OpEx Shared Practice & Applied Practice

ชื่อโครงการ: Corrosion under Insulation (CUI) Mitigation and Management System

บริษัท: PTTEP

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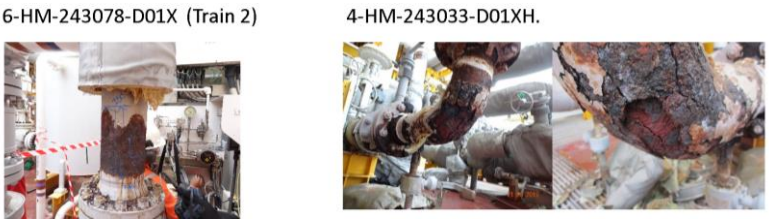
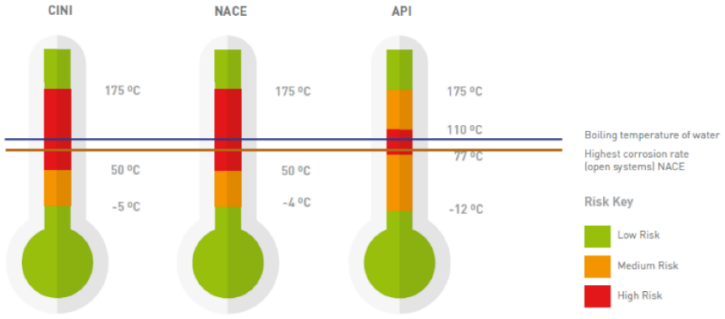
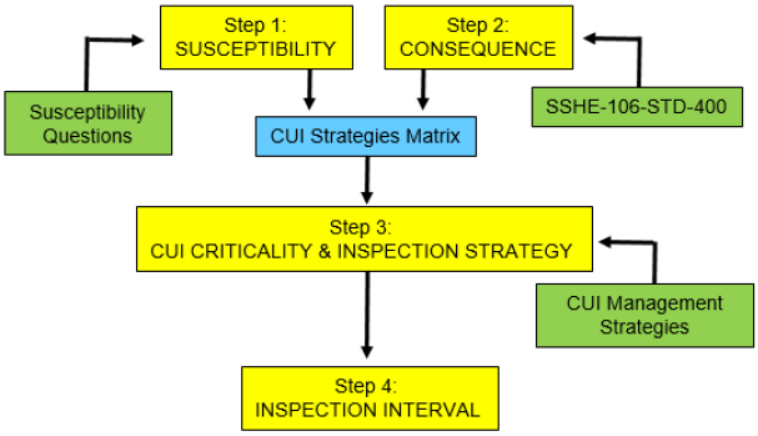
1. Project Details

No.	Title	Details
1	Project Name*	(English*) Corrosion under Insulation (CUI) Mitigation and Management System (Thai) การติดตั้งเครื่องวัดอัตราการไหลแบบหลายเฟสสำหรับการวัดอัตราการไหลของหลุมผลิตผลิตที่แหล่งบงกชเหนือและบงกชใต้
2	Objective*	Corrosion Under Insulation (CUI) is a serious corrosion threat experienced in piping and pressure vessel equipment installed insulation, leading to piping and pressure vessel failure, loss of containment and unexpected plant shutdown. The proper mitigation and complete solutions for CUI problem should be reviewed and developed under current operating conditions of PTTEP asset to provide holistic management system to prevent CUI threats and its drastic consequences.
	Project Type	○ Operation ◉ Operation-support
3	Executive Summary*	• CUI Management system tackles CUI issues for both pressure vessel and piping systems from root causes – water ingress from insulation and coating defects. The study establishes risk matrix and susceptibility evaluation for insulated piping and equipment for assessment in order to remove insulations which manageable operating conditions to completely prevent water ingress problem. It includes inspection technique verification and inspection strategy set-up to suit current operation conditions and provide proactive and preventive inspection program to system for unremovable insulations. This management system will be applied at GBS first for evaluation and then further applied to other assets. • The study and re-assessment provides the list and priority for insulation removal for piping and equipment systems. The list is

No.	Title	Details
		developed by using CUI risk assessment matrix which combined susceptibility and consequences of CUI issue for each piping system referred from corporate susceptibility questionnaires and corporate SSHE standard. The assessment results in 3 categories of CUI issue: Extreme, High and Medium. Extreme category is mainly heating medium system which consists of more than 70 piping lines and set to be the first group to remove insulation. The process performance monitoring after insulation removed is required to confirm the insulated necessity and result will be updated once the plan is executed completely. ● Apart from insulation removal criteria set-up, inspection strategy and technique have also been re-evaluated and developed. Advanced inspection technique called "Pulsed-Eddy Current" has been verified and applied for CUI inspection and scanning which will reduce workload and cost of insulation removal and reinstallation. Inspection interval has also been reset to comply with the management system and new inspection technique. ● The system helps reduced leakage problem and plant shutdown from CUI issue to zero. Inspection cost is reduced for 50 percent and improves plant integrity significantly.
3.1	Detail	1) Statement of Theory and Definitions ● Corrosion Under Insulation (CUI) is common in process that operates with specific temperature; carbon steel (-5 to 175°C) and stainless steel (50 to 175°C). The corrosion happens when water is absorbed by or collected in the insulation. CUI is difficult to find because the insulation covers the problem until it's too late and causes catastrophic effect (oil/gas leakage, fire & explosion, downtime and repairs). Several equipment &

