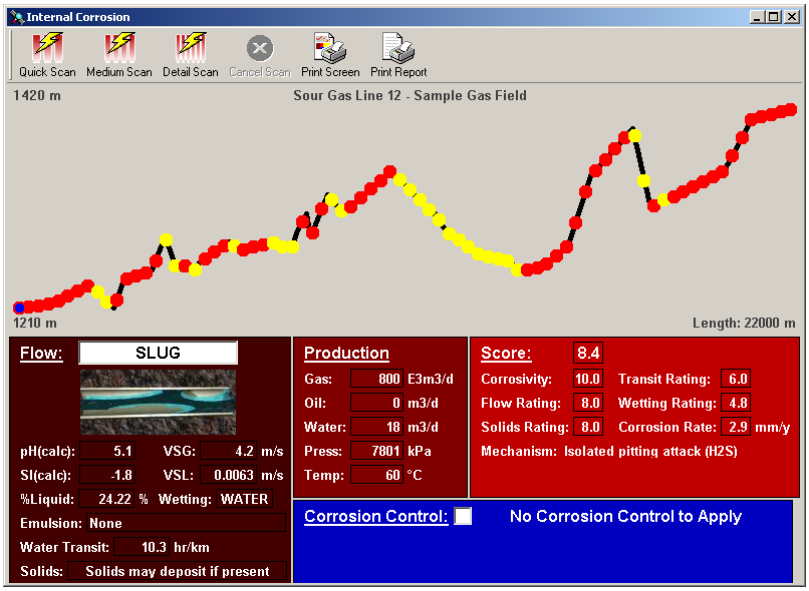
CorrosionWATCH accurately predicts where and when corrosion is likely to occur in oil and gas pipelines.

CorrosionWATCH is more than just corrosion, however: it is a one-stop solution for pipeline integrity management.

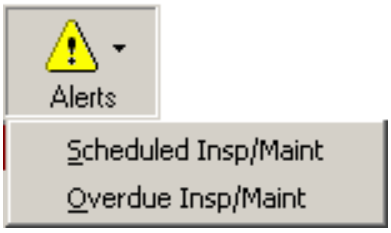
CorrosionWATCH: Key Benefits

Predict and Assess Internal Corrosion.

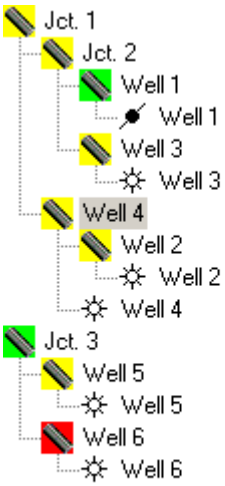
Using proven algorithms and accepted industry practices, CorrosionWATCH uses *your* data on *your* pipelines to assess and predict corrosion.



Schedule pipeline inspection and maintenance on a priority basis. CorrosionWATCH ranks pipelines according to the likely severity of internal corrosion…allowing you to prioritize inspections and maintenance on a rational, cost-effective basis.



Forecast results of pipeline maintenance. As you complete maintenance activities, CorrosionWATCH updates its corrosion assessments. Proper maintenance keeps corrosion assessments low; deferred maintenance on high risk lines raises assessments—triggering alerts.



Establish a central repository for pipeline conditions—from wellhead to plant.

The CorrosionWATCH database—in an easily updated, industry-standard format—integrates data across the system: from wellheads, to pipelines and junctions, to plants. (This production and composition data can be automatically loaded from existing accounting systems and analysis reports).

Thus corrosion assessments are calculated from integrated data: chemistry, flows, and pipeline physical characteristics across the system.

Easily produce documentation for internal use…

and for regulatory authorities.

CorrosionWATCH automatically produces a range of reports, from pipeline inspection history and maintenance schedules, to the physical and chemical details of individual pipelines.


Reports

Print Export

CorrosionWATCH

8/25/2003 10:17:39 PM

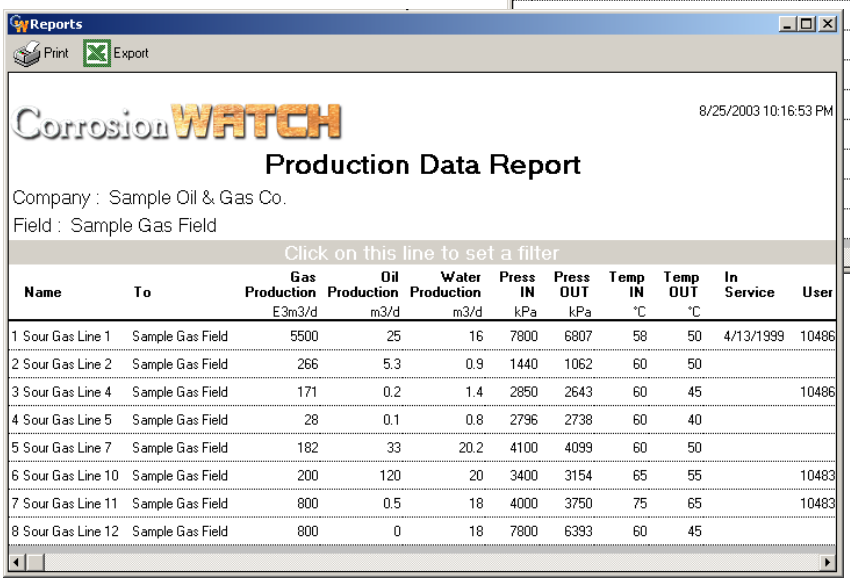
I/M Activities Report

Company : Sample Oil & Gas Co.

Field : Sample Gas Field

Click on this line to set a filter

	Name	Status	Scheduled	Scheduled Start Date	Completion Date
1	Sour Gas Line 1	Pig (Remove Solids)			
2	Sour Gas Line 1	Batch Inhibition			
3	Sour Gas Line 1	General Inspection			
4	Sour Gas Line 1	General Inspection			
5	Sour Gas Line 1	General Inspection			
6	Sour Gas Line 1	General Inspection			
7	Sour Gas Line 10	Pig (Remove Solids)	6/28/2000		6/23/2000 1:47:30 PM
			6/21/2000		6/22/2000 1:47:22 PM
			6/28/2000		6/28/2000 1:48:50 PM
					6/30/2000 1:49:24 PM
			6/10/2000		6/12/2000 1:51:40 PM
			7/7/2000		6/30/2000 1:52:50 PM
			6/14/2000		
			6/7/2000		
					6/30/2000 1:53:24 PM


Reports

Print Export

CorrosionWATCH

8/25/2003 10:16:53 PM

Production Data Report

Company : Sample Oil & Gas Co.

Field : Sample Gas Field

Click on this line to set a filter

	Name	To	Gas Production E3m3/d	Oil Production m3/d	Water Production m3/d	Press IN kPa	Press OUT kPa	Temp IN °C	Temp OUT °C	In Service	User
1	Sour Gas Line 1	Sample Gas Field	5500	25	16	7800	6807	58	50	4/13/1999	10486
2	Sour Gas Line 2	Sample Gas Field	266	5.3	0.9	1440	1062	60	50		
3	Sour Gas Line 4	Sample Gas Field	171	0.2	1.4	2850	2643	60	45		10486
4	Sour Gas Line 5	Sample Gas Field	28	0.1	0.8	2796	2738	60	40		
5	Sour Gas Line 7	Sample Gas Field	182	33	20.2	4100	4099	60	50		
6	Sour Gas Line 10	Sample Gas Field	200	120	20	3400	3154	65	55		10483
7	Sour Gas Line 11	Sample Gas Field	800	0.5	18	4000	3750	75	65		10483
8	Sour Gas Line 12	Sample Gas Field	800	0	18	7800	6393	60	45		

Designed for Customization

Although CorrosionWATCH is used successfully by many firms 'out-of-the box', the program has been designed with a modular system architecture that allows us to customize it for your specific needs.

Let Our Experience Take You to the Front Lines of Corrosion Management

Our program's corrosion assessment engine is the industry's best. Tell us about your experience in corrosion analysis, and we can add it in for you.

Different firms operate in different environments, with different production, plant, corrosion and maintenance histories. CorrosionWATCH can fine-tune and focus its predictive abilities to your specific field conditions.

Features to Tailor CorrosionWATCH to Your Needs:

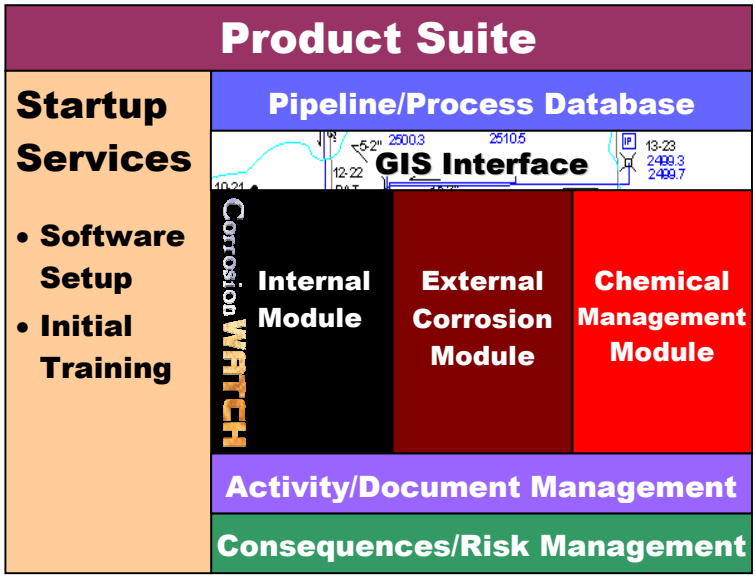
Integrate any scientific routine

Connect to any SQL database

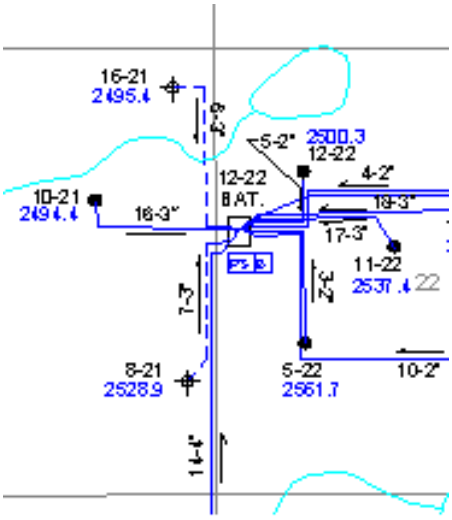
Edit and store any form of data

Multiple language support

Produce customized documentation



A Complete Suite of Products and Services, Out-of-the-Box, and Customizable, to Assess Pipeline Corrosion.

