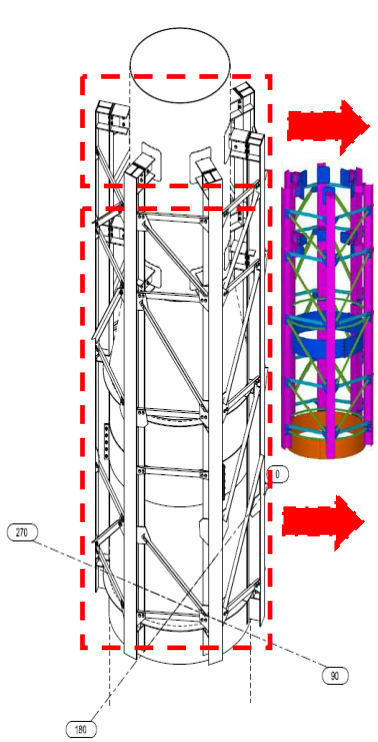


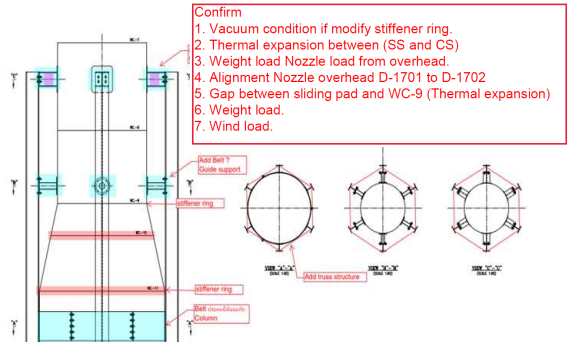
1. Phase array UT to monitor the cracks found some point were growth





2. Fitness for service applied to evaluate the condition By Corrosion Engineer PTTGC





3. D-1701 temporary support, external wrapping
- Protect column collapse

AGENDA

1. Background
2. Chronology
3. Finding & Correction
4. Root Cause Failure Analysis
5. Solution & Optional
6. Risk Monitoring
7. **Fabrication & Construction**
8. Conclusion & Key Takeaway

RISK ASSESSMENT

- Risk Assessment workshop was conducted on 23rd of Feb.
- The Risk Migration task will be followed up and close before execution. Below is a high severity risk from the assessment.

8	Construction					
a	Delay to complete dismantle and re-install for related component (D-1701, structure, Piping, E&I) in T/A period.	C/T/Q	2	5	M	Set up project schedule to follow up progress with plan. Hiring experienced subcontractor to execute and 2 shifts shall considered.
b	New internal tray of D-1701 cannot install on new column D-1701.	C/T/Q	2	5	M	Review and comment vendor print from vendor to follow with new column layout. Re-check dimension at Vendor workshop before delivery to site.
c	New internal tray of D-1701 installation incorrect layout and may effect to performance of process.	C/T/Q	2	5	M	Review and comment vendor print from vendor to follow with existing internal tray layout and hiring vendor inspector to inspect and accept at site when installation.
d	Laydown area for new column D-1701 nearly with existing location to prevent more lifting and transportation.	C/T	2	3	M	Clarify and request Owner for laydown all equipment on road in front of existing location.
e	Existing road cannot carry load from heavy lifting.	C/T/Q	2	3	M	Site survey and prepare lifting plan. Confirm calculation for existing road and related paving with operation load. Compact area with gravel and crane base plate for temporary lifting area.
f	New D-1701 transportation on obstruction.	C/T	2	3	M	Transportation survey and prepare procedure.
g	Dismantle existing column D-1701 with safe condition.	C/T/Q	2	5	M	Intent to review method statement of works and confirm calculation with weld existing support structure to existing column D-1701 to ensure that column not failure from existing crack point. Confirm calculation for lifting lug, new lug maybe required. Protect internal part drop from existing D-1701 while lifting.
h	New column D-1701 cannot install on existing bolting layout foundation and lost time to prepare new padding.	C/T/Q	2	5	M	Review existing MDR to ensure existing bolting layout match with as-built drawing layout. Verify at site by demolish some part of fire proof to ensure sizing and layout match with as-built drawing layout. Prepare JMS, materials, manpower, machine and other required for shipping existing concrete padding and prepare new padding with leveling. Select suitable grouting concrete grade (24hr for cureing time) to prepare new padding for reduce curing time of concrete. In case of as found existing foundation damaged, suitable concrete grade (24hr for cureing time), form work shall prepared.