No.	Title	Details
		piping in GBS field have been insulated for heat conservation, explosive atmosphere and human protection. Equipment is corroded due to being in contact with aerated water. • On 15th June 2019, GBS found hot oil leak at 6"-HM-243065-D01X-H line of WHRU train 1 and severe corrosion under insulation (CUI) at the same location of WHRU train 2 (see figure 1). The survey of potential to have corrosion under insulation at a heating medium system was conducted and completed for 66 locations. However, the removed insulation cannot reusable. The results found the severe corrosion under insulation at some locations.  **Figure 1** Heating Medium Failure from CUI • The Failure Reporting, Analysis and Corrective Action System (FRACAS) was conducted. The potential root cause of CUI is the insulation system including sealant failure or damage. Then, the moisture or water can present in the insulation and promote CUI of the piping system. The detail of FRACAS is shown in attachment. • Detecting corrosion under insulation (CUI) is very difficult resulting in serious damage or failure to the processing system. To minimize the number of CUI in GBS field, insulation should be removed for the equipment/piping that are not necessary to be insulated. Moreover, the proper material of insulation or insulation upgrade must be considered as the lesson learnt from GBS.

No.	Title	Details
		2) Description and Application of Equipment and Processes 2.1 CUI Information The major factor in preventing CUI is to keep liquid from intruding into the insulation. Water decreases the effectiveness of the insulation and leads to corrosion of pipe or equipment. Poor conditions caused by wet insulation can be aggravated by weathering, vibration or abuse from people. The degradation rate for CUI varies significantly depending on numerous factors. These factors include temperature, time, insulation type, coating, equipment configuration and the presence of water. These factors are described in the sections below. a. Water b. Corrosion Rate c. Insulation Type d. Temperature e. Coating Based on FRACAS, temperature is the main factor of water vaporization and also CUI. Figure 2 shows the risk of corrosion at any temperature for 3 standards. In this work, PTTEP corrosion guideline is used as the reference for CUI risk assessment.  **Figure 1** CUI Risk Profile as a Function of Temperature There are five factors in preventing CUI: (1) Insulation selection (2) Equipment design

No.	Title	Details
		(3) Protective paints and coatings; (4) Weather barriers (5) Maintenance practices If an area is subject to spills or high humidity, special consideration must be given to selecting the insulation. Some insulation leaves the system less sensitive to defects in weatherproofing or paint films because the insulations are nonabsorbent and chemically nonreactive. To understand the life cycle of CUI, a typical progression is as table 1 (see in secion 2 support information). **2.2 CUI Management Strategy Determination** Steps of CUI Inspection Strategy determination can describe in figure 3 below;  **Figure 3** CUI Management Strategy **Step 1: Determine the Susceptibility score** The Susceptibility to CUI is determined with questions in the figure 4 (Susceptibility to CUI failure for Carbon/Low alloy steels) and figure 5 (Susceptibility to CUI failure for Stainless steels) – see in section 2 Support Information. The cumulative score is ranged in Probability class (CUI Criticality Matrix).

No.	Title	Details
		Material: classified into 2 groups; carbon steel, stainless steel and alloy **Temperature**: temperature is the key parameter of CUI. The specific temperature affects to the corrosion rate. Point represent potential to occur CUI in any range. **Coating life**: In this work, platform life is over that 7 years which is assuming to be the as insulation life. CUI can occur if the coating life is longer. **Cladding/Insulation Condition**: insulation condition can be known by inspection. Almost of insulation in GBS is in average condition. Only in hot oil section, the insulation condition is in poor condition. Background is already showing the damage of CUI in hot oil section. **Insulation type**: Type of insulation affects to corrosion rate. Rockwool is used for all GBS insulation. Therefore, GBS insulation material is proper for corrosion representing in high point. **Heat tracing**: For electric insulation, CUI can be occurred easier than normal. Heat tracing is almost in fuel gas section to prevent condensation. **External Environment**: High wetting rate is the most suitable for offshore location. For all results, the probability for CUI is high so that consequence the then the key parameter to determine that which line is in high or low risk for CUI. **Step 2: Determine the Consequence of failure** The Consequence of failure is identified as per the SSHE-106-STD-400: SSHE Risk Management Standard. The Consequence of failure information can be obtained from safety study. The detail of consequence scoring is shown in figure 6 (see

<table>
<tr><th>No.</th><th>Title</th><th>Details</th></tr>
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in section 2 Support Information). Operation team attends the CUI workshop to provide the score for this section.

Step 3: Determine CUI Criticality and select Inspection Strategy

The Inspection Strategy is selected base on Susceptibility score and Consequence of failure from the CUI Strategy matrix as shown in figure 7 and 8 (see in section 2 Support Information). The CUI Inspection Strategy is classified into 6 levels (Negligible, Low, Medium, Medium High, High and Extreme).

Step 4: Determine the CUI Inspection Interval

Document 10008-GDL-5-COR-007-R00 Guideline for Corrosion under Insulation Management shown the recommended inspection interval and the following action after inspection in case CUI is present or not present. After that initial inspection, the inspection interval should be reassessed by the method in CUI guideline. For carbon and low alloy steels, the inspection interval can be determined from Expected Coating Life and Interval based on Inspection Strategy (IS). The inspection interval then becomes. Inspection Interval = Expected Coating Life + Interval in table 2.