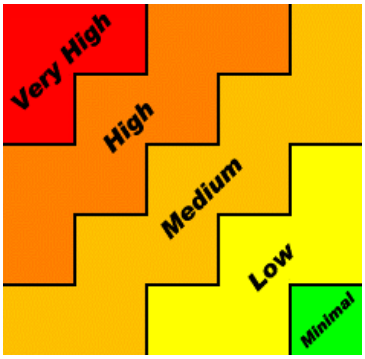


Geo-Referencing:

Use GIS to track hard-to-find, buried and mobile assets. CorrosionWATCH overlays your pipeline vectors onto imagery from up-to-date aerial rasters.

Just read the GPS coordinates from the CorrosionWATCH screen, and drive to the exact location.

Consequences: expand your pipeline rating paradigm beyond corrosion—include environmental, human and financial consequences in your risk assessments.



Services

CorrosionWATCH services start with turnkey solutions, including PL100 validation, data gathering/loading and field mapping.

If you don't have the pipeline data necessary for CorrosionWATCH to produce predictive analysis (and if you don't, you're not in compliance with regulations), then we will put in place the people you need for this task.

Follow-up service providing detailed assessment and support for inspection and maintenance are available.

CorrosionWATCH 2002 User Manual

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A One-Stop Solution to Assess and Control Internal Pipeline Corrosion

CorrosionWATCH is a highly predictive software tool that determines where corrosion is likely to occur in oil & gas pipelines. Based on proven algorithms and widely accepted industry practices, CorrosionWATCH uses data on oil & gas production and pipeline characteristics to identify potential corrosion.

The program easily scales from a company with dozens, to thousands of pipelines.

Proven Predictive Ability

CorrosionWATCH has been rigorously field tested for over 5 years on hundreds of lines with known failure history. This extensive field testing on sour and sweet oil and gas lines ensures that theory matches reality. A demonstration database containing many of these real cases is included so you can see the data for yourself.

Ease of Use

CorrosionWATCH color codes at-risk areas, making it easy for anyone to interpret results, regardless of technical skill in the corrosion arena. The product creates a graphical "side-view" of your pipeline that is color-coded (red/yellow/green) for immediate recognition of high risk areas. At the click of a mouse at any point on the pipeline, it also displays flow, production, and corrosion assessment information for that specific point.

Corrosion information includes predicted likelihood scores, corrosion mechanisms and corrosion rates.

Advanced Predictive Features

CorrosionWATCH allows you to play out 'what-if' scenarios of inhibitor programs or varying pig effectiveness and instantly see the effect, color-

coded, on your pipeline. A simple check box allows you to apply these maintenance programs on-the-fly to graphically show their real effect.

Historical conditions can form a pattern for prediction. CorrosionWATCH automatically updates a complete history record for each pipeline every time a corrosion scan is performed. Using these past records as a reference, you can easily identify historical conditions that may be in fact be creating your problem. Long-term use of CorrosionWATCH develops this historical catalog and provides the key to a comprehensive corrosion management strategy. Over time an even stronger correlation to specific issues in each field can be built, and the influence of changing operating conditions can be quickly and effectively identified. CorrosionWATCH even reduces the chance of oversight with user-defined thresholds and automatic alerts that can be set to notify you when high risk areas reach unacceptable levels.

Self-Documenting

From its database, CorrosionWATCH self-compiles a range of reports, including:

- Detailed physical descriptions of the entire pipeline network.
- Corrosion probability assessments.
- Pipeline data on production and chemicals, oil and gas composition, etc.
- Inspection and maintenance alerts.
- Inspection and maintenance history.

This feature can greatly simplify in-house management reports, as well as regulatory reporting.

Licensing

CorrosionWATCH is a licensed product.

The downloadable demo from our Website is a fully functional version, complete with a sample database, which you can evaluate for 30 days after installation. Upon purchase of a license, we will e-mail a key to you that will activate the product to provide you with full functionality during the license period.

To order a license, click Setup on the CorrosionWATCH menu bar, then click License, and License Request. We will send you the license, and product activation instructions.

Support

We offer standard, and extended support.

Standard support, which includes help in installation, configuration, data entry and interpretation, is via phone and e-mail, during North American business hours.

For customers outside of our local area, our real-time troubleshooting feature simplifies support requests and accelerates solutions. To send automatically generated technical information about your issue to our support group, click Help on the CorrosionWATCH menu bar, then Technical Support, then Email CorrosionWATCH Support. We will diagnose your problem and contact you with a solution. Any data you send will be kept confidential, and used for support only.

You may desire extended support for your mission-critical installations. We can provide it.

Overview

This section shows you how to login, and presents the basic design of the interface.

Logging in

Your databases are protected with user-level security. At your first login, after choosing your database and typing in your Login Name, the program will ask you for your password (if you prefer not to use the security feature, just leave the password field blank).

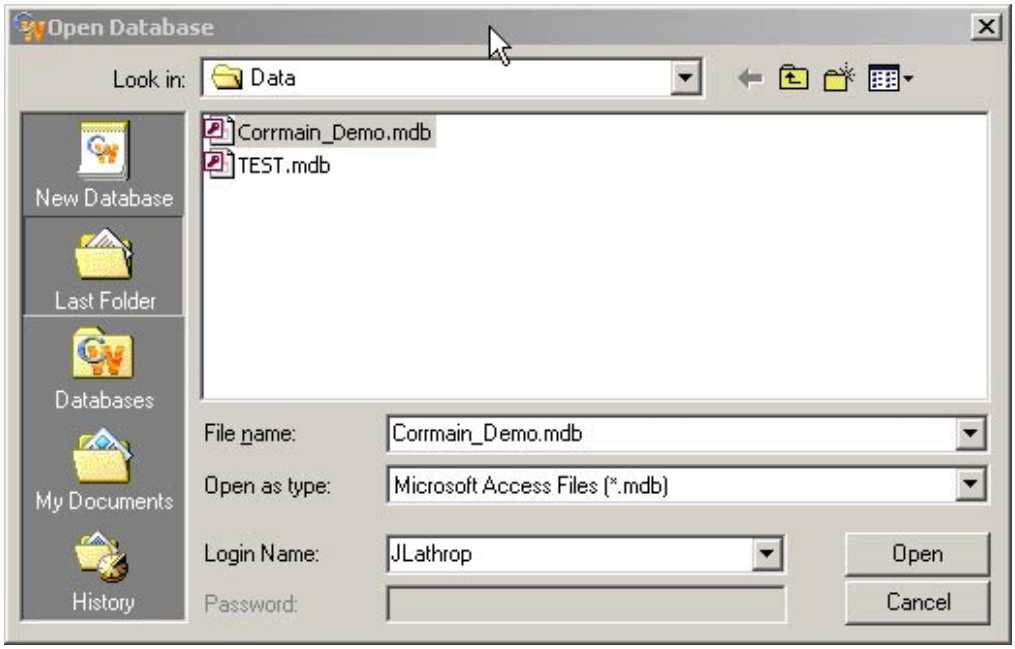


Fig 1: Login Screen, with a Database Selected.

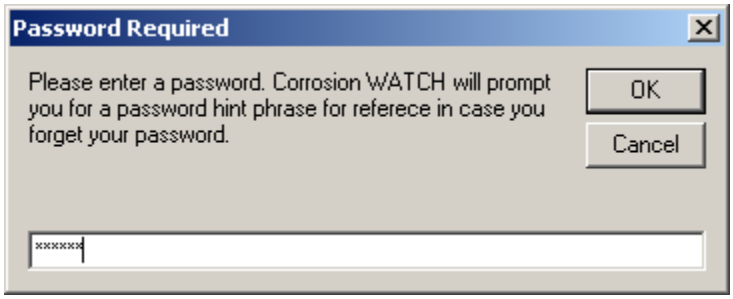


Fig. 2: Entering Your Password.

It will then prompt you to reenter your password, and again prompt you for a 'hint' to display, to assist you in recalling the password in the future.

Choosing a Unit of Measurement

At this point you are prompted to choose your preferred unit standard, either Metric (Canada), or Imperial (US). Enter the number corresponding to your preference. Then click Open, agree to the disclaimer, and the program will start.