New column & Tray Fabrication (Replacement Project)

Top head Fit-up

Shell nozzle fit-up / welding

Tray support welding

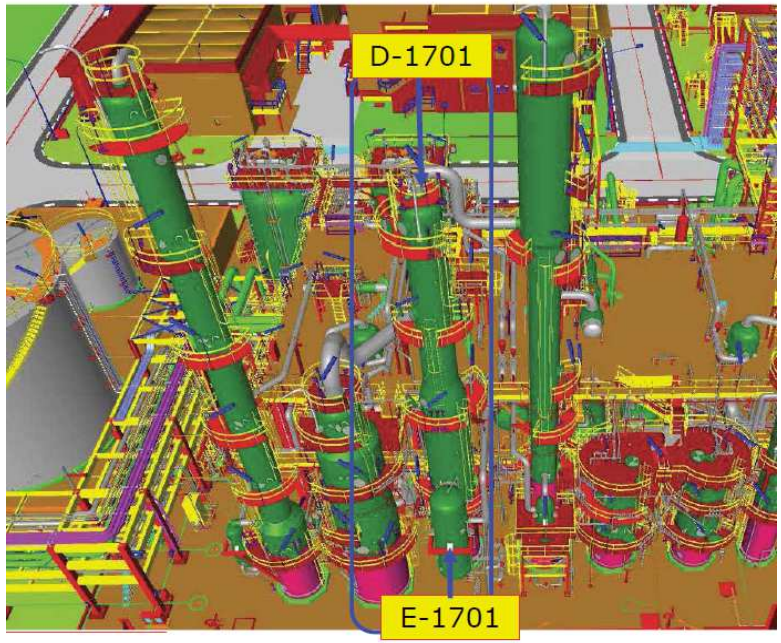
Foundation Plate

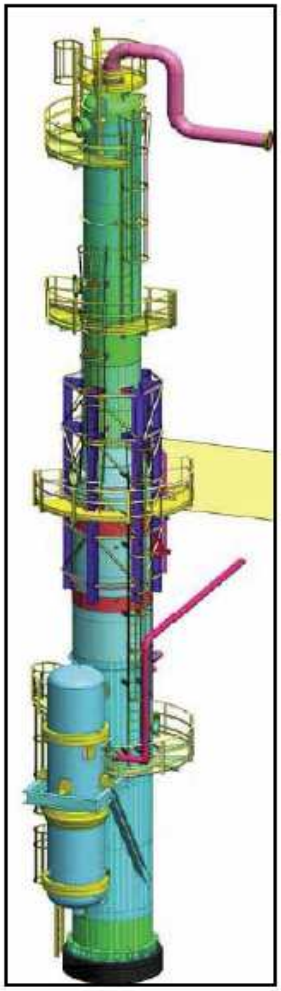
Tray Assembly

COLUMN REPLACEMENT METHOD [1/5]

WATER COLUMN

- Design Pressure : 280 kPaG. / FV.
- Diameter : 1700 x 2400 mm.
- Material (Top/Bottom) : SUS 836L / SS316L
- Height : 21,250 + 7,000 (Skirt)
- Total Weight : 23.35 T.
- Internal Trays : #1 – #50

