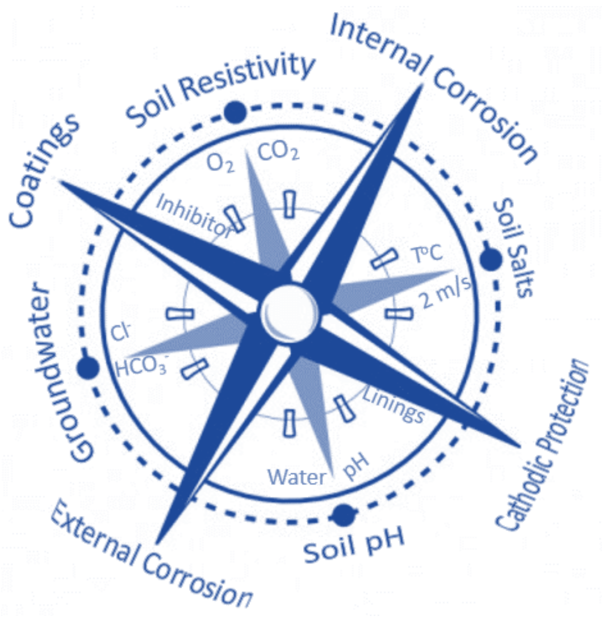


PipelineCompass®: Pipeline Corrosion Modeling, Prediction, Assessment & Solutions

Version 9.20

☆ **Performance** ☆ **Functionality** ☆ **Usability**

Anytime Anywhere Any Device Any OS

No USB dongles No installation No Browser Plug-ins

PipelineCompass is a powerful tool for pipeline corrosion modeling, prediction, assessment & solutions. The software has two predictive engines, one for predicting external corrosion from the soil side, and the other for predicting internal corrosion from the product side (oil and gas, water, or others transported by the pipelines).

Unparalleled Functionality: PipelineCompass is not just for prediction of external corrosion and internal corrosion of underground pipelines, it also allows you to optimize cathodic protection design and operation, and to assess the level of CP protection from CP survey data. Corrosion predictions from PipelineCompass include: the corrosivity of soil, the maximum corrosion depth, the corrosion rate, effectiveness of cathodic protection, the remaining life of the pipeline, the major mode of failure, the probability of high pH SCC, the probability of near-neutral pH SCC, susceptibility to cathodic delamination of coatings due to overprotection by CP, possibility of MIC at localized sites, stray current corrosion and AC corrosion.

Unmatched Usability: PipelineCompass was designed with the user in mind. Experience the industry's first cross-platform and device-independent Pipeline Corrosion Modeling, Prediction, Assessment & Solutions application on your iPads, tablets, smart phones, notebooks and desktops, at any time and anywhere, in the office or in the field. No installation files to download, no browser plug-ins required, no USB dongles to carry around, and no license keys to transfer from one PC to another. **PipelineCompass simply works on any device running any OS**. All you need is an internet browser.

A Brief Overview of PipelineCompass

Prediction of External Corrosion of Buried/Immersed Pipelines and Other Metallic Structures