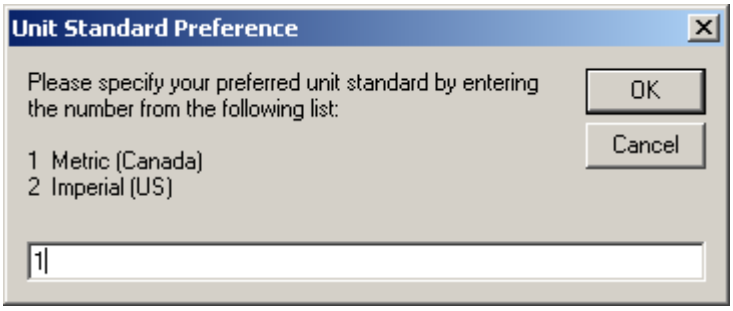


Fig. 3: Choosing Your Unit of Measurement: Metric or Imperial.

A Familiar Windows Interface

The CorrosionWATCH interface is designed to be both familiar, and as intuitive as possible. The program uses the standard Windows Toolbar and Menu Bar paradigms, with drop-down menus and a tree-view panel on the left. The large data-view screen on the right presents pipeline data in an easy-to-read, tabular view, and menus to choose which facility data to view: basic or advanced, gas/oil composition, injected chemicals, etc.

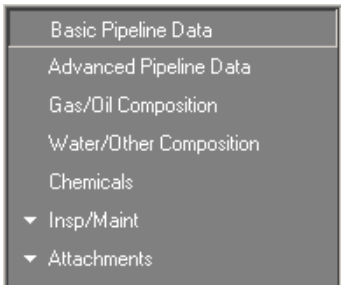


Fig. 4: Menus in the Data-View Screen.

Common Tasks

Typical first steps, upon starting the program, are to:

1. Click on the appropriate Company and Field drop-down menus to access desired company and pipeline information.
2. Use the Tree View to select a specific junction, pipeline or well.
3. Choose to view or edit pipeline data using the menus in the data-view screen.
4. Use the included Cormain_Demo database to practice these tasks.

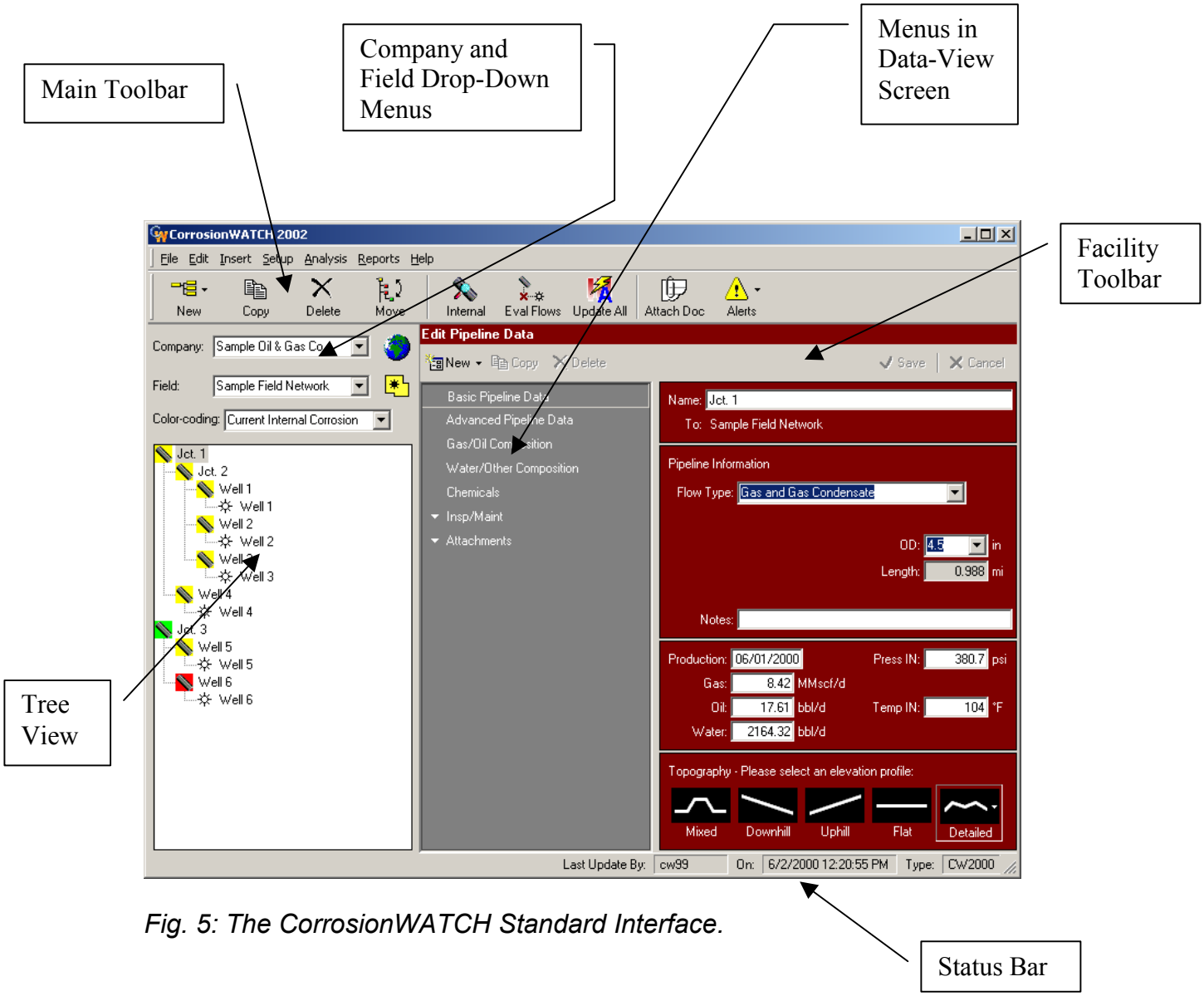


Fig. 5: The CorrosionWATCH Standard Interface.

Color-coded Data

To assist in immediately identifying the data level at which you are working, CorrosionWATCH color-codes the different levels of the pipeline network: companies, fields, junctions and pipeline, and wells.

The colors and their levels are:

Purple…….Company
Turquoise……Field
Red-brown…..Pipeline
Yellow……Well
Orange……Chemical Injection

In addition, internal corrosion probability is also color-coded, so that pipelines with high probability assessments can be immediately identified. The colors and their levels are:

Low probability assessment……Green
Moderate probability assessment…..Yellow
High probability assessment…….Red

Using CorrosionWATCH

More detailed instructions on how to use the program follow.

Adding a New Database

An entirely new database can be created, first by saving a new database, and then adding data to it.

Click on File on the menu-bar, and New. Either accept the default name for the new database, or type in your own, and click Save.

Adding and Editing Company Information

A new company can be added to the database by clicking on the New icon on the main toolbar, choosing Company, and typing in the new company's name.

You can edit information on an existing company by first selecting it in the company drop-down menu, and then clicking the adjacent Edit Company Record icon. CorrosionWATCH automatically saves your changes in all edit screens; optionally, you may click Save on the facility toolbar.

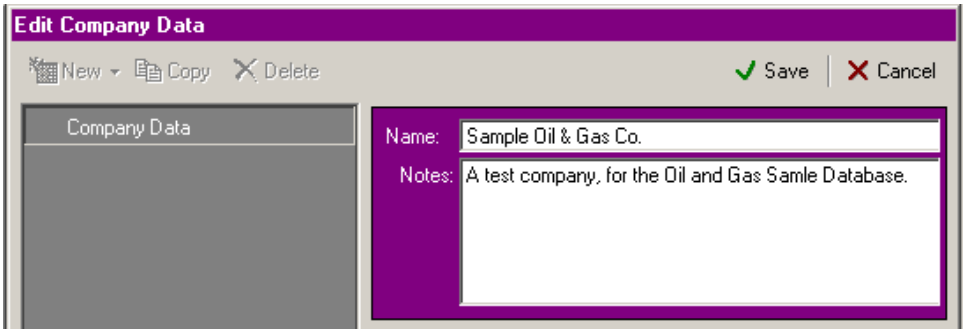


Fig. 6: Editing Company Information.

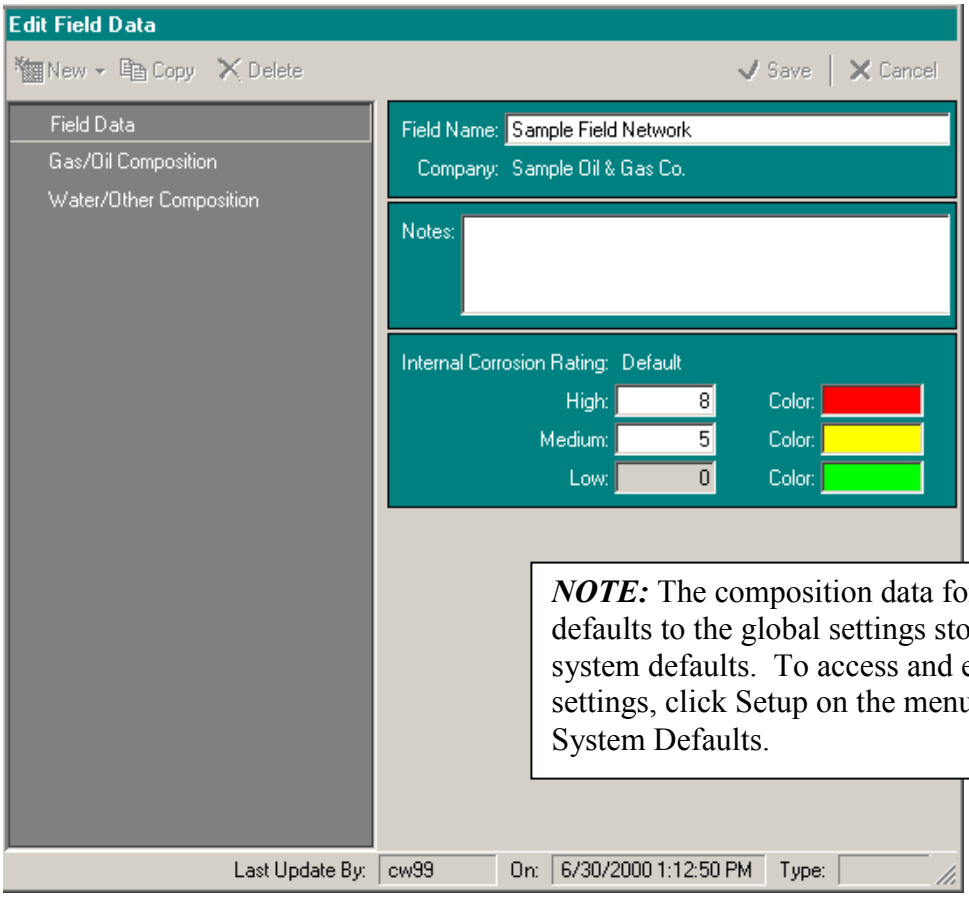
A company may also be deleted from the database by clicking the Delete icon on the main toolbar.