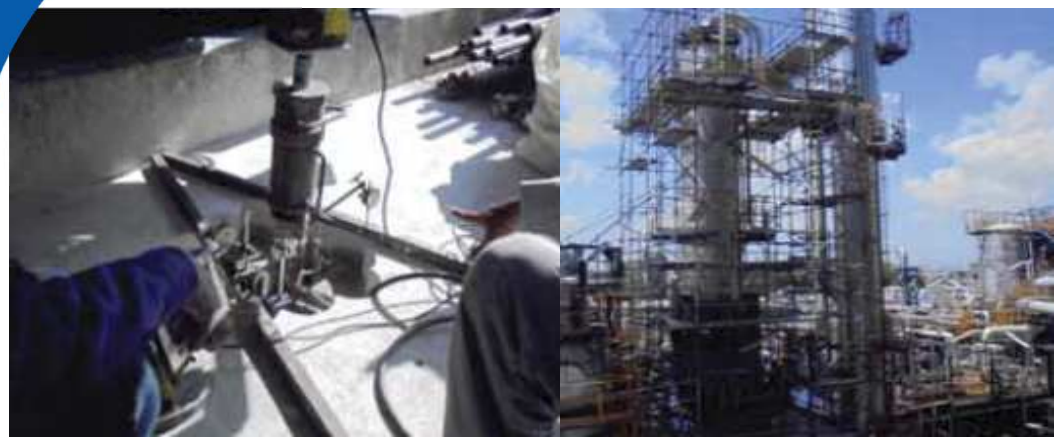




3D Water Column Drawing

Water Column AT SITE

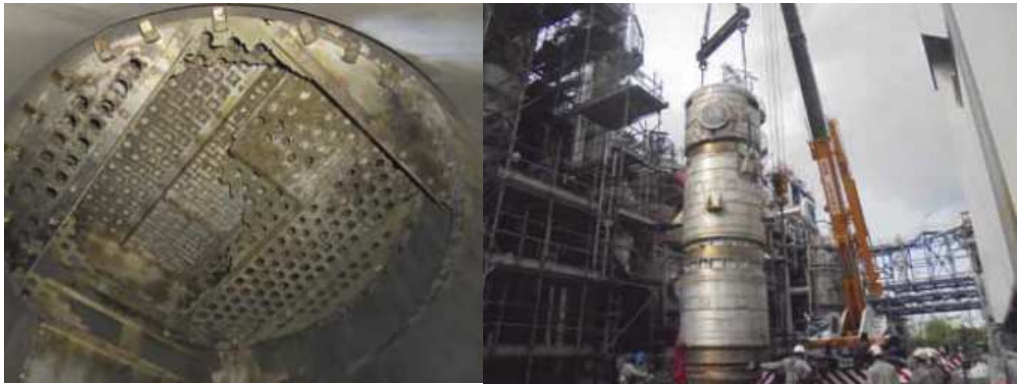
COLUMN REPLACEMENT METHOD [1/5]



Site Preparation : Soil Test and Scaffolding installation

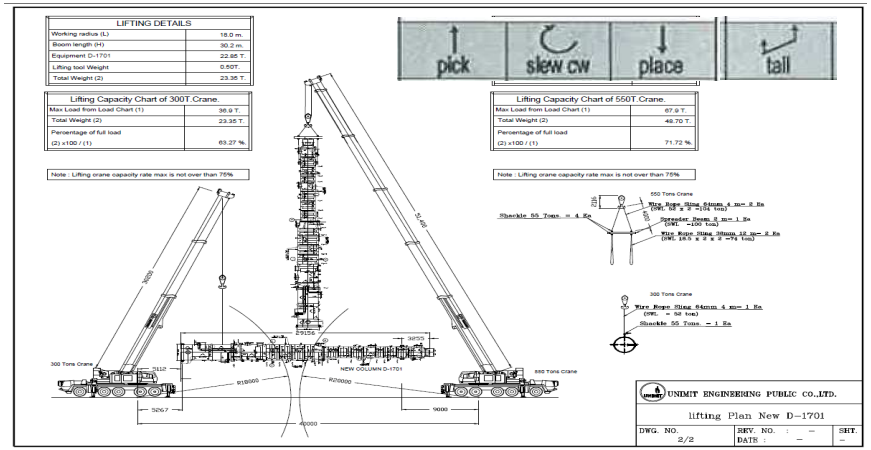
Lifting Preparation : NDE Lifting Eq. and Weld external support