Table 2 Inspection Interval Based on CUI Criticality

<table>
<tr><th>Inspection Strategy (IS)</th><th>Interval based on IS</th></tr>
<tr><td>IS-1 (E)</td><td>1 year</td></tr>
<tr><td>IS-2 (H)</td><td>2 years</td></tr>
<tr><td>IS-3 (MH)</td><td>3 years</td></tr>
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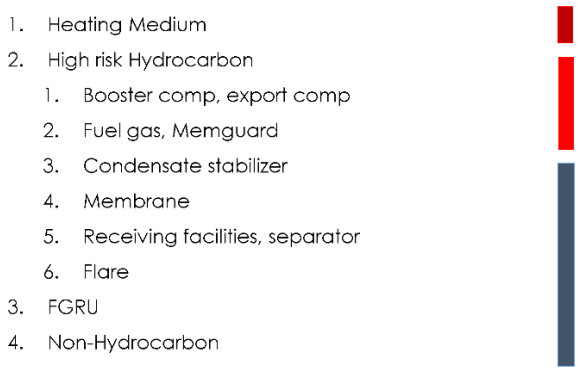
No.	Title	Details
		IS-4 (M/L/N) | 4 years Expected Coating Life = Recommended Expected Coating Life for organic coating is 5 years in dry condition, 3 years in wet condition and 1 year for poor coating condition. However, users shall consult with coating expert for appropriate expected coating life. For stainless steels, external chloride stress corrosion cracking is the only feasible degradation mechanism and it is non-trend able. Therefore, the next CUI inspection is followed to time-based strategy. For Example, or more information, it can be seen in "10008-GDL-5-COR-007-R00" or Guideline for Corrosion under Insulation Management. **2.3 CUI Potential** Potential can be classified by 2 categories. First, results of CUI workshop can identify the risk and consequence. Second is the experience of operation to located that which area they can found CUI in the previous situation. Both of that are combined and then to be the removal plan of GBS insulation. **3) Presentation of Data and Results** **3.1 CUI Workshop Results** For all insulation line of GBS, the workshop has been conducted with GBS operation team, engineering, inspection and reviewed by safety. Results of work shop will be used to categorize the insulation line in to the several CUI critically level based on consequence and probability. The one of the key

No.	Title	Details
		parameters is the shut down time. The results are mostly high or extreme in case that the maintenance for that section required shutdown or long-time activity. Moreover, As shown in CUI guideline, temperature of that section is also the one of the key parameters. The CUI level represents the level of consequence and probability as shown in below figure 9 (see in section 2 Support Information). For less than medium, 129 lines is recommended to neglect for insulation removal. The extrema and high level need to be considered which can affects high and extreme either probability or consequence. The plan will be focused on total 300 lines. The strategy of insulation removal is depending on types of insulation. For expected life, all of heating medium line are in poor condition. The expected life base of CUI guideline is 1 year. The expected life of other line is assuming to be 3 years for the other system because offshore is in wet conditions. For all extreme line the additional inspection interval will be 1. For extreme heating medium line, inspection interval will be within 2 years. For high heating medium line, inspection interval will be within 3 years. For the other system, the inspection period will be 4 years for extreme and 5 years for high criticality. For the other stream or more information please see the CUI guideline for estimate the inspection interval. 3.2 CUI Priority There are many root causes for CUI or corrosion in piping. The other parameter such as specific environment, area, or operation activity also can affect to piping damage. From

No.	Title	Details
		operation experience and historical, the CUI in the system can be categorized in to 4 main priority as shown in figure 10.  **Figure 10** CUI Risk Priority Based on Historical Failure and Operation Experience The highest risk is heating medium system. The damage was found in heating medium line and almost of that line are inspected. This section is very critical and need to be concerned for all hot insulation. The second risks are high risk hydrocarbon. From this section, compressor, fuel gas system, Memguard has high probability. In case the insulation removal cannot cover all selected line, this priority can be used to select which insulation line need to be removed. The removal plan can be following this priority to remove the critical line before to make sure that the CUI will be minimized. In this work, all insulation can be removed in 1 campaign so, no need to follow this section. Figure 11 is the mapping from the workshop results and operation priority. Almost of savior insulation line is in heating medium and high-risk hydrocarbon that recommended to be removed.

No.	Title	Details

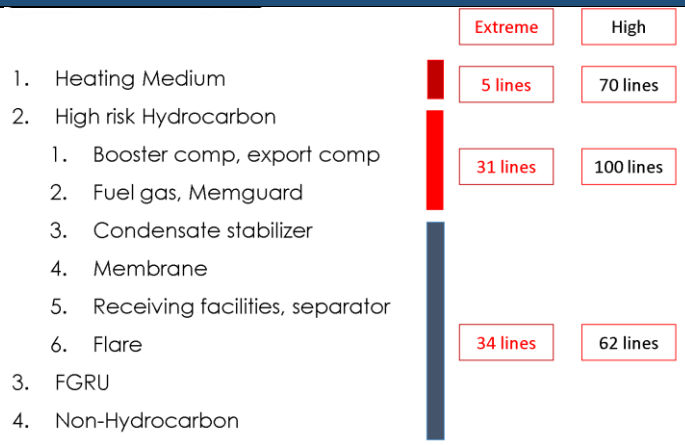


Figure 11 Results of Workshop and Priority to Remove

3.3 Proposed Solutions

For GBS insulation, 5 types of insulation found in CUI workshop results. Each type of insulation is design with different purposes but CUI can be occured for all insulation. Figure 12 shows the type of insulation in high and extreme level. Almost of that is hot insulation which can affect to temperature of process and utility. Condensation and heat tracing are mostly used to maintain the gas phase in gas stream. Therefore, the removal strategy will depend on the type of insulation and the system.