Adding and Editing Field Information

All fields are attached to their company record, and may have multiple pipeline records attached. Most of the data in the field record is gas, oil and water composition data that sets default values for pipelines attached to that field. See the section below titled *Updating Composition Information* for more information.

To add a new field, click on the New icon on the main toolbar, choose Field, and type in the new field's name. To edit an existing field, first select it in the field drop-down menu, and then click on the adjacent Edit Field Record icon.

The levels that determine the corrosion rating level—low, medium, or high—can be adjusted for each field.



NOTE: The composition data for a new field defaults to the global settings stored in the system defaults. To access and edit the global settings, click Setup on the menu bar, then System Defaults.

Fig. 7: Editing Field Data.

You may delete a field by clicking the Delete icon on the main toolbar after previously removing all related pipeline and well record.

The Most Important Data: the Pipeline

The level below the field is the pipeline, but in CorrosionWATCH, this is the most important level, holding the most critical data for corrosion analysis.

Adding and Editing Pipeline Information

To add a new pipeline, click the New icon on the main toolbar, choose Pipeline, and enter the new pipeline's name. After entering the pipeline's data, make sure to select the elevation type. To edit data on an existing pipeline, select it in the Tree View and edit the information in the Edit Pipeline Data screen. Your changes are automatically saved as you make them; optionally, you may click Save on the facility toolbar.

Pipelines, like fields, can be deleted with the toolbar's Delete icon after previously removing all upstream pipelines and wells.

> ***NOTE***: Adding new pipeline records can be simplified by copying existing pipeline records that resemble the new records you wish to create. Use the Copy Record icon on the toolbar.

Basic and Advanced Pipeline Information

The Basic Pipeline Data view allows you to input the minimum data required in order to produce a first cut probability assessment. All data in the Basic view can be seen and updated in the Advanced view—the Advanced view allows additional and more detailed information.

To access any pipeline in Basic view, select the desired pipeline in Tree View, and then click on the Basic Pipeline Data menu in the data-view screen.

In this screen the emphasis is on production and pipeline topography. *Flow Type is critical: always use the same flow type for similar pipelines in a field.* Select the best fit from:

- Oil Emulsion—use this for liquid dominated flows.
- Gas and Gas Condensate—gas-driven flows.
- Sales Oil.
- Water.
- User Specified—contact us for a customized flow type tailored for your pipeline conditions.

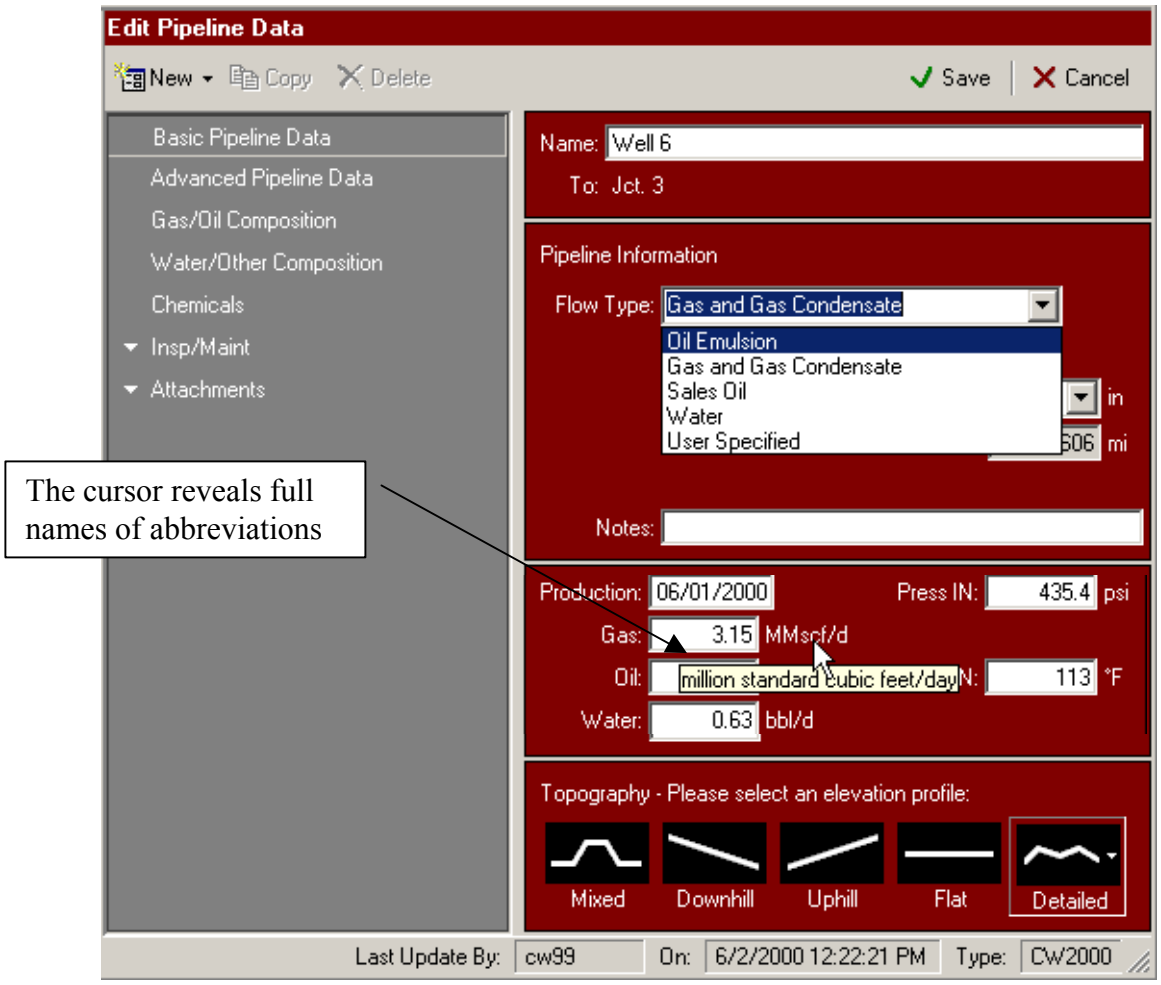


Fig. 8: Basic Pipeline Data View, Showing Flow Type Selection.

The Advanced view allows you to input and store more information for more detailed analysis of high risk lines. In particular, more pipeline metallurgical information in included.

In both views, pipeline topography may be selected. This can be a significant factor in corrosion analysis. You may choose one of four simplified elevation profiles, or you can produce a highly detailed data picture by importing data on chainage or XYZ elevation. Just click on the Detailed icon.

> ***NOTE:*** After importing detailed topography, the length field can no longer be edited. This is done to protect data integrity: segment lengths are summed to calculate the total pipeline length.

Updating Composition Information

To save time and effort, gas, oil and water composition may be maintained at two levels, field and pipeline. By saving a default composition at the field level, data at the pipeline level need only be changed where necessary.

To access the field defaults, click the yellow Edit Field Record icon (next to the Field Selector drop-down menu), and choose the Gas/Oil Composition or Water/Other Composition menus in the data-view screen. To enter or edit composition at pipeline level, choose a pipeline in Tree View, and select the identical menu items.

When a new pipeline is created, the composition information automatically defaults to its associated field default data.

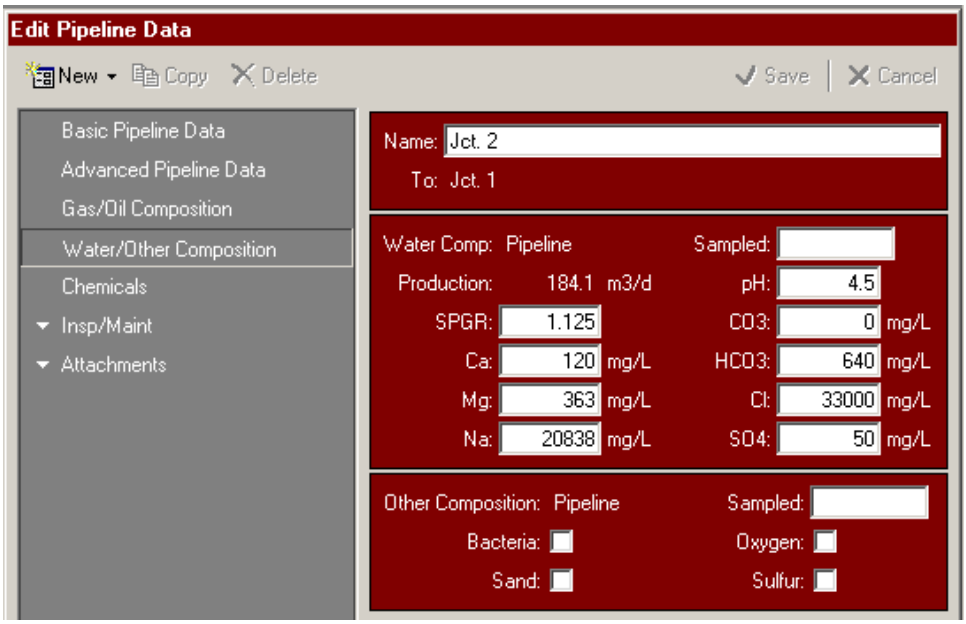


Fig. 9: Editing Water/Other Composition at the Pipeline Level.