Site Preparation : Rigger plate preparation and plumbness check

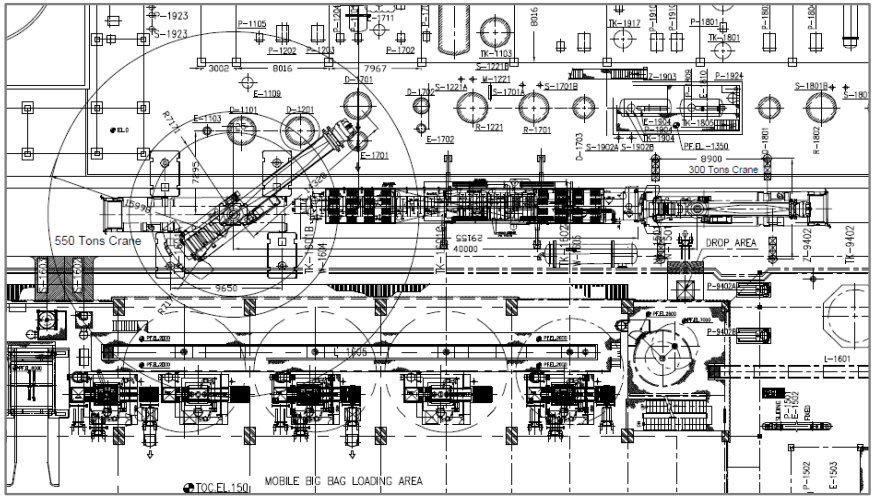


Execution : Actual condition before lifting and demolish E-1701

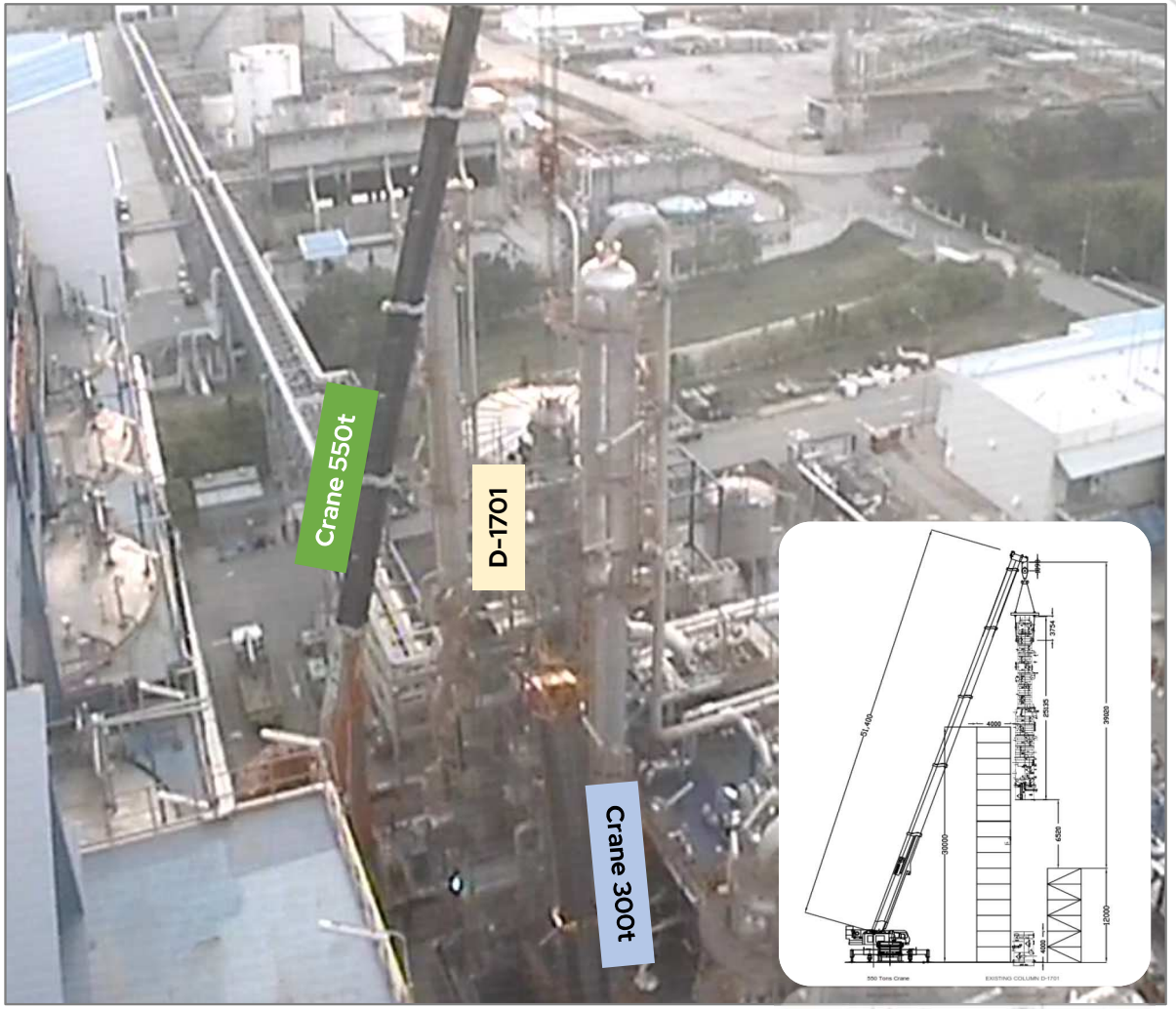