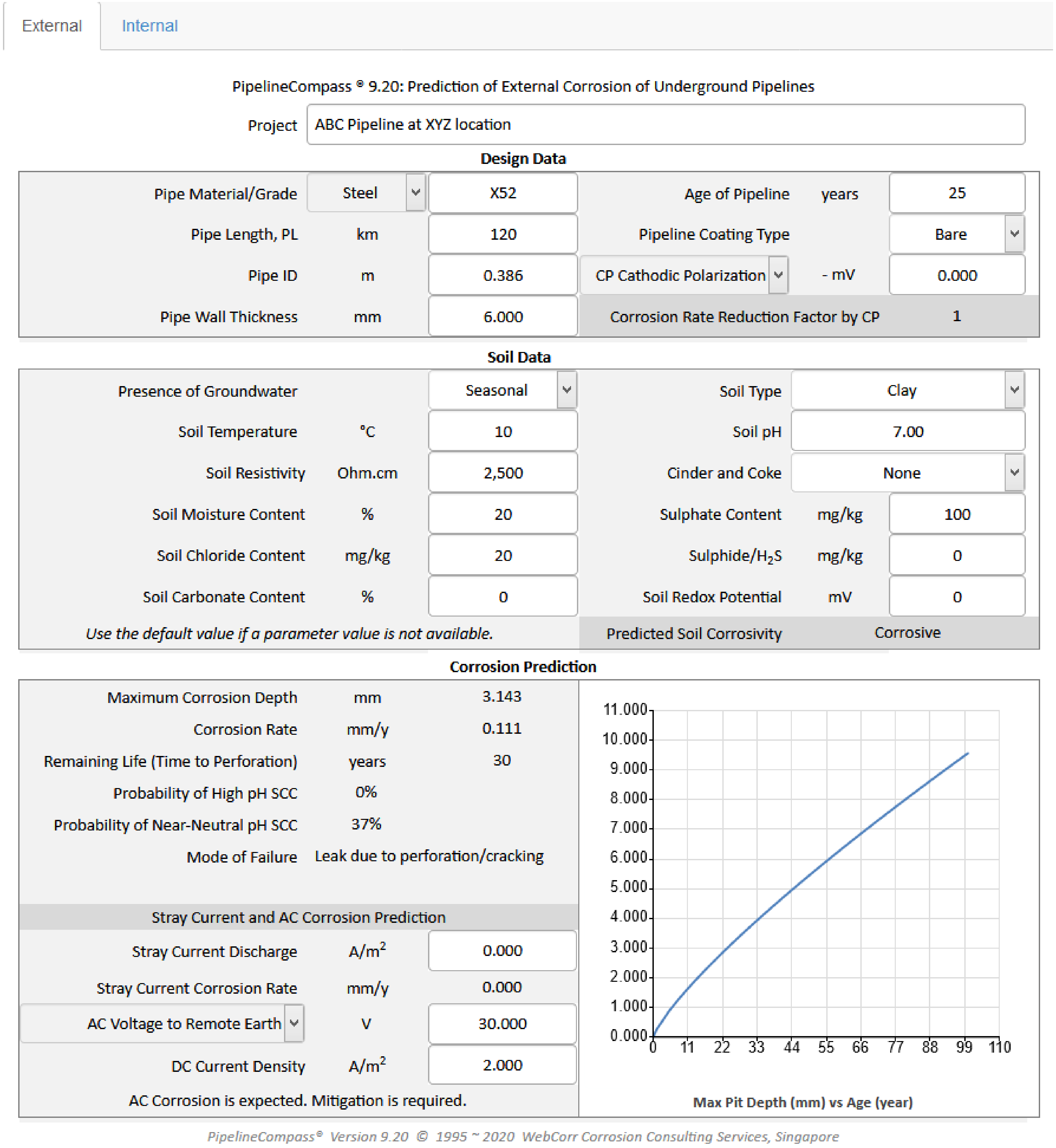


Figure 1 Prediction of External Corrosion of Underground Pipelines

The predictive engine for the external corrosion from the soil side models the effects of the following parameters (inputs) on the type and rate of external corrosion:

Pipe material: cast iron, ductile iron, steel

Age of pipeline

Pipeline coating type: Bare, Asphalt Enamel, Wrap-Tape, Coal-Tar, FBE/PE/PP

CP polarization: This is the actual CP polarization (mV) measured on the pipeline, an indicator for the level of cathodic protection. If the pipeline is protected by a cathodic protection system, the software calculates the residual corrosion rate at the measured CP polarization. This feature is unique to PipelineCompass and can be used in both CP design and CP operation to optimize the level of CP protection throughout of the design life of the pipeline. For example, the CP survey data can be used to determine the CP polarization (-mV) or the polarized potential (- V vs CSE) along the pipeline route, the residual corrosion rate of the pipeline can then be calculated by PipelineCompass, producing a corrosion rate profile or corrosion depth profile along the pipeline route.

Corrosion Rate Reduction Factor by Cathodic Protection

This is the effect of cathodic protection on the corrosion rate of the pipeline under the prevailing design and soil conditions. The procedures for CP optimization and assessment in PipelineCompass are as easy as 1-2-3:

(1). Select the input parameter, CP Polarization (- mV) or the polarized potential (- V vs. CSE), either from the design inputs for a new pipeline or from field survey of existing CP system in operation.

(2). Based on the design and soil data, PipelineCompass computes the effect of cathodic protection on the corrosion rate of the pipeline (Figure 2). In the example shown in Figure 2, the corrosion rate is reduced by a factor of 60 from 0.111 mm/y (Figure 1, no CP) to 0.002 mm/y when CP polarization of 100 mV is applied.

(3). Now adjust the CP polarization (e.g. -150 mV) or the polarized potential (e.g. -0.90 V) and see the effect on the corrosion rate. The corrosion rate reduction factor is drastically affected by cathodic polarization over -100 mV or polarized potential over - 0.85V. The remaining life of the pipeline is computed with the effect of cathodic protection taken into consideration. By optimizing the cathodic protection to meet the desired remaining life, significant cost savings can be realized.