Adding and Editing Well Information

To add a new well, click on the New icon on the toolbar, choose Well, and type in the new well's name. After entering the well's data—you will notice that gas, oil and water composition are already filled in to the defaults. To edit the data on an existing well, select the well to be edited in Tree View.

Wells, like pipelines and fields, can be deleted with the main toolbar's Delete icon. Well production is calculated on a monthly basis; the dates can be entered by double-clicking in the appropriate fields in the Production panel.

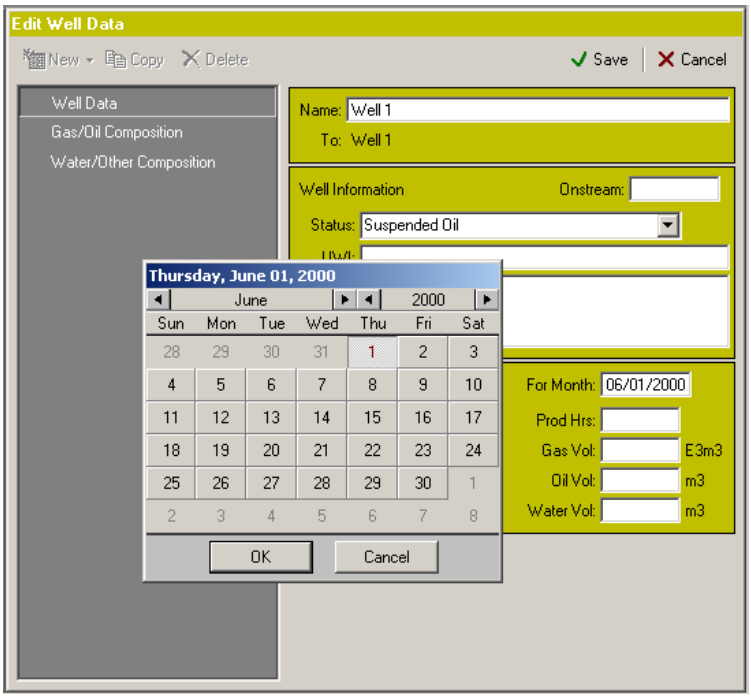


Fig. 10: Selecting the Date for Monthly Production Values.

You may select the well's status—the type of fluid or gas it is currently carrying—by clicking on the arrow at the right of the Status field (see Figure 11). There are eight different choices.

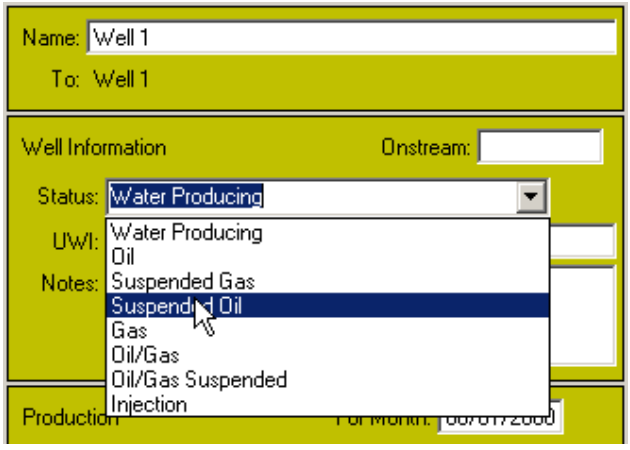


Fig. 11: Choosing the Current Well Status.

Attaching Documents

You may attach documents to the items in the CorrosionWATCH interface in a manner similar to e-mail attachments. In this way, documents such as Word documents or Excel spreadsheets can be linked with their associated data, and opened at will.

Click the Attach Doc icon on the main toolbar. Use the standard Windows technique to find the correct folder and file, and click on the Attach button.

Double-click on the document in the Attachments box to open it. All Windows file types, including executables and Internet Shortcuts are supported.

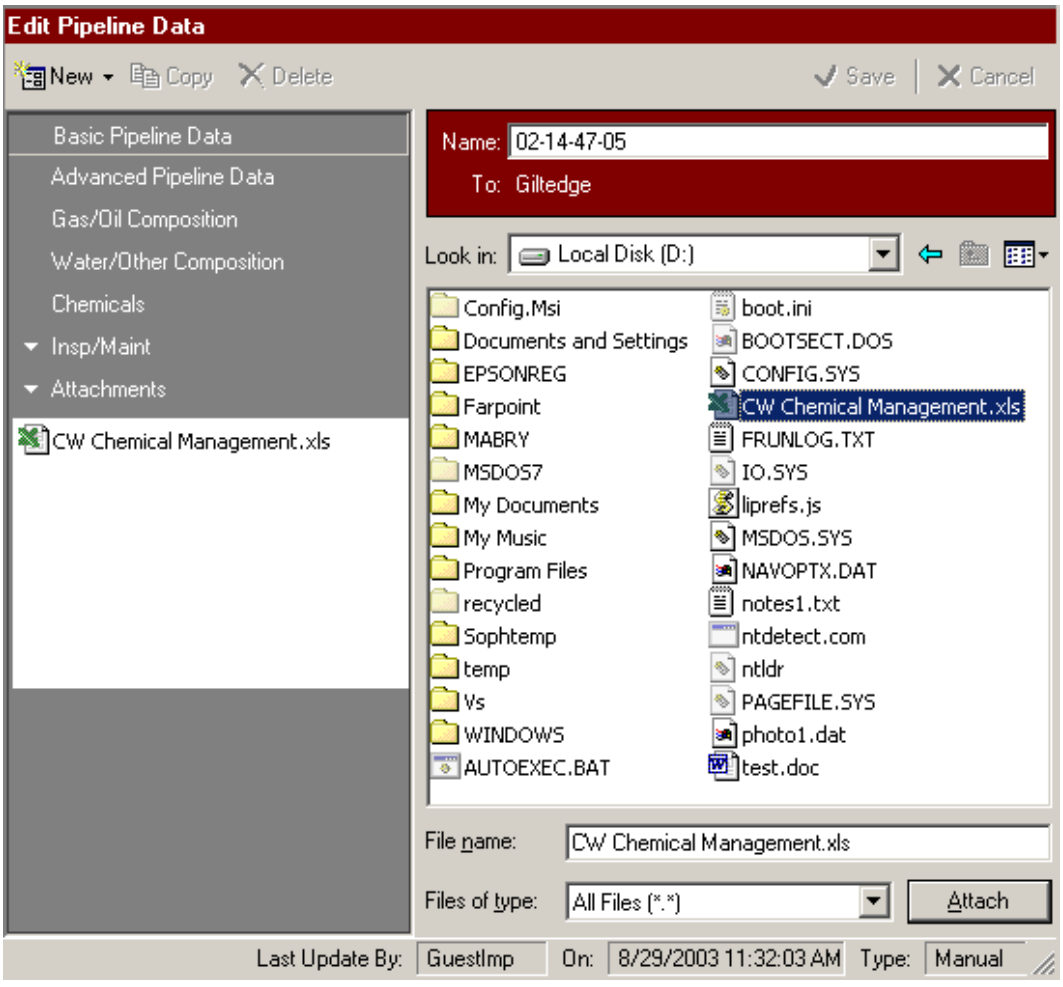


Fig. 12: Using the Attach Document Facility.

Viewing Pipelines: the Internal Corrosion Screen

Visual representation is always the most direct way to pinpoint a problem.

CorrosionWATCH uses the data you input to produce a visualization—a visual schematic—of your pipelines. Detailed elevations, color-coded risk areas, and visual keys to describe flow conditions and potential problems all aid in quickly identifying potential corrosion.

Access the Internal Corrosion screen by clicking on the Internal icon on the toolbar, or clicking on Analysis on the menu bar and selecting Internal Corrosion.