COLUMN REPLACEMENT METHOD [2/5]



Lifting Plan : Pick and Tail (550t + 300t)



Crane Location : Road W = 6.0 M.



Lifting Arrangement : Separate column and skirt

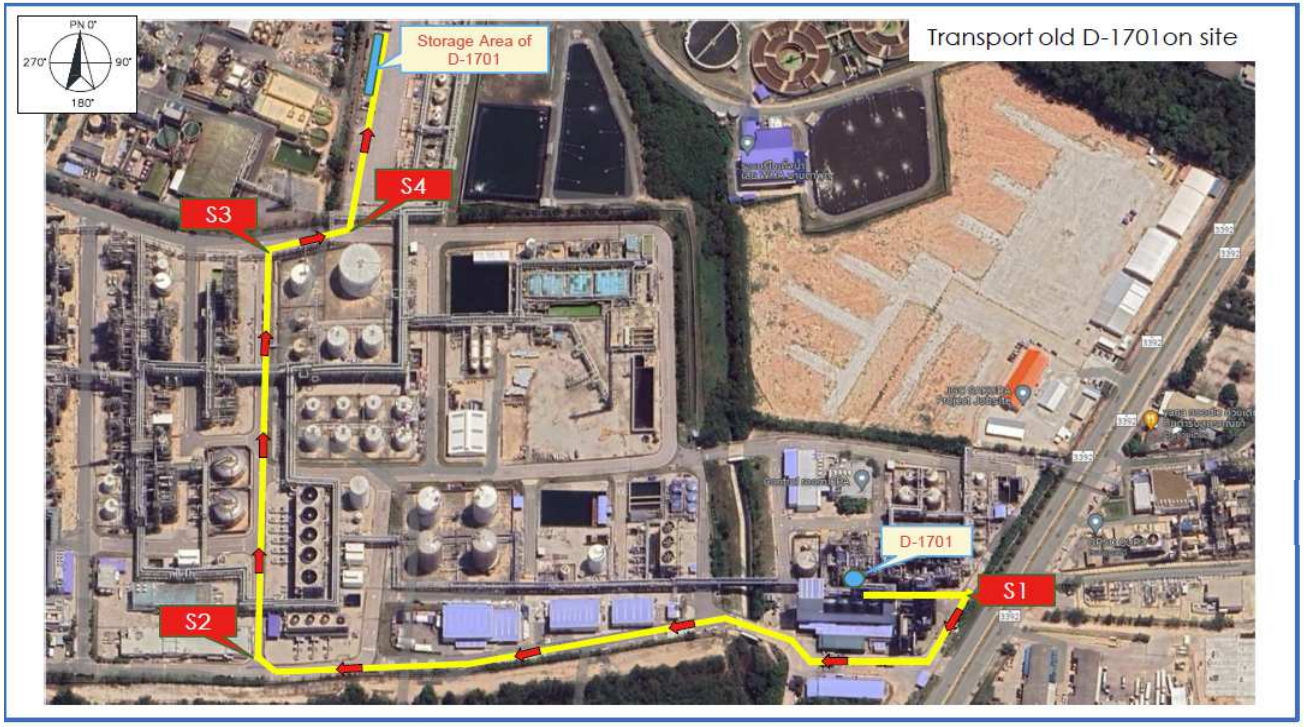
COLUMN REPLACEMENT METHOD [3/5]

