APPENDIX A

TECHNICAL MODULE SUBFACTOR FOR CORROSION UNDER INSULATION

External corrosion can occur on most equipment and piping system resulting is a gradual thinning of some material or may result in stress corrosion cracking of other materials. API 581 highlights that the most serious cases of corrosion is corrosion under insulation (CUI) and treated this problem as a special case. CUI is especially hazardous because insulation can become wet or contaminated, accelerating the corrosion process. Another reason why CUI is particularly serious is that CUI is very difficult to detect. The problem of CUI can be reduced or eliminated by proper inspection for corrosion, proper installation and maintenance of insulation, or by proper selection, application and maintenance of protective coatings.

According to API 581, external corrosion is evaluated separately for carbon/low alloy steels (subject to thinning) and austenitic stainless steels (subject to stress corrosion cracking (SCC)). External corrosion for carbon/low alloy steels is a special case for application of the thinning technical module. External SCC for stainless steels is similar to the cracking technical module. Table A1 shows the basic data required in completing the module for CUI. The methodology for CUI module is shown in Figure A1 and A2.

Table A1: Basic Data Required for CUI

	Comments
Variables	**Carbon and Low Alloy Steels**
Driver	The driver for external corrosion under insulation. This can be the weather at a location (e.g. marine), the potential for cooling tower drift, the use of sprinkler system, or other contributors.
Rate, in mpy	Corrosion rate for external corrosion. Based on temperature and driver (Table N-9) or user input
Date	Determines the time (in years) to be sent to theThinning Technical Module. Defaults to date installed. Can change based on date of coating, time since last complete stripping and reinsulation.
Inspection effectiveness	The effectiveness of the CUI inspection program (Table N-15).
Inspection number	The number of CUI inspections.
Coating quality	Relates to the type of coating applied under the insulation (Table N-10) None: no coating or primer only Medium: single coat epoxy High: multi coat epoxy or filled epoxy
Coating date/age	Determines the age of the coating.
Complexity	The number of branches (Table N-11)
Good insulation condition?	Determine whether the insulation condition is good based on external visual inspection of jacketing condition. Good insulation will show no signs of damage (i.e. punctured, torn or missing water proofing and missing caulking) or standing water (i.e. brown, green or black stains). Take careful note of areas where water can enter into the insulation system, such as inspection ports and areas where the insulation is penetrated (i.e. nozzles, ring supports and clips). Horizontal areas also accumulate water. If any damage is noted, default to “No” (Table N-12).
Pipe support penalty (Y/N)	If piping is supported directly on beams or other such configuration that does not allow for proper coating maintenance, external corrosion can be more severe (Table N-13)
Interface penalty (Y/N)	If the piping has an interface where it enters either soil or water, this area is subject to increased corrosion (Table N-14).