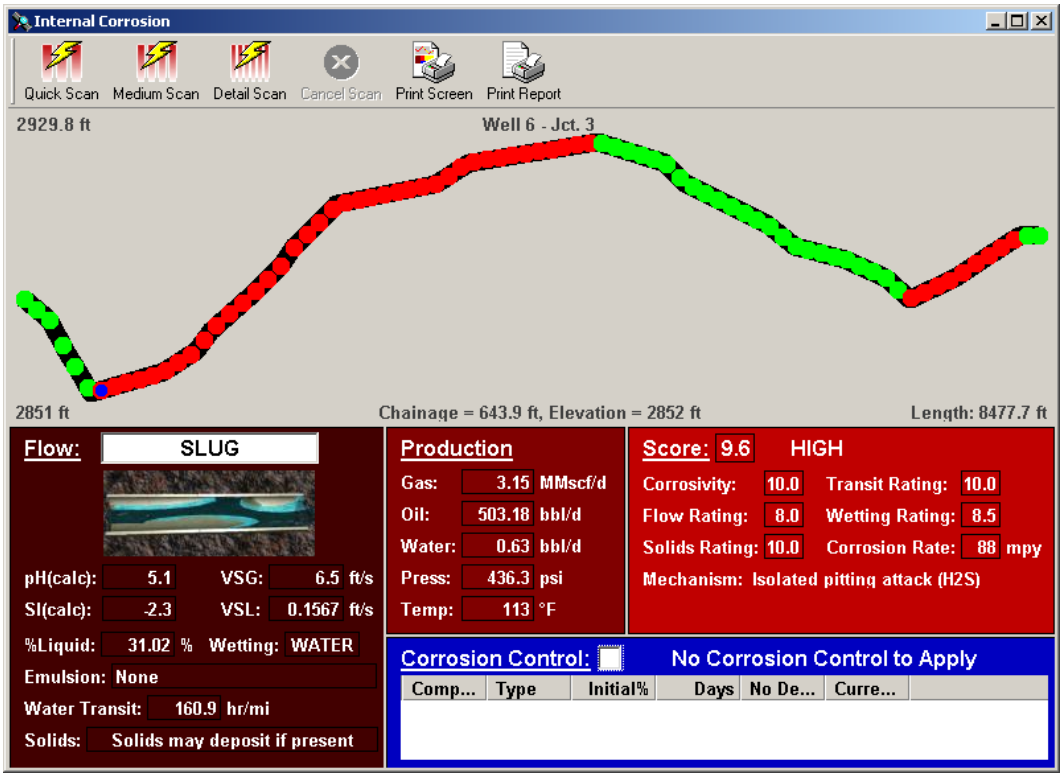


Fig. 12: The Internal Corrosion Screen, Showing a Detail Scan of a Pipeline with a High Corrosion Risk Assessment.

Scanning for Corrosion Probability

When first opened, the pipeline in the internal corrosion screen will be colored black. You can run an analysis of flow, production and corrosion probability score on any part of the pipeline by simply clicking on that part with your mouse. The active point in indicated by a + sign.

The entire pipeline can be scanned for corrosion probability by clicking one of the scan buttons on the top of the screen: Quick, Medium, or Detail. The detail scan's default is 80 intervals along the length of the pipeline, but you can enter several hundred, or even thousand intervals if you wish—the only limits are your time and your machine's processing power. When the scan is complete, the results are displayed as color-coded dots along the length of the pipeline.

At the completion of the scan, the point at the start of the highest corrosion probability score is indicated by a blue dot.

> ***NOTE***: A complete pipeline scan is the easiest method to quickly identify problematic sections of pipe. And a modern computer should be able to rapidly assess most pipelines, even at a much higher number of intervals than the 80 default for the detail scan.

Probability is reported on a 1 to 10 scale—the highest risk is 10. Scores are calculated based on velocities, flow conditions and corrosivity. The default color-code scheme is:

Red……. 7.5 to 10
Yellow……5. to 7.5
Green……..0 to 5

The internal corrosion screen itself, or a detailed report, can be printed out by clicking the appropriate icons on the toolbar.

Viewing Corrosion Assessment Calculations

Corrosion assessments are calculated from flow characteristics, flow chemistry, and pipeline data, and how they all interact. Although corrosion assessments come in countless variations, an example can be instructive.

In the Flow window below (Figure 14), from the Internal Corrosion window of an oil pipeline, a SLUG flow pattern is predicted for the section indicated by a blue circle in Figure 13.

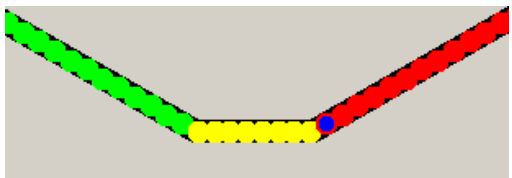
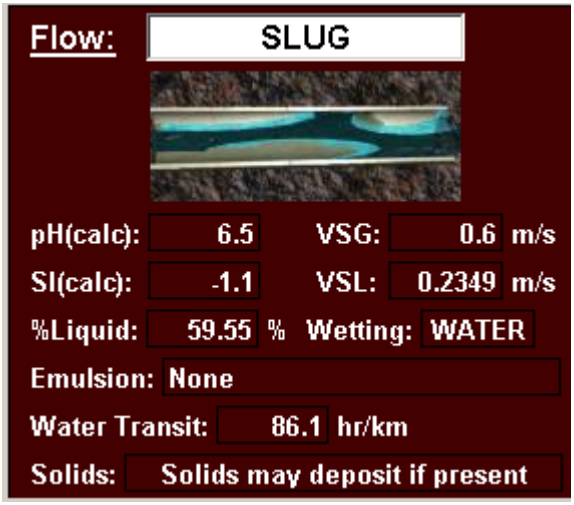


Fig. 13: Blue Indicates the Beginning of a High Corrosion Risk Area.



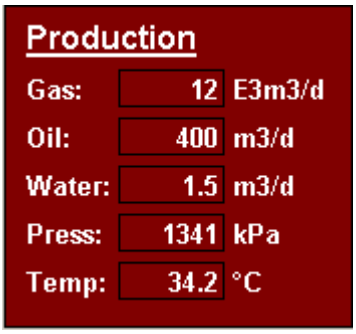


Fig. 15: Production Values.

Fig. 14: Slug-type Flow Predicted.

In this example, velocity, elevation, and the relative viscosities of the fluids coursing through the pipeline make it doubtful that all water will be swept from the line. Stagnant pockets will probably be formed, hence 'Wetting: WATER'. The pH is determined using composition data; in this case it is acidic: pH 6.5. The water's movement is particularly slow, but given the other factors—including elevation—it is predicted that solids may deposit. (Water Transit is the inverse of velocity: larger values indicate slower flows).

More operating conditions are displayed in Figure 15, and the final probability score in Figure 16. In this case the score is quite high—the selected area of the pipeline is at real risk of corrosion. It is important to note that values in all three fields are updated every time a new point on the pipeline is clicked.

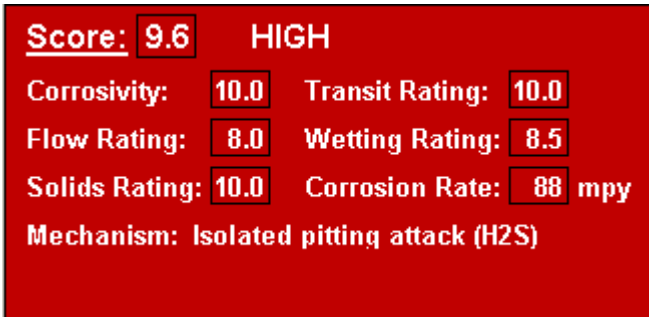


Figure 16: Final Probability Score, and Other Corrosion Ratings.

Applying Maintenance Programs to Pipelines

Records of maintenance can be entered by clicking the New button on the Facility toolbar in the Edit Pipeline Data window, and choosing either Pig (remove solids) or Batch Inhibition. Records of inspection can be entered into the database using the same method, selecting General Inspection. Figure 17 shows a record of batch inhibition, on a well which also has records of inspection and pigging.

> ***NOTE:*** Detailed forms for tracking other types of activities can be tailored to fit your corporate inspection and maintenance programs—see the section on customization, on page three.

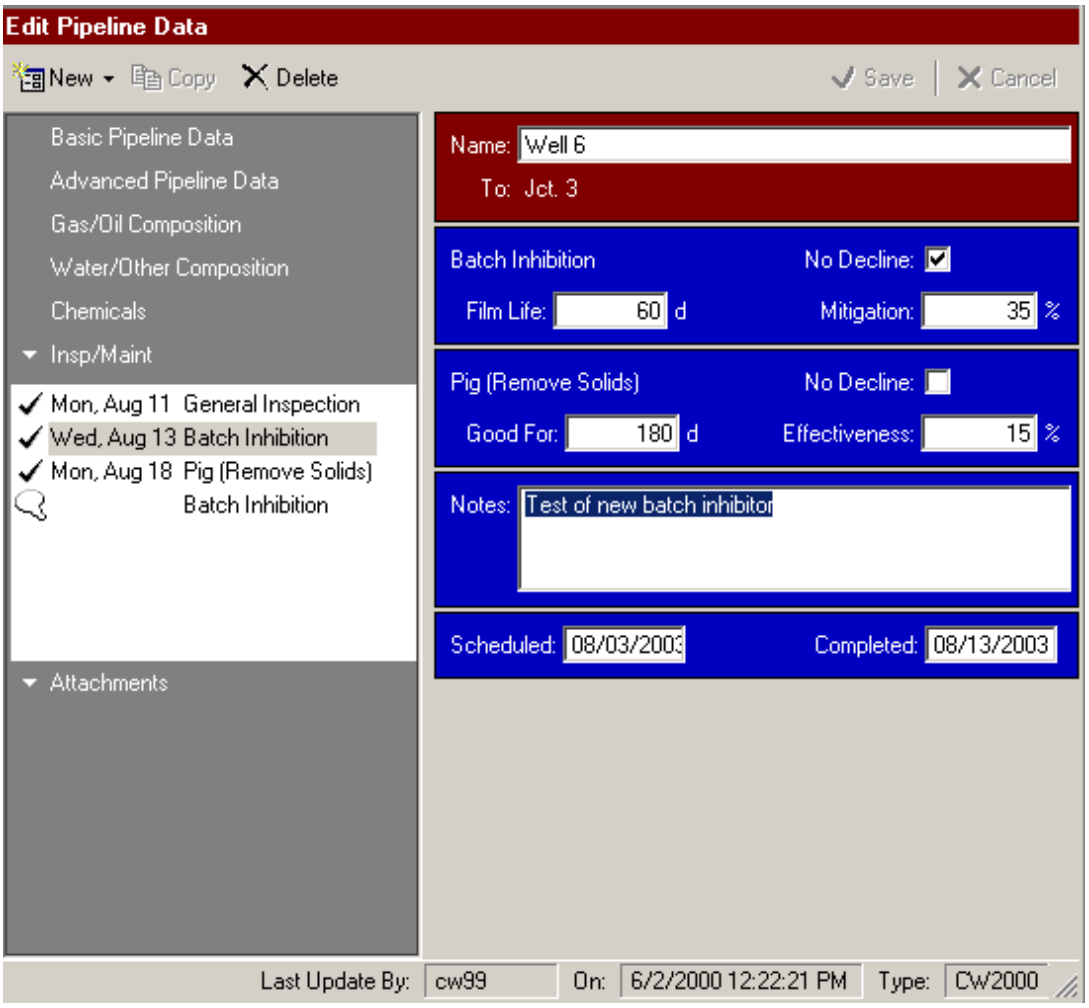


Fig. 17: Records of Inspection and Maintenance.