Insulation	No	Service	System
Hot Insulation	184	Hot Oil, Gas, Condy	Heating Medium
Cold Insulation	40	Gas	Memguard
Acoustic	9	Gas	Compressor
Heat Tracing (electric)	58	Gas	Fuel Gas, Gas
Condensation	11	Gas	Fuel Gas

Figure 12 Insulations and System for GBS Production Platform Classified

No.	Title	Details
4	Best Practice Process / Procedures *	**Insulation Removal Strategy** **1) Thermal Insulation (Hot, Cold)** Temperature insulation is used to maintain the temperature in process. Hot insulation is used in high temperature area. It is almost at the heating medium system, Memguard and other area which the temperature stable is required. Cold insulation is at mem guard system before Memguard unit at the around JT valve area. In design phase, the temperature insulation is required because heat loss will affect process such as separation of operating temperature. In current operation, it may have some heat duty to handle that heat loss so, insulation can be tried to remove and then monitor the process condition within the trial period. The overall step for temperature insulation is shown in following points. Remove insulation which is Extreme and High results from CUI workshop. As explain in workshop results, less than medium high represent medium consequence or probability that can be neglect. In this step is mainly focused on heating medium and Memguard system. Monitor process condition at least 1 week to make sure that the process is not disturb by loss of energy in insulated line. Following parameter need to be close monitored. Temperature of that insulated line; can represent process condition Temperature of downstream unit; can represent process condition

No.	Title	Details
		Duty of upstream and downstream unit; can represent limitation of energy equipment In case the insulation can be removed, personal protection should be provided for the hot line which has temperature more than 70°C. For line that insulation cannot remove, insulation upgrade and PM plan should be considered. Hot oil system is one of the main key systems which contains a lot of hot insulation. WHRU is the main unit for heating medium. Outlet of WHRU is high temperature stream which go to heat exchanger in process. The highest operating temperature is at Memguard and mem brane (membrane inlet heater, regen gas heater) for adsorbent regeneration about 300°C. Its shown that the section from inlet WHRU to those 2 heaters is the critical section that the insulation is still required. Therefore, this section is recommended to use the insulation upgrade and PM plan. The permanenting remove insulation of this section may leads to the production effect so, it need to be very close monitoring. See figure 13 in section 2 Support Information for further process diagram. 2) Acoustic Insulation Acoustic insulation is used to prevent noise in process that is mainly for engine and rotating equipment. The main focused of this insulation is at compressor. For noise, it can be mitigated by using alternative options. In this work, 3 options are provided for acoustic insulation.

No.	Title	Details
		Option 1: Remove that insulation. The noise can be protected by noise protection equipment such as ear plug or ear muff. The level of noise is needed to be confirmed and make sure that PPE is enough for protection. Option 2: Not remove insulation. CUI can be mitigated by inspection and maintenance plan. Only 9 lines of acoustic insulation can be managed by PM to avoid CUI. Option 3: Insulation upgrade. Please see the next section for the detail of insulation upgrade. **3) Phase Change Insulation (Condensation, Electric or Heat Tracing)** Heat tracing and condensation insulation is used to prevent condensation in process that is mainly for fuel gas system. Heat tracing is still required inside the fuel gas package so, this section is not recommended to remove. Insulation upgrade and not replace heat tracing. The mitigation of this section is inspection plan and maintenance plan. See figure 14 in section 2 Support Information for further process diagram. Exclude condensation and heat tracing, it is remaining 233 pipings to be removed including acoustic insulation. After trial insulation removal, personal protection, inspection plan and also insulation upgrade are the important issues to handle CUI in case insulation removal strategy is not works. Exclude the phase change condensation, all remaining insulation are shown in table 3 – section 2 Support Information

No.	Title	Details
		which needed to be removed. In case contractor work, about 10 lines of insulating can be removed in one day. Below table shows that 25 working days is required for this insulation removal job. 28 days is the maximum for on campaign so, this job can be completed in 1 campaign. Because the 1-week monitoring is required, the sequence of insulation removal between the system need to be plan. GBS heating medium will be the first loop to do removal plan and trial test for GBS. **4) Insulation Design Upgrade** There are five factors in preventing CUI; (1) insulation selection (2) equipment design (3) protective paints and coatings; (4) weather barriers (5) maintenance practices In case that insulation is still required, after trial period from the insulation removal strategy, it is recommended to consider upgrading of the insulation system at the specific portions those found to be under severe CUI. Due to the fact that corrosion under insulation is caused from wet insulation with coating that may be damaged or degraded over time, so the recommended insulation upgrade as listed below should be considered when re-instate the insulation back on to the equipment or piping in those portions with CUI problem. **Insulation Coating**

No.	Title	Details
		In addition to proper installation of insulation system that can prevent water or moisture ingress, a coating system to create seamless water and weatherproofing of insulation and cladding material, e.g. Lagseal from Belzona should be considered for insulation upgrading. **Coating with Thermal Spray Alluminium (TSA)** Per API RP 583, TSA coatings are generally reported to have a useful service lifetime in excess of 35 years. Within the past few years there have been a few reports of TSA coatings failure in offshore applications after less than 10 years' service. Norsok M501 specify TSA coating for all insulated surfaces of carbon steel T>120°C. TOTAL GS EP COR 355 for "External protection of piping and equipment by thermal spray coating" also specify this system for high durability protection of new built offshore or coastal piping and equipment - more than 15 years. So, this coating system is also recommended for the retrofit of the corroded portions. However, more detailed study in term of constructability either in fabrication shop or at site is required to confirm its applicability. **High Temperature Painting for CUI Prevention** This Management system includes study and demonstration on High Temperature Painting system for CUI anomaly repair and CUI long-term prevention. This study demonstrated the applicability of high temperature painting system on elevated temperature steel surface up to 300°C. It is common knowledge that the higher grade of surface preparation will ensure higher results/ performance of properly applied