External | Internal

PipelineCompass ® 9.20: Prediction of External Corrosion of Underground Pipelines

Project: ABC Pipeline at XYZ location

Design Data

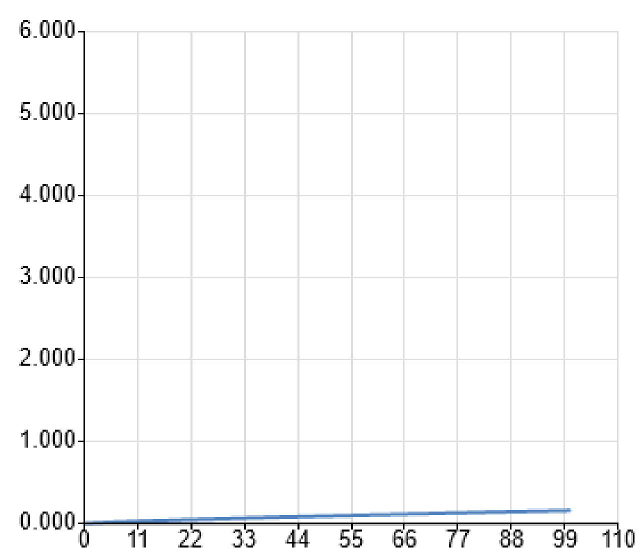
Pipe Material/Grade	Steel	X52	Age of Pipeline	years	25
Pipe Length, PL	km	120	Pipeline Coating Type		Bare
Pipe ID	m	0.386	CP Cathodic Polarization	- mV	100.000
Pipe Wall Thickness	mm	6.000	Corrosion Rate Reduction Factor by CP		60

Soil Data

Presence of Groundwater		Seasonal	Soil Type		Clay
Soil Temperature	°C	10	Soil pH		7.00
Soil Resistivity	Ohm.cm	2,500	Cinder and Coke		None
Soil Moisture Content	%	20	Sulphate Content	mg/kg	100
Soil Chloride Content	mg/kg	20	Sulphide/H_2S	mg/kg	0
Soil Carbonate Content	%	0	Soil Redox Potential	mV	0
Use the default value if a parameter value is not available.			Predicted Soil Corrosivity		Corrosive

Corrosion Prediction

Maximum Corrosion Depth	mm	0.052
Corrosion Rate	mm/y	0.002
Remaining Life (Time to Perforation)	years	over 100
Probability of High pH SCC	14%	
Probability of Near-Neutral pH SCC	0%	
Mode of Failure	Leak due to perforation/cracking	
Stray Current and AC Corrosion Prediction		
Stray Current Discharge	A/m^2	0.000
Stray Current Corrosion Rate	mm/y	0.000
AC Voltage to Remote Earth	V	30.000
DC Current Density	A/m^2	2.000
AC Corrosion is expected. Mitigation is required.		



Max Pit Depth (mm) vs Age (year)

Figure 2 Effect of Cathodic Protection on the Corrosion Rate

Soil data:

presence of groundwater at the pipe burial position;

soil type: calcareous/sandy, loam, clay, peat;

soil temperature at the pipe burial position;

soil resistivity;

soil pH;

presence of cinder and coke in soil

soil moisture content;

soil chloride content;

soil carbonate content;

soil sulphate content;

soil sulfide/H2S content;

soil redox potential

Based on the above 12 soil properties, PipelineCompass computes the **Soil Corrosivity** and produces **4 levels of corrosivity ranking: non-corrosive, slightly corrosive, corrosive, very corrosive**

Corrosion Prediction Outputs

Based on the inputs of the design data and soil data, PipelineCompass assesses the overall system by considering the combined effects of pipe material/age, type of pipeline coating, CP polarization and soil corrosivity on the type and the rate of corrosion. The corrosion prediction outputs include:

The accumulated **Maximum Corrosion Depth**: this is the loss of pipe wall thickness **from the soil side only** (Note that Internal Corrosion will also result in loss of thickness from the inside of the pipe. The life of a pipeline will be determined by both external corrosion and internal corrosion. Figure 7 below shows overview of prediction of internal corrosion).

Corrosion Rate: this is the external corrosion rate computed at the current age and conditions of the pipeline (Figure 1).

Remaining Life (Years to Perforation):

Based on the inputs of the design data and soil data, PipelineCompass assesses the overall system by considering the combined effects of the input parameters on corrosion and predicts the remaining life of the pipeline.

Probability of High pH SCC and Probability of Low pH or **Near-Neutral pH SCC** (Figure 1).

Susceptibility to **Cathodic Delamination of Coatings** (Figure 3) and the Possibility of **MIC at localized sites** (Figure 4).