Existing column Removal : Focus to avoid anchor bolt and padding damage

Padding and anchor bolt inspection :
To Ensure bolt arrangement and pad leveling

Foundation Preparation

COLUMN REPLACEMENT METHOD [4/5]



Transportation : Old Column to Phenol scrap yard

Transportation : New Column Available on Site

OLD D-1701 WATER COLUMN (TOP SECTION)

COLUMN REPLACEMENT METHOD [5/5]

New Column Installation

E-1701 Re-Installation and Internal tray final inspection

Column vertical alignment inspection

Grouting and Fireproof

AGENDA

1 Background

2 Chronology

3 Finding & Correction

4 Root Cause Failure Analysis

5 Solution & Optional

6 Risk Monitoring

7 Fabrication & Construction

8 Conclusion & Key Takeaway

Conclusion

- Risk Management is important for helps organization & company
  - 1.1 Minimizes losses
  - 1.2 Enhances decision-making
  - 1.3 Ensures compliance
  - 1.4 Protects reputation
  - 1.5 Promotes long-term operational & financial stability
  - 1.6 Optimizes Resource Allocation
- Inspection is one of the best tool available to find problem and assess static equipment risks before accidents and other losses occur.
- Fitness-for-Service is technique to analyze inspection results and decision-making tool in operating or shutdown the plant for repairing.
- Expand the result of Stress Corrosion Cracking (SCC) problem by setting SCC Condition Monitoring Plan for the other piping and equipment.
- Review and Re-assessment of failure modes and consequence in RBI Program.

Key Takeaway

- Multidiscipline team including specialist and top management supporting are accountability to decide based on risk evaluation, risk control and risk monitoring.
- Effective Monitoring (PAUT) and Analysis Technique (Fit for Service) are required to response with the change during plant operation.
- Root Cause Failure Analysis (RCFA) is a systematic process aimed at identifying the underlying causes of failures, including physical, human, and system factors, to ensure a thorough understanding and effective solutions.
- Chloride awareness shall be considered refers to the corrosion of metals, particularly austenitic stainless steels. This is a significant concern in environments in chemical processing plants.

TIChE

GC

THANK YOU

QUESTION & ANSWER

Thank you for your attention

Topic: PSE Tier 1 Prevention via Maintenance and Reliability

Experience Sharing Case Column Severe Corrosion
Effect to Mechanical Integrity and How to Manage the Risk