No.	Title	Details
		painting system. However, our situation is limited to apply during equipment online which blasting is not permitted. Therefore, the surface to be coated shall be mechanically pretreated to St 2 or 3 ISO 8501-02 by brass or no sparking hand tools/ power tools. Demonstration of the application techniques including spray, brush, and roller have been done. Spray application is the preferred method and should be used whenever possible since it provides a more uniform coat with more consistent dry film thickness and provide a superior aesthetic appearance compared to brush or roller application. Spray application is also the safest technique to paint applicator. Roller and brush made from natural hair can be used when necessary to prevent burning. Another observation is solvent fume extraction which is a very distinct process that removes fumes created from the evaporation of solvents after applicable use. Solvents evaporate very quickly, forming chemical fumes or vapors, which can easily be inhaled causing harmful side effects. To prevent this hazard, habitat shall be installed at working area and ventilate to safe location. With limited of surface preparation and application mentioned previously, adhesion property testing with X cut, cross cut, and pull off test demonstrated that this kind of high-build heat-resistance multipolymeric matrix or inorganic ceramic copolymer can achieve good to better adhesion to substrate when apply on elevated temperature steel surface compares to ambient surface. This because higher temperature makes closer and longer of polymer cross linking.

No.	Title	Details
		The last important thing is CUI prevention efficiency. From simulation test, it shows satisfactory results of CUI prevention even in the accelerated severe condition. In conclusion, though this is not the way we normally try to solve the CUI problems from the root cause, this high temperature painting system can be a possible solution for equipment that requires shutdown to repair since it can be used for either online or offline equipment. In addition, this is also another CUI mitigation when we apply together with other mitigations such as ensuring the integrity of insulation (no water ingress). It helps enhancing and improving CUI prevention efficiency of our process equipment operated at CUI susceptible temperature or even at elevated temperature above 200°C. Finally, it helps preventing significantly lost revenue from downtime, saving life cycle cost of maintenance and replacement of corroded parts, preventing LOPC, and catastrophic failure. Refers API 583 Corrosion Under Insulation and Fireproofing, typically CUI susceptibility at operating temperature range from -12°C to 175°C. However, even at surface metal temperatures up to 316°C CUI still has been reported. This because it could occur during operation if water reaches the metal surface during a shutdown period and flashes off during start-up. This study help addressing the additional of high temperature painting system which can be used for CUI prevention at temperature above 200°C in our PTTEP PEGS 10008-STD-6-COR-010-R00 Painting of Offshore Coastal Structures and Facilities.

No.	Title	Details
		5) Insulation System Upgrade Due to the fact that the existing insulation system are based on old TOTAL specification at the time they were built. Some new insulation materials found to be more suitable than those specified in the past may be updated in the new revision. It is suggested that we may follow the latest TOTAL specification for insulation system of the retrofit portion. **6) Inspection Tools and Method** There are both direct and indirect inspection methods for detecting surface corrosion damage (CUI or CUF) on equipment or structural supports. Direct inspection methods are inspection methods conducted without the presence of a protective barrier (i.e. insulation or fireproofing system). Indirect inspection methods are inspection methods conducted with the protective barrier (i.e. the insulation or fireproofing system) still in place. For cost optimization and integrity assessment purposes, both indirect and direct inspection methods will be applied to PTTEP asset. By using indirect inspection method (Pulsed Eddy Current Method) as a screening tool to find damaged and CUI potential areas, which will be inspected further via direct inspection method.  **Figure 15** Inspection Methodology and Strategy **Pulsed Eddy Current Method (PEC)**

No.	Title	Details
		Pulsed Eddy Current (PEC) is a nondestructive examination technique used for detecting flaws or corrosion in ferrous materials or measuring the thickness of objects. PEC has been used in recent years to detect areas of wall thinning on insulated piping through aluminum or stainless-steel jacketing. It is also used to inspect fireproofed legs on storage spheres. It is a noncontact, electromagnetic examination method used to detect the average wall loss of carbon and low alloy steel materials.  **Figure 16** Pulsed Eddy Current Inspection Tools PEC works using the principle of electromagnetic induction. It applies the step function of voltage to a conductor. A magnetic field will be developed around it. This field changes in intensity as the current alternates. If brought close to the first field, another conductor will have a current induced in it as well. If there are any flaws in this material, then the eddy current will distort. In the case of PEC, the first conductor is an eddy current probe. The second is the test material. PEC can be used on carbon and low alloy steel equipment and piping through up to 8 in. (200 mm) of insulation and jacketing. The advantages and disadvantages for pulsed eddy current inspection are shown below. **PEC Advantages**

No.	Title	Details
		• Noninvasive, noncontact method that does not require surface preparation; • Can be used between -150°F and 930°F (-100°C and 550°C). **PEC Disadvantages** • Averages corrosion over 4 in. (100 mm) diameter area so that isolated pitting may be difficult to detect • Affected by ferromagnetic appurtenances such as insulation rings, vents, and drains that can obscure surface damage • Technique is operator dependent • Cannot be used on insulated systems with galvanized or aluminized steel jacketing
5	Operation Duration*	**start date**: August 2019 **end date:** January 2021
6	Application *	The proposed CUI risk matrix can be applied for any asset with various operating condition. It can be utilized to reduce cost of insulation installation and maintenance. The inspection technique proposed in the system helps providing set of data for piping and pressure vessel equipment for further assessment to avoid CUI problem in the future.
7	Investment (Mil.Baht)*	7.13 Mil.Baht
9	Benefit*	• The new proposed management system offers holistic management of CUI issue and problem systematically. • The system helps reduced leakage problem and plant shutdown from CUI issue to zero. • Inspection cost is reduced for 50 percent.

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Improves plant integrity.
Advanced inspection technique called “Pulsed-Eddy Current” has been verified and applied for CUI inspection and scanning which will reduce workload and cost of insulation removal and reinstallation.