External | Internal

PipelineCompass ® 9.20: Prediction of External Corrosion of Underground Pipelines

Project: ABC Pipeline at XYZ location

Design Data

Pipe Material/Grade	Ductile Iron	X52	Age of Pipeline	years	25
Pipe Length, PL	km	120	Pipeline Coating Type		FBE/PE/PP
Pipe ID	m	0.386	CP Polarized Potential	- V(CSE)	1.500
Pipe Wall Thickness	mm	6.000	Corrosion Rate Reduction Factor by CP		22490511401117

Soil Data

Presence of Groundwater		Seasonal	Soil Type		Clay
Soil Temperature	°C	10	Soil pH		7.00
Soil Resistivity	Ohm.cm	2,500	Cinder and Coke		None
Soil Moisture Content	%	20	Sulphate Content	mg/kg	100
Soil Chloride Content	mg/kg	20	Sulphide/H_2S	mg/kg	0
Soil Carbonate Content	%	0	Soil Redox Potential	mV	0
Use the default value if a parameter value is not available.			Predicted Soil Corrosivity		Corrosive

Corrosion Prediction

Maximum Corrosion Depth	mm	0.000
Corrosion Rate	mm/y	0.000
Remaining Life (Time to Perforation)	years	over 100
Probability of High pH SCC	0%	
Probability of Near-Neutral pH SCC	0%	
Mode of Failure	Leak due to perforation/cracking	
Over-protection! Cathodic delamination of coatings may occur.		
Stray Current and AC Corrosion Prediction		
Stray Current Discharge	A/m^2	0.000
Stray Current Corrosion Rate	mm/y	0.000
AC Voltage to Remote Earth	V	30.000
DC Current Density	A/m^2	2.000
AC Corrosion is expected. Mitigation is required.		

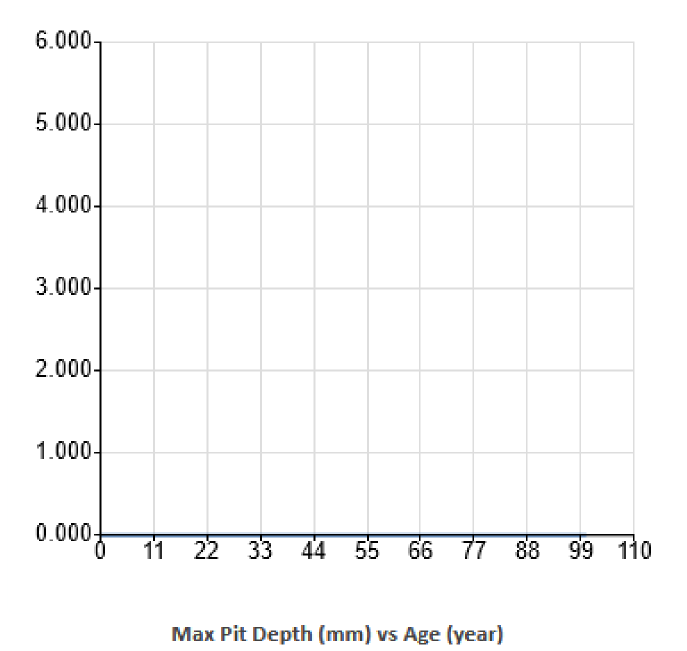


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Figure 3 Prediction of External Corrosion of Underground Pipelines:

Cathodic delamination of coating is predicted under the prevailing conditions.