The Good For (time interval), Effectiveness (initial value), and Completed Date boxes ***must be filled in,*** for the effects of maintenance to be calculated as corrosion control. Checking the No Decline box will maintain the initial value for the time interval specified; initial values are ramped *down to zero* over the time interval unless the No Decline box is checked.

The user inputs the estimated effectiveness of any maintenance procedure. This estimate should always come from a trusted source, usually as the result of experimental research or field investigation. Different types of maintenance will have a varying effect depending on pipeline conditions. Inhibitor, for instance, affects corrosivity rates but has little affect on other factors. Pigging affects solids, but loses its effect over time as they are redeposited.

Updating All Corrosion Scores

Clicking the Update All icon on the main toolbar is a one-click way to update all corrosion assessments in the current field. The mitigating effect, if any, should be apparent in the Corrosion Control window, as in Figure 18.

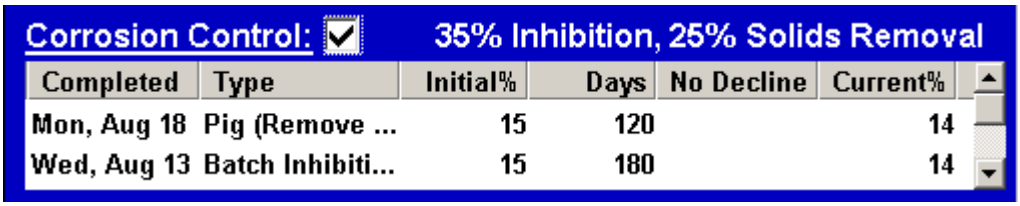


Fig. 18: A Successful Maintenance Intervention.

Viewing Corrosion Assessment Results

The effects of maintenance—and a lack of maintenance—can be seen across the entire well and pipeline network, by use of the Color-Coding pull-down menu just over the Tree View panel. You may choose from three settings, to observe how your maintenance procedures are making a difference:

- Current Internal Corrosion—controlled score if present, otherwise inherent
- Inherent Internal Corrosion
- Controlled Internal Corrosion

In each case, color-coding will show the wells and pipelines most at risk, and the effect of your maintenance procedures.

Enabling Production Flows

While setting up or editing your pipeline and well data, CorrosionWATCH tracks distinct 'evaluation' flow and composition records for each pipeline, irrespective of the upstream production values. Use this feature to examine 'what if' scenarios for individual lines.

Before calculating corrosion probability scores in a production environment, click on the Flow Status icon on the toolbar (Figure 19), to replace the evaluation flows with production flows. The evaluation flows are not lost; they are recorded in the historical database.

Fig. 19: The Flow Status Icon, Having Switched From Evaluation to Production Flows.

This feature provides a quick and robust way to update connected pipelines in a field network with new production data (entered at the well level), providing management of change (MOC) and responsive analysis in a dynamic production environment.

Automated Reports

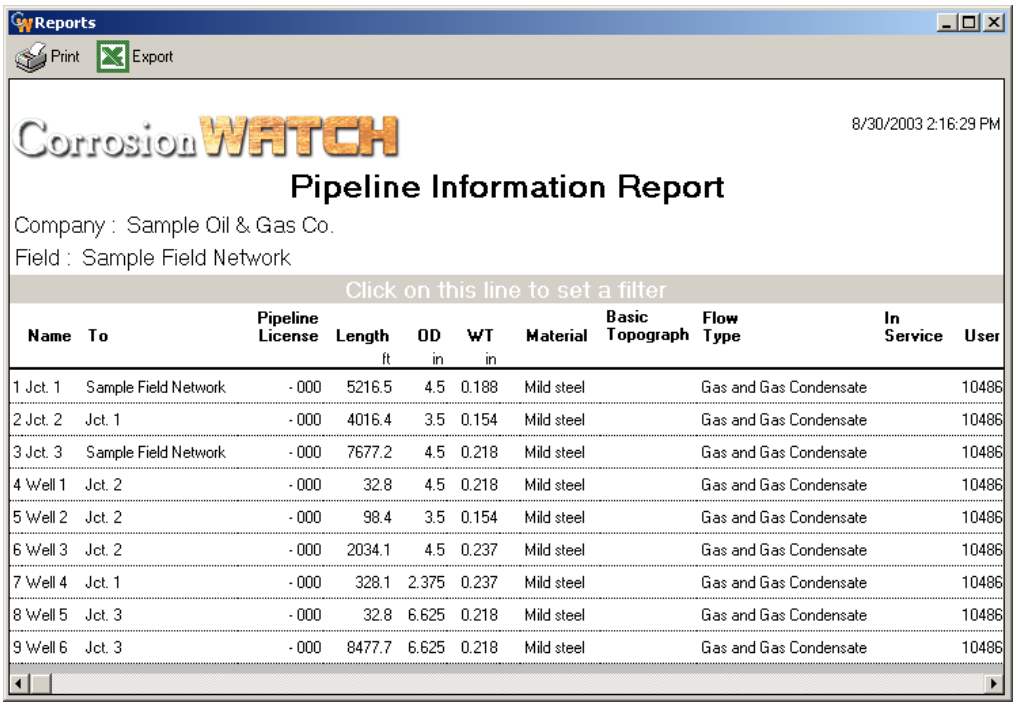
By clicking on the Reports menu on the menu bar, CorrosionWATCH offers to automatically generate nine different types of reports:

- Field Network
- Probability Results
- Pipeline Data: Pipeline Information
  Production and Chemicals
  Oil and Gas Composition
  Water Composition
- Alerts: Overdue Inspection and Maintenance
  Scheduled Inspection and Maintenance
- Inspection and Maintenance History

These reports are generated from the data you input, and from the program's corrosion assessment calculations. They can be assessed on screen, exported to an Excel spreadsheet, or printed.

Note that by clicking on a column header you may sort information by that column, and by clicking the 'set a filter' line, you may filter information by subsets.

Figure 20 shows a sample pipeline information report.



Name	To	Pipeline License	Length ft	OD in	WT in	Material	Basic Topograph	Flow Type	In Service	User
1 Jct. 1	Sample Field Network	- 000	5216.5	4.5	0.188	Mild steel		Gas and Gas Condensate		10486
2 Jct. 2	Jct. 1	- 000	4016.4	3.5	0.154	Mild steel		Gas and Gas Condensate		10486
3 Jct. 3	Sample Field Network	- 000	7677.2	4.5	0.218	Mild steel		Gas and Gas Condensate		10486
4 Well 1	Jct. 2	- 000	32.8	4.5	0.218	Mild steel		Gas and Gas Condensate		10486
5 Well 2	Jct. 2	- 000	98.4	3.5	0.154	Mild steel		Gas and Gas Condensate		10486
6 Well 3	Jct. 2	- 000	2034.1	4.5	0.237	Mild steel		Gas and Gas Condensate		10486
7 Well 4	Jct. 1	- 000	328.1	2.375	0.237	Mild steel		Gas and Gas Condensate		10486
8 Well 5	Jct. 3	- 000	32.8	6.625	0.218	Mild steel		Gas and Gas Condensate		10486
9 Well 6	Jct. 3	- 000	8477.7	6.625	0.218	Mild steel		Gas and Gas Condensate		10486

Fig. 20: Automatically Generated Pipeline Information Report.

Appendix

Interpreting Risk Assessments

The most significant cause of pipeline failure is internal corrosion.

CorrosionWATCH provides pipeline operators with a tool for increasing their understanding of actual pipeline operating environments and determining the general corrosivity of the producing fluids along each pipeline. The operating environment often results in the creation of localized areas of high susceptibility to internal corrosion. CorrosionWATCH is designed to identify these conditions and the location along the pipeline to facilitate the management of the internal corrosion potential.

Corrosion Probability Factors

Use of CorrosionWATCH as a diagnostic tool provides ratings for each pipeline in one these aforementioned categories with the numerical assessment of individual operating parameters as outlined below:

Flow Pattern

CorrosionWATCH calculates the flowing conditions in each pipeline with detailed modeling of each pipeline making it possible to define flowing conditions through the entire length of each pipeline.

Flow patterns that result in continuous contact of the liquid phase with the pipeline are most conducive to internal corrosion development. Flow patterns such as stratified flow are particularly troublesome because they fail to impart any significant mechanical agitation of the liquid phase, which may assist in oil wetting, solids movement, and/or corrosion inhibitor distribution.

Liquid Hold Up Volumes

CorrosionWATCH calculates the volume of the liquid carried in the pipeline with the use of industry accepted flow calculations (2-phase - gas and liquid modeling). The amount of liquid in the pipeline and the flowing conditions are required to estimate the potential for oil and water phase separation.