</td></tr>
<tr><td>10</td><td>Benefit Value (Mil.Baht/ Yr)*</td><td>9.26 Mil.Baht/ Yr</td></tr>
<tr><td>11</td><td>Benefit Value Calculation</td><td>
<table>
<tr><th>Description</th><th>Equation</th><th>Value</th><th>Unit</th></tr>
<tr><td>Conventional Method: Project Cost & Investment (ART, GBN, GBS)</td><td></td><td></td><td></td></tr>
<tr><td>Overall cost</td><td>(1)</td><td>16.38</td><td>MMTHB/year</td></tr>
<tr><td>PEC Method: Project Cost & Investment (ART, GBN, GBS)</td><td></td><td></td><td></td></tr>
<tr><td>Overall cost</td><td>(2)</td><td>7.13</td><td>MMTHB/year</td></tr>
<tr><td>Benefit Value</td><td></td><td></td><td></td></tr>
<tr><td>Ramaining Lifetime</td><td>(3)</td><td>15</td><td>year</td></tr>
<tr><td rowspan="2">Net Benefit Value</td><td>(1)-(2)=(4)</td><td>9.26</td><td>MMTHB/year</td></tr>
<tr><td>(3)x(4)=(5)</td><td>138.83</td><td>MMTHB</td></tr>
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<tr><td>12</td><td>Apply From</td><td>None</td></tr>
<tr><td>13</td><td>Company</td><td>PTTEP</td></tr>
<tr><td>14</td><td>Team member*</td><td>
1. Petch Janbanjong
2. Kamonwan Ruangpattanatawee
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		10. Matina Thammachart 11. Ekkalak Somroop 12. Suthorn Domhom 13. Sitthipong Seesad
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16	Year Contest	2021

2. Support Information

Table 1 Typical Progression & Coating Lifetime

Year	Typical Progression & Coating Lifetime
0	New equipment properly coated, insulated and installed and operates continuously at 80°C.
0-3	No maintenance has been performed on the insulation system. The caulking has failed, the insulation is wet, and water has accumulated in water traps and low areas.
3-5	The coating system begins to fail, especially in water traps and low areas.
5-7	The coating system has failed nearly completely, and CUI is underway.
7	Significant corrosion has occurred with corrosion rates averaging 0.125 – 0.250 mm/yr and as high as 0.50 mm/yr in severe cases. Leaks begin to appear.
7+	Through-wall failures not uncommon at this point and susceptible equipment will have experienced significant degradation.

Constantly Operating Temperature	Coating Life*1	Cladding/ Insulation Condition	Insulation Type	Heat Tracing	External Environment	Point
< -5°C or > 175°C	Life ≤ 3 yr	Good to Engineering Standards (undamaged), Regular inspection/ Maintenance every 5 yr	Regular inspection and maintenance (every 5 yr)	Not present	Inside building, not sweating	**0**
151 to 175°C	3 < Life ≤ 5 yr	Average condition, but with special precautions taken at susceptible areas	Expanded Perlite, Foamglass, Closed Cell Foam	High integrity design (steam) or electrical	Arid or in-land Low wetting rate (< 20% of time)	**1**
-5 to 50°C or 121 to 150°C	5 < Life ≤ 7 yr	Average condition, no special precautions taken at susceptible areas	Fiberglass, Asbestos, Regular Perlite, Mineral/Rock Wool (< 10 ppm Cl)	Medium integrity design (steam)	Moderate climate Meium wetting rate (20-50% of time)	**3**
51 to 120°C	Life > 7 yr	Poor condition, damaged/wet/broken seals/ unknow	Cal Sil, Rockwool (no spec), Unknown	Low integrity design (steam)	Coastal & marine High wetting rate (> 50% of time)	**5**

Remark: *In case coating is not applied, point is 5.

Figure 4 Susceptibility to CUI Failure for Carbon/Low Alloy Steels

Constantly Operating Temperature	Service Life of Coating*1	Cladding/ Insulation Condition	Insulation Type	Heat Tracing	External Environment	Point
< 50°C or > 175°C	Life ≤ 3 yr	Good to Engineering Standards (undamaged), Regular inspection/ Maintenance every 5 yr	Regular inspection and maintenance (every 5 yr)	Not present	Inside building, not sweating	**0**
-	3 < Life ≤ 5 yr	Average condition, but with special precautions taken at susceptible areas	Expanded Perlite, Foamglass, Closed Cell Foam	High integrity design (steam) or electrical	Arid or in-land Low wetting rate (< 20% of time)	**1**
-	5 < Life ≤ 7 yr	Average condition, no special precautions taken at susceptible areas	Fiberglass, Asbestos, Regular Perlite, Mineral/Rock Wool (< 10 ppm Cl)	Medium integrity design (steam)	Moderate climate Meium wetting rate (20-50% of time)	**3**
50 to 175°C	Life > 7 yr	Poor condition, damaged/wet/broken seals/ unknow	Cal Sil, Rockwool (no spec), Unknown	Low integrity design (steam)	Coastal & marine High wetting rate (> 50% of time)	**5**

Remark: *In case coating is not applied, point is 5.