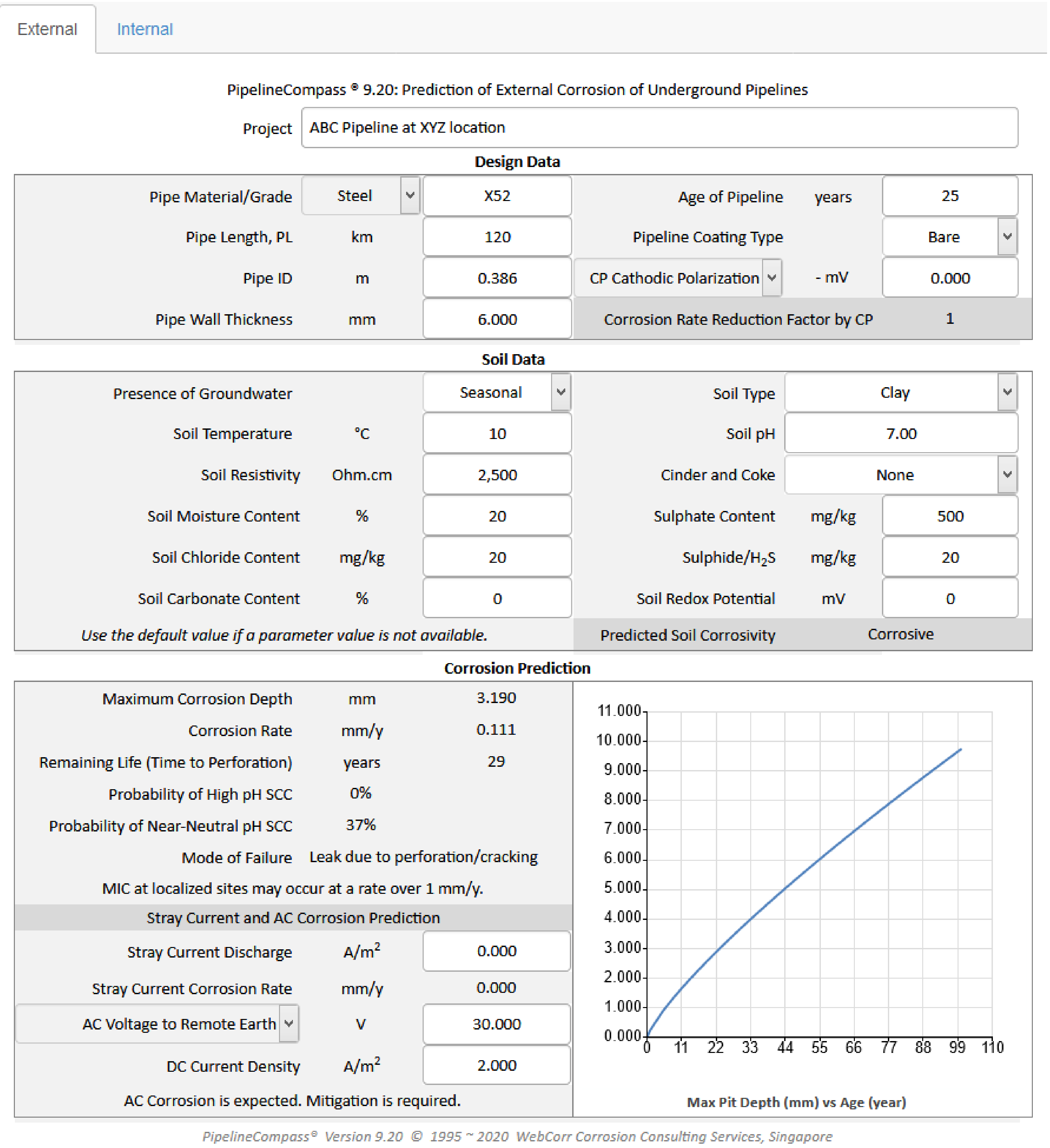


Figure 4 Prediction of External Corrosion of Underground Pipelines:

MIC is predicted under the prevailing conditions.

Mode of Failure: this is the predicted major mode of failure IF a failure eventually occurs. The modes are burst or fracture under impact, or leak due to perforation (Figure 4).

Stray Current Corrosion

Prediction of stray current corrosion is based on the measured DC stray current density at the points of discharge on a pipeline (Figure 5).

SC-Compass is a computer software package specifically designed for AC and stray current corrosion prediction, assessment and modeling. Click here for details on SC-Compass.

AC Corrosion

The A.C. voltage on a pipeline is the driving force for the A.C. corrosion processes taking place on the steel surface at coating defects. Among other things, corrosion damage depends on A.C. current density, level of D.C. polarisation, defect geometry, local soil composition and resistivity. Prediction of the likelihood of AC corrosion is based on the relevant codes and standards such as BS EN and NACE (Figures 5-7). Users can simply choose any one of the following inputs from the dropdown menu for PipelineCompass to assess the likelihood of AC corrosion: (1) AC Current Density, (2) Pipe AC Voltage to Remote Earth.

External | Internal

PipelineCompass ® 9.20: Prediction of External Corrosion of Underground Pipelines

Project: ABC Pipeline at XYZ location

Design Data

Pipe Material/Grade	Steel	X52	Age of Pipeline	years	25
Pipe Length, PL	km	120	Pipeline Coating Type		Bare
Pipe ID	m	0.386	CP Cathodic Polarization	- mV	0.000
Pipe Wall Thickness	mm	6.000	Corrosion Rate Reduction Factor by CP		1

Soil Data

Presence of Groundwater		Seasonal	Soil Type		Clay
Soil Temperature	°C	10	Soil pH		7.00
Soil Resistivity	Ohm.cm	2,500	Cinder and Coke		None
Soil Moisture Content	%	20	Sulphate Content	mg/kg	500
Soil Chloride Content	mg/kg	20	Sulphide/H_2S	mg/kg	0
Soil Carbonate Content	%	0	Soil Redox Potential	mV	0
Use the default value if a parameter value is not available.			Predicted Soil Corrosivity		Corrosive