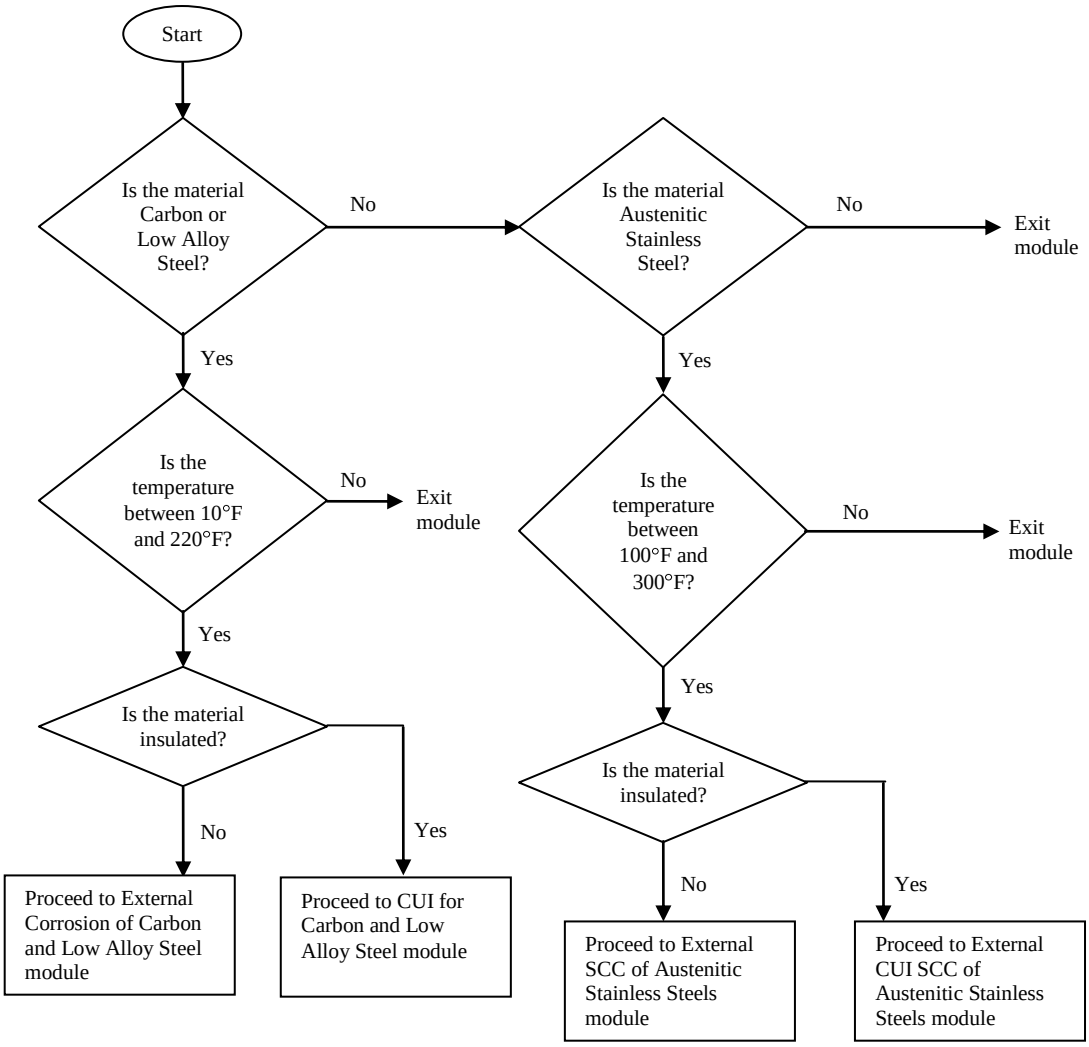

Figure A1: Flowchart for External Corrosion

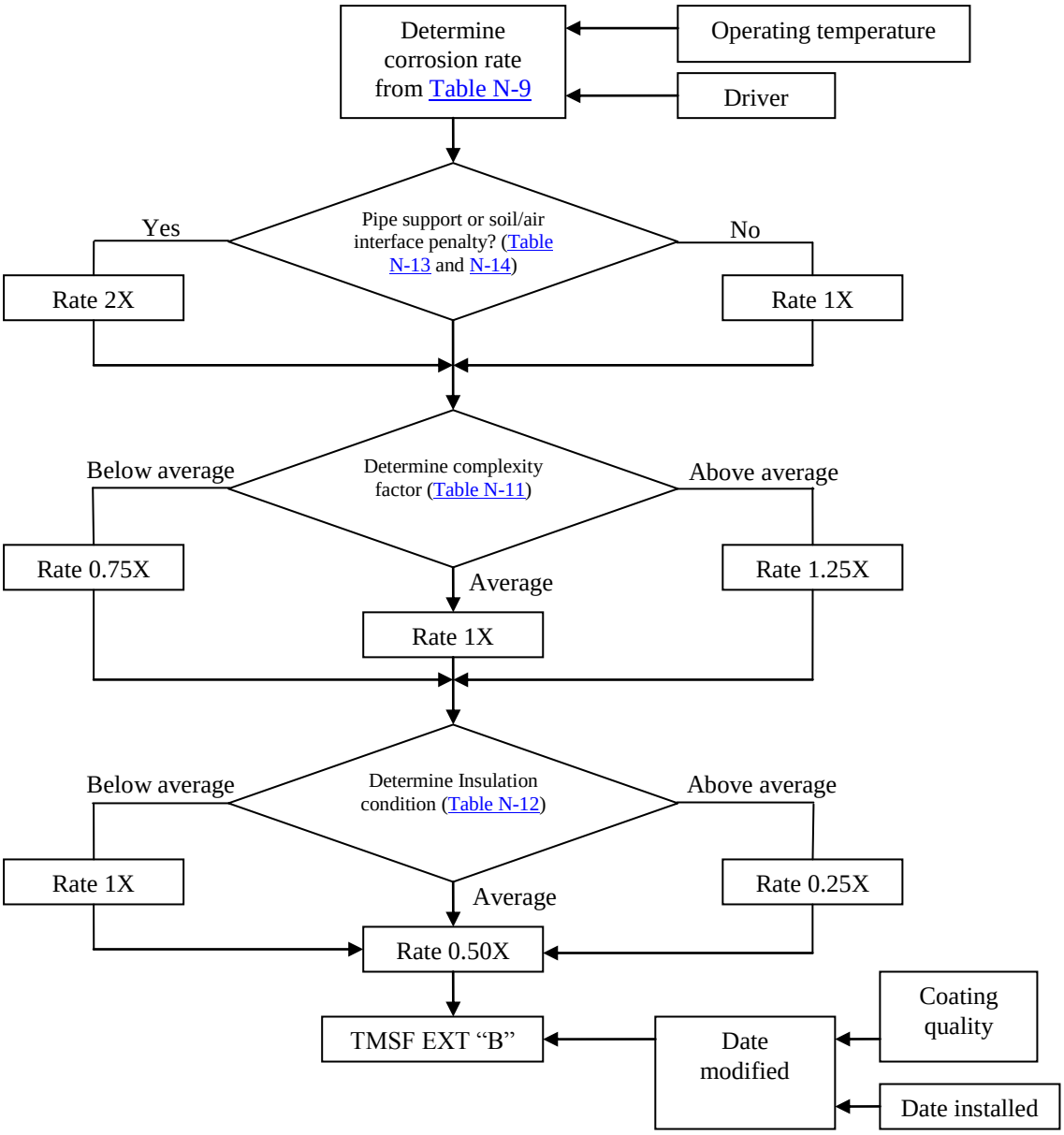

Figure A2: CUI Flowchart for Carbon and Low Alloy Steels

Table N-9: Basic assumptions and methods for CUI for carbon and low alloy steels

	Driver		
Operating Temperature (°F)	**Marine/Cooling Tower Drift Area (mpy)**	**Temperate (mpy)**	**Arid/Dry (mpy)**
10 or less	0	0	0
11 to 60	5	3	1
61 to 120	2	1	0
121 to 200	10	5	2
201 to 250	2	1	0
> 250	0	0	0

Table N-10: Adjustments for coatings

Coating Quality		
None	Medium	High
Date = Date installed	Date = Coating Date + 5	Date = Coating Date + 15

Table N-11: Adjustments for complexity

Below Average	**Average**	**Above Average**
Rate = Rate × 0.75	Rate = Rate × 1.0	Rate = Rate × 1.25

Table N-12: Adjustments for Insulation condition

Below Average	**Average**	**Above Average**
Rate = Rate × 1.0	Rate = Rate × 0.5	Rate = Rate × 0.25

Table N-13: Adjustments for pipe support penalty

Penalty applies	**Penalty does not apply**
Rate = Rate × 2.0	Rate = Rate × 1.0

Table N-14: Adjustments for interface penalty

Penalty applies	Penalty does not apply
Rate = Rate × 2.0	Rate = Rate × 1.0

Table N-15: CUI for carbon and low alloy steels inspection categories

Inspection Effectiveness Category	Insulation Removed	Insulation Not Removed
A	• Remove > 95% of the insulation; AND • Visual inspection of the exposed surface area with follow-up by UT, RT or pit gauge as required.	For the total surface area: • > 95% profile or real-time radiography.