Figure 5 Susceptibility to CUI Failure for Stainless Steels

(*) Effect to people (Workforce and Public[1])

No.	Description
1	**Minor** – Slight injury/illness (First Aid Case-FAC) OR No or slight damage to health e.g. non-toxic dusts (as an acute hazard)
2	**Moderate** – Cases of Medical Treatment Case (MTC) OR a single Restricted Work Day Case (RWDC). Minor health effects, which are reversible, e.g. skin irritation, food poisoning.
3	**Significant** - Multiple cases of RWDC OR a single Lost Work Day Case (LWDC) Affecting work performance in the either short or long term, absence from work. Irreversible health damage without loss of life e.g. noise, poor manual handling tasks, hand/arm vibration syndrome, chemicals causing systemic system effects, repetitive strain injury.
4	**Serious**- Multiple LWDC OR one or more permanent disability OR one Fatality from an accident/illness. Irreversible health damage with serious disability or death e.g. corrosive burns, known human
5	**Major** - Multiple Fatalities from an accident e.g. chemical with acute toxic effects (Hydrogen sulphide, carbon monoxide), known human carcinogens (large exposed population)

Note 1: Effect to public shall be considered with the severity at least equal to the workforce. Depending on societal risk perception in the region, public risk may have to be considered one order of magnitude more severe than that of the workforce.

(**) Property damage & repair / replacement

No.	Description
1	**Minor Effect** – Minimal damage. Negligible down time or asset loss. Losses less than $10K.
2	**Moderate Effect** – Some asset loss, damage and/or downtime. Losses between to $10K - $100K.
3	**Significant Effect** – Serious asset loss, damage to facility and/or down time. Losses between $0.1 - $1 M.
4	**Serious Effect** – Major asset loss, damage to facility and/or down time. Losses between $1M - $10 M.
5	**Major Effect** – Massive asset loss, significant damage to facility and/or down time. Losses more than $10 M.

Note: Only monetary term is specified and has been calibrated in the same order of magnitude with PTTEP Corporate's risk perception and made more stringent to be able to apply at Asset level. However, at asset/site management discretion, the decision for implementation of safeguard and mitigation may be more stringent commensurate with the asset/site perception of acceptable property damage. In no case it can be less stringent.

(***) Effect to Environment

No.	Description
1	**Minor Effect** – Minor environmental damage, within the fence and within systems or vicinity of the installation. No or negligible financial consequences
2	**Minor Effect** - Sufficiently large contamination or discharge to damage the environment, but no lasting effect. Single breach of statutory or prescribed limit, or single complaint.
3	**Localized Effect** - Limited discharges affecting the neighborhood and damaging the environment. Repeated breaches of statutory or prescribed limit, or many complaints.
4	**Serious Effect** - Severe environmental damage. The company is required to take extensive measures to restore the damaged environment. Extended breaches of statutory or prescribed limits, or widespread
5	**Major Effect** - Persistent severe environmental damage or severe nuisance extending over a large area. Loss of commercial, recreational use or nature conservancy, resulting in major financial consequences for the Company. Ongoing breaches well above statutory or prescribed limits.

Figure 6 Consequence Criteria

PROBABILITY CLASS	SUSCEPTIBILITY TO CUI FAILURE		CUI Criticality and Inspection Strategy Matrix for CS/Low alloy steel				
	H	Total Score > 20	IS-4 (L)	IS-3 (MH)	IS-2 (H)	IS-1 (E)	IS-1 (E)
	M	Total Score 17 to 20	IS-4 (L)	IS-4 (M)	IS-3 (MH)	IS-2 (H)	IS-1 (E)
	L	Total Score 11 to 16	IS-4 (N)	IS-4 (L)	IS-4 (M)	IS-3 (MH)	IS-2 (H)
	N	Total Score 1 to 10	IS-4 (N)	IS-4 (N)	IS-4 (L)	IS-4 (M)	IS-3 (MH)
CONSEQUENCE CATEGORY	HEALTH & SAFETY*		Minor Effect	Moderate Effect	Significant Effect	Serious Effect	Major Effect
	PROPERTY DAMAGE & REPAIR / REPLACEMENT (USD)**		Minor Effect (<10K)	Moderate Effect (10K - 100K)	Significant Effect (0.1 - 1M)	Serious Effect (1 - 10M)	Major Effect (> 10M)
	ENVIRONMENT***		Minor Effect	Minor Effect	Localized Effect	Serious Effect	Major Effect
CONSEQUENCE CLASS			Negligible	Low	Medium	High	Extreme

Figure 7 CUI Criticality and Inspection Strategy Matrix for Carbon/Low Alloy Steels

PROBABILITY CLASS	SUSCEPTIBILITY TO CUI FAILURE		CUI Criticality and Inspection Strategy Matrix for SS				
	H	Total Score > 19	IS-5 (L)	IS-4 (MH)	IS-3 (H)	IS-2 (E2)	IS-2 (E1)
	M	Total Score 15 to 19	IS-5 (L)	IS-5 (M)	IS-4 (MH)	IS-3 (H)	IS-2 (E2)
	L	Total Score 10 to 14	IS-5 (N)	IS-5 (L)	IS-5 (M)	IS-4 (MH)	IS-3 (H)
	N	Total Score 0 to 9	IS-5 (N)	IS-5 (N)	IS-5 (L)	IS-5 (M)	IS-4 (MH)
CONSEQUENCE CATEGORY	HEALTH & SAFETY*		Minor Effect	Moderate Effect	Significant Effect	Serious Effect	Major Effect
	PROPERTY DAMAGE & REPAIR / REPLACEMENT (USD)**		Minor Effect (<10K)	Moderate Effect (10K - 100K)	Significant Effect (0.1 - 1M)	Serious Effect (1 - 10M)	Major Effect (> 10M)
	ENVIRONMENT***		Minor Effect	Minor Effect	Localized Effect	Serious Effect	Major Effect
CONSEQUENCE CLASS			Negligible	Low	Medium	High	Extreme

Figure 8 CUI Criticality and Inspection Strategy Matrix for Stainless Steels

Probability	Susceptibility to CUI Failure	CUI Criticality and Inspection Strategy Matrix				
	High	L	MH	H	E	E
	Medium	L	M	MH	H	E
	Low	N	L	M	MH	H
	Negligible	N	N	L	M	MH
Consequence Class		Negligible	Low	Medium	High	Extreme