Corrosion Prediction

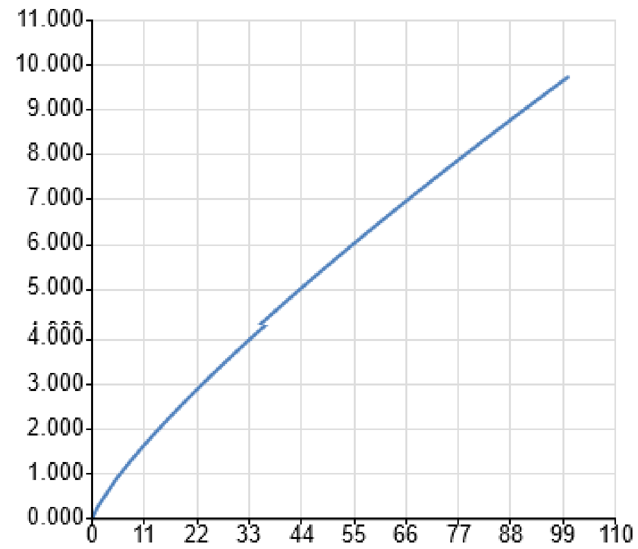
Maximum Corrosion Depth	mm	3.190
Corrosion Rate	mm/y	0.111
Remaining Life (Time to Perforation)	years	29
Probability of High pH SCC	0%	
Probability of Near-Neutral pH SCC	37%	
Mode of Failure	Leak due to perforation/cracking	

MIC at localized sites may occur at a rate over 1 mm/y.

Stray Current and AC Corrosion Prediction

Stray Current Discharge	A/m^2	1.230
Stray Current Corrosion Rate	mm/y	1.437
AC Voltage to Remote Earth	V	12.000
DC Current Density	A/m^2	2.000

AC Corrosion is expected. Mitigation is required.



Max Pit Depth (mm) vs Age (year)