B	For the total surface area: • > 95% external visual inspection prior to removal of insulation; AND • remove > 60% of total surface area of insulation including suspect areas; AND • Visual inspection of the exposed surface area with follow-up by UT, RT or pit gauge as required.	For the total surface area: • 95% external visual inspection; AND • Follow-up with profile or real time radiography of > 60% of total surface area of insulation including suspect areas.
C	For the total surface area: • > 95% external visual inspection prior to removal of insulation; AND • remove > 30% of total surface area of insulation including suspect areas; AND • Visual inspection of the exposed surface area with follow-up by UT, RT or pit gauge as required.	For the total surface area: • > 95% external visual inspection; AND • Follow-up with profile or real time radiography of > 30% of total surface area of insulation including suspect areas.
D	• > 95% external visual inspection prior to removal of insulation; AND • Remove > 5% of total surface area of insulation including suspect area; AND • Visual inspection of the exposed surface area with follow-up by UT, RT or pit gauge as required.	For the total surface area: • > 95% external visual inspection: AND • Follow-up with profile or real time radiography of >5% of total surface area of insulation including suspect areas.
E	• < 5% insulation removal and inspection; OR • No inspection or ineffective inspection technique.	No inspection or ineffective inspection technique or < 95% visual inspection.

Table N-16: Failure probability categories (API, 2000)

Range of failure probability	Likelihood Category	
$\mathbf{1 \times 10^{-4}}$ **to 1.0**	5	Very high
$\mathbf{1 \times 10^{-5}}$ **to** $\mathbf{1 \times 10^{-4}}$	4	High
$\mathbf{1 \times 10^{-6}}$ **to** $\mathbf{1 \times 10^{-5}}$	3	Medium
$\mathbf{1 \times 10^{-8}}$ **to** $\mathbf{1 \times 10^{-6}}$	2	Low
$\mathbf{< 1 \times 10^{-8}}$	1	Very low