Category	Definition	No
Extreme Probability	• Very high consequence or probability • High for both consequence and probability • Recommend to remove	70
High Probability	• High consequence or high probability • Recommend to remove	232
< Med	• Medium or low consequence and probability • No concerns	129

Figure 9 CUI Workshop Results

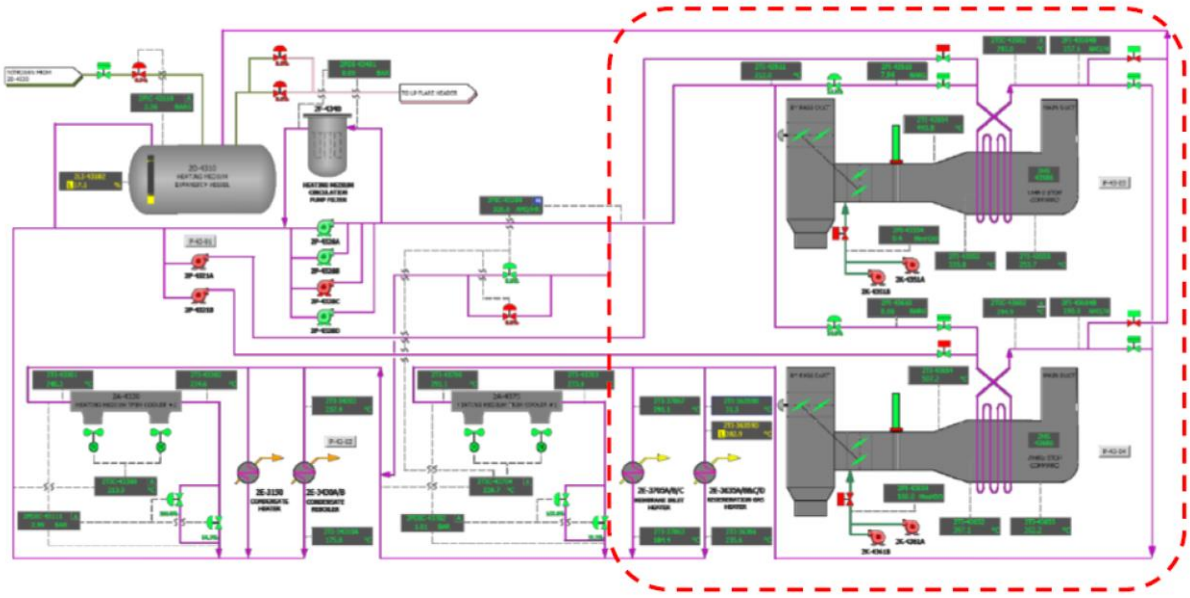

Figure 13 Heating medium system

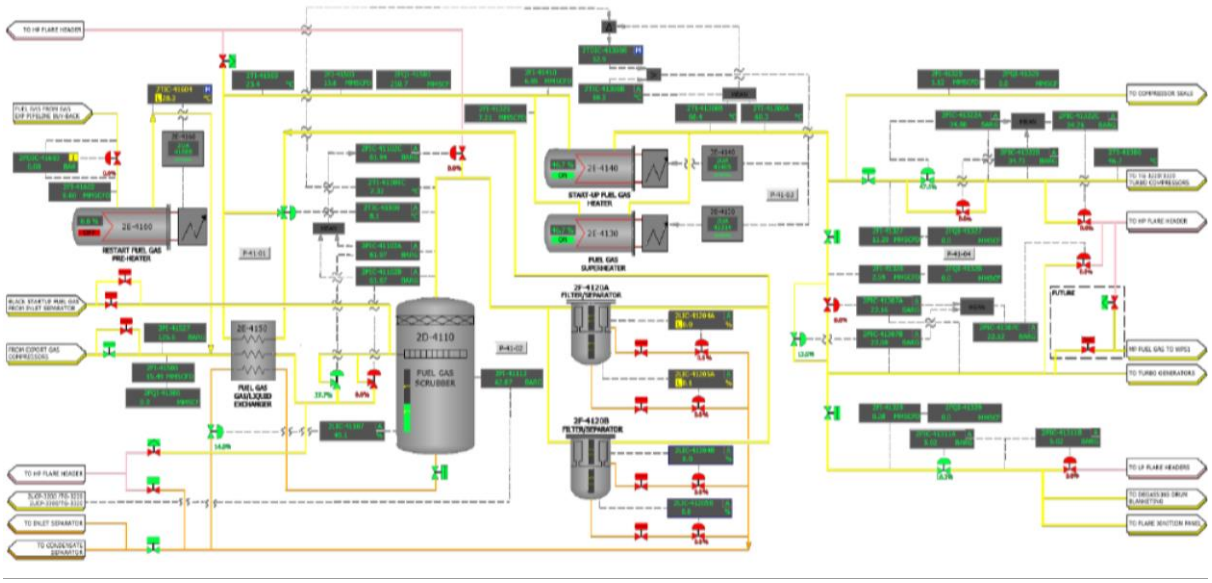

Figure 14 Other Production System

Table 3 Execution Plan for Insulation Trial Removal

Priority	Piping (Loops)	Size	Working Period (Day)	Insulation Type
1	75	2"-12"	7	H
2.1	9	1"-18"	1	A
2.2	54	3/4" - 20"	6	C, H
2.3	34	2"-10"	4	H
2.4	43	3"-24"	5	H
2.5	18	2"-12"	2	H
3	0	2"	0	
Total	233		25	