Figure 5 Stray Current Corrosion Prediction

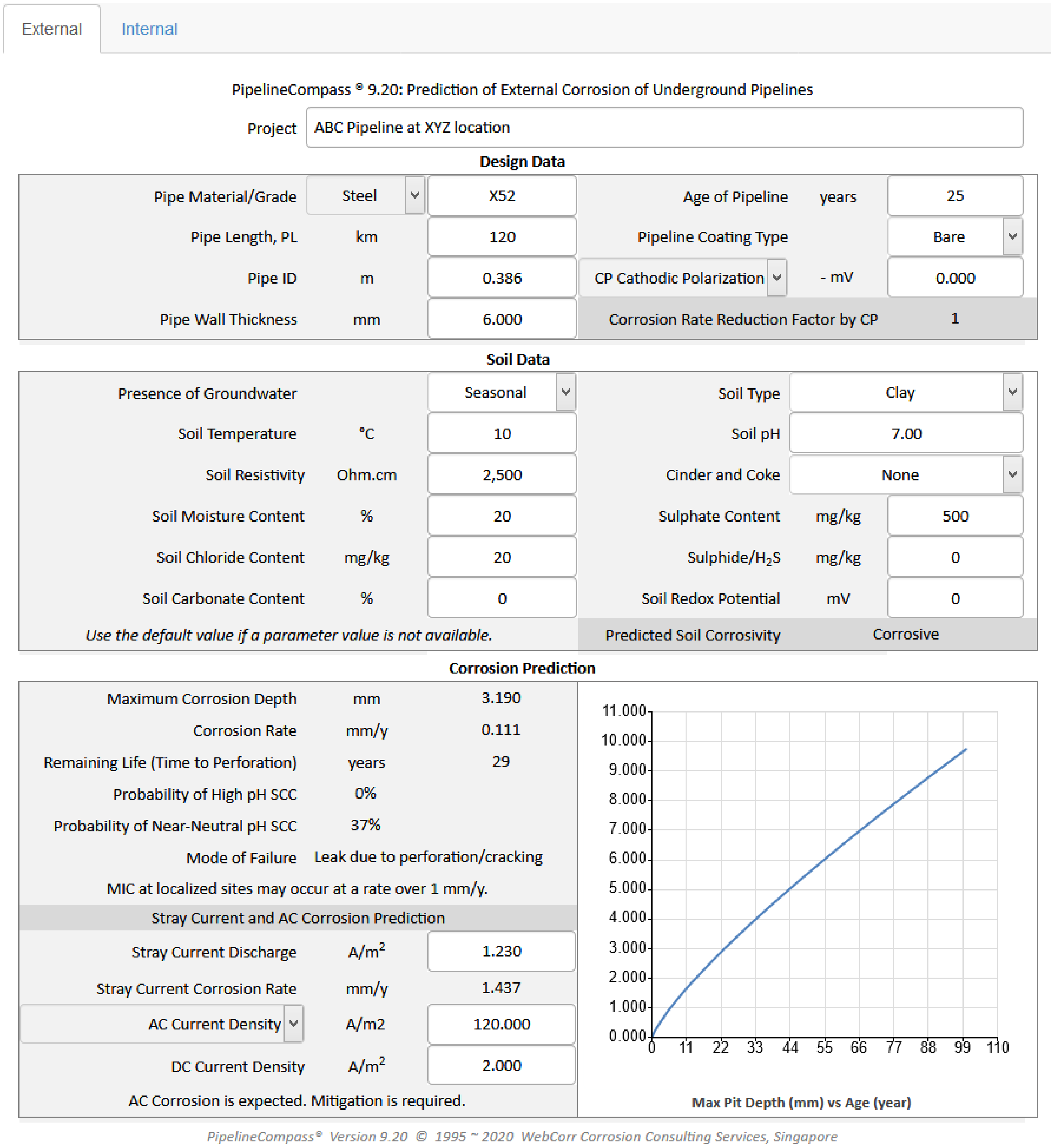


Figure 6 AC Corrosion Prediction with Pipe AC Voltage to Remote Earth as Input

SC-Compass is a highly recommended computer software package specifically designed for AC and stray current corrosion prediction, assessment and modeling. Click here for details on SC-Compass.

Applicability of Pipeline External Corrosion Prediction

External Corrosion of Underground Pipelines is due to corrosion reactions between the pipe material and the soil (groundwater and others). The contents inside the pipeline has no bearing on the corrosion reactions taking place on the external surface of the pipeline. For this reason, PipelineCompass is applicable to any buried/immersed metallic structures including oil and gas pipelines, drinking water pipelines, waste water pipelines, process piping, and also underground storage tanks. In essence, the external corrosion prediction engine in PipelineCompass is both a soil corrosion predictor and a cathodic protection optimizer. It is the only software that is capable of determining the residual corrosion rate when cathodic protection is ON (Figure 2).

Prediction of Pipeline Internal Corrosion

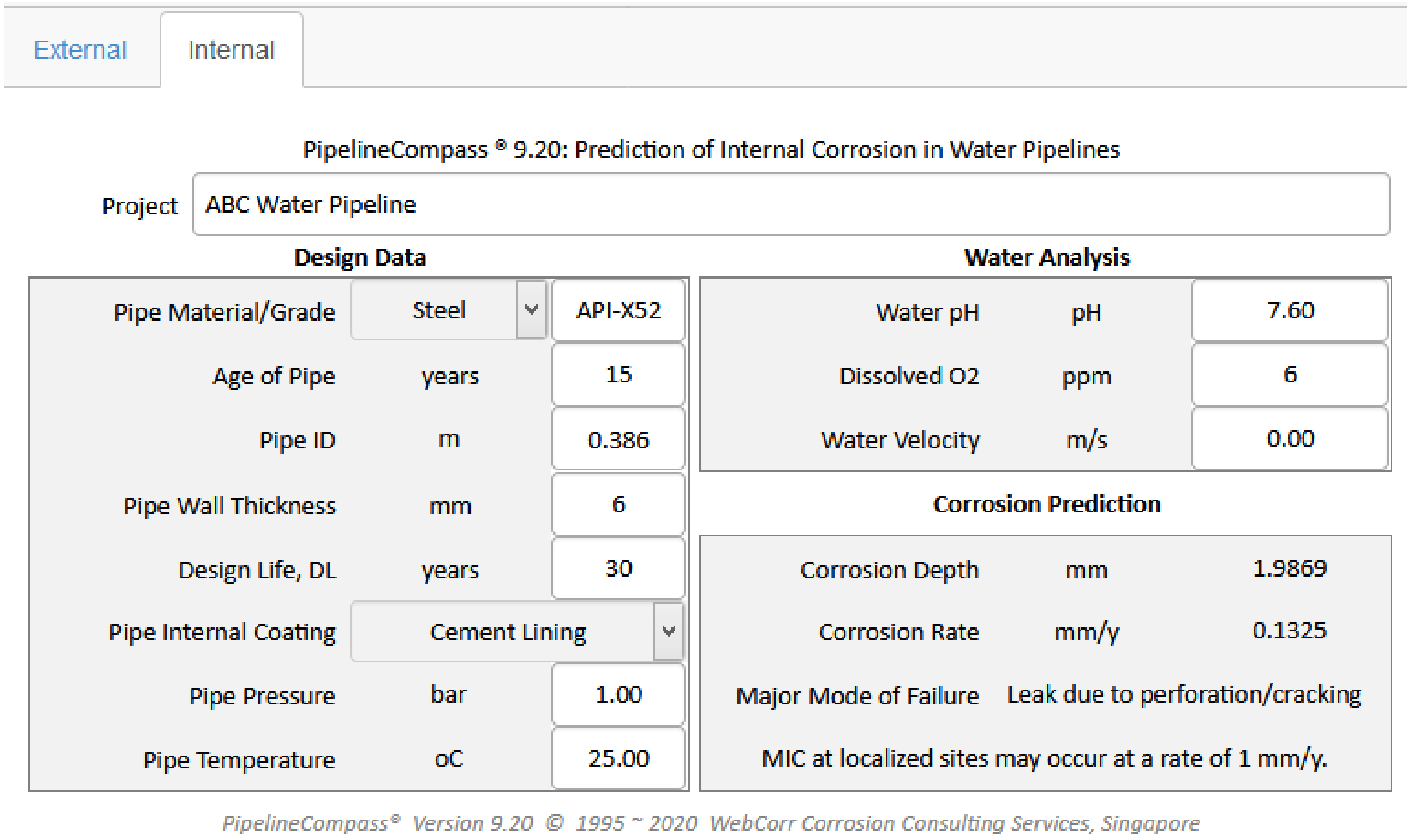


Figure 7 Prediction of Internal Corrosion of Underground Pipelines

The predictive engine for the internal corrosion from the water side models the effects of the following parameters (inputs) on the type and rate of internal corrosion:

Pipe material: cast iron, ductile iron, steel

Age of pipeline

Pipeline coating type: Bare, Cement Lining, Epoxy/Others

Pipeline Pressure

Pipeline Temperature

Water pH

Dissolved Oxygen in Water

Water Velocity

Based on the inputs of the design data and water analysis, PipelineCompass assesses the overall system by considering the combined effects of pipe material/age, type of pipeline coating, pressure and temperature, dissolved oxygen in water, water pH, and water velocity on the type and the rate of corrosion. The corrosion prediction outputs include:

The accumulated **Corrosion Depth**: this is the loss of pipe wall thickness **from the water side only** (Note that External Corrosion from the soil side will also result in loss of pipe wall thickness. The life of a pipeline will be determined by both external corrosion and internal corrosion. Figures 1-6 above show overviews of prediction of external corrosion).

Corrosion Rate: this is the internal corrosion rate computed at the current age and conditions of the pipeline (Figure 7). PipelineCompass gives users a powerful tool to evaluate the effects of temperature, oxygen, pH and water velocity on the rate of corrosion. For example, Figure 7 above shows the corrosion rate for steel is

0.1325 mm/y under stagnant condition (velocity=0 m/s). When the water velocity is increased to 1 m/s, the corrosion rate increases to 0.3183 mm/y (Figure 8 below).

External | Internal

PipelineCompass ® 9.20: Prediction of Internal Corrosion in Water Pipelines

Project: ABC Water Pipeline

Design Data

Pipe Material/Grade	Steel	API-X52
Age of Pipe	years	15
Pipe ID	m	0.386
Pipe Wall Thickness	mm	6
Design Life, DL	years	30
Pipe Internal Coating	Cement Lining	
Pipe Pressure	bar	1.00
Pipe Temperature	oC	25.00

Water Analysis

Water pH	pH	7.60
Dissolved O2	ppm	6
Water Velocity	m/s	1.00

Corrosion Prediction

Corrosion Depth	mm	4.7749
Corrosion Rate	mm/y	0.3183
Major Mode of Failure	Leak due to perforation/cracking	

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Figure 8 Prediction of Internal Corrosion of Underground Pipelines: Velocity Effect

Mode of Failure: this is the predicted major mode of failure IF a failure eventually occurs. The modes are burst or fracture under impact, or leak due to perforation (Figure 8).

Possibility of MIC at localized sites: PipelineCompass assesses the prevailing conditions for the possibility of microbiologically-influenced corrosion (MIC) (Figure 6).

Applicability of Pipeline Internal Corrosion Prediction

Internal Corrosion of Underground Pipelines is due to corrosion reactions on the internal surface of the pipe. The contents inside the pipeline has direct bearings on the corrosion reactions taking place on the internal surface of the pipeline. For any type of corrosion to take place, a threshold level of water must be present. No water, No Corrosion! The Internal Corrosion prediction engine in PipelineCompass is optimized for water pipelines or "dry" gas/process pipelines with oxygen being the major corrosion contributor. For oil and gas pipelines (multiphase or otherwise) that contain significant amount of CO2 (with or without H2S), a more specialized software called CO2Compass is available from WebCorr. In essence, the internal corrosion prediction engine in PipelineCompass is an oxygen corrosion predictor and water treatment optimizer.

Pipeline Corrosion Risk Assessment and Pipeline Integrity Management

PipelineCompass is an indispensable tool in pipeline corrosion risk assessment and pipeline integrity management program. The unique capabilities outlined above allow users of PipelineCompass to predict when, where, what type and how fast corrosion will take place. Predictive inspection and predictive maintenance are made possible by PipelineCompass.

Contact Us for Licensing Details.

PipelineCompass, giving you the right directions in the fight against Pipeline Corrosion.