Surface Wetting Characteristics

The potential for water wetting in pipelines is of critical importance in determining the likelihood of internal corrosion. When pipelines become water

wet, the water provides the electrolyte required for corrosion process initiation. If there is no water wetting of surfaces, the pipelines will not deteriorate form internal corrosion processes.

Calculation of wetting tendency relies on an understanding of the emulsion forming potential of the crude oil phase, the physical characteristics of both oil and water phases, and the flowing conditions in the pipeline. The estimation of wetting potential reflects the ability of the crude to carry the water phase in a semi-stable dispersion or emulsion under the flowing conditions in the pipeline. This is largely a function of oil phase viscosity, differences in specific gravity of the two phases, and to lesser extent, the surface tension existing between the flowing phases. For low corrosion probability, the actual flowing conditions must be sufficient to support the suspension of the water phase as the internal phase in the formed flowing emulsion as calculated in terms of shear stress level.

Correlation to actual operating conditions is enhanced with the use of an "Emulsion Tendency" factor to allow the CorrosionWATCH user to adjust the emulsion forming tendency to reflect actual inspection and testing results. The emulsion tendency factor should be reduced to 1 or 2 when demulsifiers or other surface active agents that promote water wetting are used. When a particularly stable emulsion is produced, setting the emulsion tendency to 9 or 10 may be required to accurately reflect actual pipeline wetting conditions.

When the flowing and physical conditions within the pipeline do not provide for the formation of a flowing water-in-oil emulsion, a separate and distinct water phase will form. This is a significant event creating the necessary surface required for internal corrosions - the occurrence of water wetting.

Water Transit Rates

The movement of the water phase is provided in two forms by CorrosionWATCH. The first method is the velocity of the water phase as shown on the detailed topographic assessment. The second is the velocity converted to a rate speed expressed as hours per kilometer of distance down the pipeline. The second measurement is generally referred to as the water transit rate.

Historical investigation of operating conditions in pipelines finds that corrosion processes often result from high water washing rates when weak corrosion product scales are formed (iron carbonate scales at operating temperatures of less than 60 C). In sweet systems (no H2S corrosion scales formed), rapid water transit rates such as < 0.2 hours per kilometer may indicate high velocities capable of corrosion product film removal and accelerated corrosion.

Conversely, high likelihood of internal corrosion is also experienced when stagnant water pockets form - particularly in the presence of H2S and the formation of iron sulfide corrosion product films. In these stagnant conditions, corrosion cell formation occurs as anodic and cathodic areas polarize. When iron

sulfide films form under highly dynamic conditions, initiation of the corrosion process does not occur as quickly - although in some cases this can be attributed to increased effectiveness of film forming corrosion inhibitors. In systems where iron sulfide scales form, water transit rate of > 9 hours per kilometer should be avoided (if possible). Where these stagnant conditions are encountered, maintenance activities such as pipeline pigging or use of batch applied corrosion inhibitors may be required to prevent premature pipeline failure.

Stagnant water pocket formation can be particularly troublesome in systems prone to solids deposition.

Solids Deposition

Deposition of solids suspended in the produced fluids in pipeline poses a significant threat to the integrity of the pipeline system. Deposition creates local environments with increasing potential for corrosion initiation. The collection of solids may preclude the effectiveness of corrosion control measures such as film forming corrosion inhibitors. Crevice corrosion may result from chloride concentration and produce acidic conditions far more corrosive than the bulk fluid composition. In the presence of depolarizing agents such as oxygen, high rates of pitting may be encountered beneath deposits.

When solids are encountered in production systems, pipeline efficiency can be lost as deposition occurs. This results in increasing pressure drops across pipelines with deposition.

Maintenance activities such as periodic pipeline pigging will assist in removing solids to provide efficient pipeline operation and long service life.

Water Phase Corrosivity of the produced water can be estimated under the flowing conditions along each pipeline with the data available in CorrosionWATCH. The compositional data provides an accurate representation of basic water chemistry and acid gas loading. The mineral content of the water may provide some buffering of the acidity imparted by the dissolution of the acid gases into the water phase at operating pressures and temperatures.

Highly acidic conditions are possible in many pipelines. The acidity of produced fluids is provided as a calculated pH in the detailed assessment mode. Caution should be exercised by the producer when pH of less than 6.5 are encountered.

Corrosion Rate Estimation

CorrosionWATCH converts the acidity of the produced water to provide an estimate of corrosion rate at the operating pressure and temperature along each pipeline. These corrosion rates reflect potential rates of acid attack in the absence of any corrosion control program. When high operating temperatures are encountered, accelerated corrosion rates may result.

Corrosion Mechanisms

No assessment of internal corrosion can be considered complete without some discussion of potential deterioration mechanisms. The understanding of these corrosion mechanisms is required to adequately plan inspection and control measures to reduce likelihood of unanticipated internal corrosion in pipeline systems.

CorrosionWATCH identifies several common corrosion mechanisms found in oilfield pipeline systems. Many of these mechanisms will serve to accelerate corrosion rates beyond the estimated acid attack rate provided by CorrosionWATCH.

Particular caution should be exercised in the following conditions:

- The presence of oxygen when solids deposition may occur requires immediate attention. The potential for rapid pitting attack beneath solids is very high. Oxygen will generally not travel very far in a production system as the oxygen reacts when water wet conditions are first encountered.
- Localized attack can occur in sweet systems where high water flow rates are found or when acidic corrosion rates are unacceptable.
- Isolated pitting of sour systems is particularly a concern when stagnant water pockets form. Inspecting for isolated pitting attack can be challenging and requires careful review of location along the pipeline and inspection technique
- Corrosion rates can be accelerated when crevice corrosion occurs and maintenance activities should address these situations, particularly when highly corrosive brines already exist in the system.
- Corrosive bacteria are present in many systems. While the influence of micro-biologically influenced corrosion (MIC) is still under study, the ability of a biofilm to accelerate corrosion rates is generally accepted. The acceleration of corrosion rates results form the life cycle of the bacteria as well as the formation of acidic environments beneath the biofilm. Significant bacteria are generally regarded as sulfate d reducing bacteria (SRB), acid producing bacteria (APB), and iron bacteria.
- In western Canada, many sour gas production systems are encountered. While most systems with significant liquid hydrocarbon production operate without element sulfur deposition, some reservoirs contain sour gas with little liquid hydrocarbon content. In these systems, deposition of elemental sulfur can produce highly corrosive conditions. In the area of the sulfur deposits corrosion rates of 17 mm/y are reported indicating highly acid conditions and the depolarizing influence of the sulfur compounds. The extreme pH conditions encountered near the deposit are often too severe for effective use of corrosion

inhibitors. Mechanical removal of sulfur with periodic pipeline pigging and judicious use of corrosion inhibition is required.

- Methanol is used for hydrate control in many systems. Methanol also increases internal corrosion potential in pipeline systems. Methanol carries oxygen and is a source of oxygen ingress into production systems. Methanol with high oxygen levels also degrades (with time) to produce weak organic acids that accelerate rates of attack. In some sour gas systems, corrosion in the upper portion of the pipeline has been attributed to condensation of methanol. The presence of methanol is reported to alter the generally protective nature of iron sulfide corrosion byproduct and produce a weaker porous and unprotective scale. Distribution of water dispersible corrosion inhibitors does not occur under some flow patterns and corrosion of the upper quadrant of the pipeline can result in each pipeline.

Likelihood Scales for Internal Corrosion

The scale of values has been corrected to produce a rating between 0 and 10. The following categories are produced:

- 7.5 to 10 - high likelihood of internal corrosion
- 5 to 7.5 - moderate likelihood of internal corrosion
- 0 to 5 - low likelihood of internal corrosion

The use of assessment values in ranking pipelines occurs in the basic assessment phase to reduce the scope of detailed assessment recommended for the user. After detailed assessment is completed, specific area of interest are identified along each high risk pipeline.

Inspection Planning

CorrosionWATCH identifies the most significant area of risk in a pipeline system for the user to investigate. Reducing the scope of investigation is possible by focussing on the areas of highest susceptibility. Areas of suitable access are obviously preferrable when they have similar operating conditions as identified “hot spots” along the pipeline right-of-way.

Pipeline right-of-way surveillance should be reviewed to minimize the potential impact of a release until inspection of the pipeline can be completed. Many inspection options are available to the producer and vary from self-contained intelligent pigging tools to excavation and non-destructive testing of sections of the pipeline. Verification of pipeline wall thickness is the best way to confirm pipeline integrity.

Use of corrosion monitoring devices such as hydrogen foils, corrosion coupons or electrochemical corrosion rate monitoring probes is encouraged with placement of these devices focussed on areas of high corrosion likelihood.

Iterative Assessment

Use of inspection results in the correlation of CorrosionWATCH is very important . The use of inspection results in providing accurate prediction of corrosion rates and calibrating the emulsion forming tendency of crude in oil pipelines must be emphasized. As the user begins to understand the dominant deterioration mechanisms and rates in the pipeline system, the risk assessment module can be updated to provide the most accurate reflection of corrosion potential for assessment of all pipelines. The user can get tremendous value for the investment in inspection or corrosion rate monitoring with the use of CorrosionWATCH.

Pipeline Maintenance Practices

The pipeline operator will provided with and in-depth understanding of pipeline operating conditions by using CorrosionWATCH. The influence of maintenance activities on internal corrosion occurrence must be reviewed. Locations of deposition of suspended solids should have periodic pigging to prevent accelerated attack by crevice corrosion mechanisms. The use of appropriate cleaning pigs is advised to ensure proper sealing of the pig against the pipeline and to ensure efficient use of the hours invested by operating personnel in completing pigging of pipelines.

The commissioning of pipelines and decommissioning during production outages should also be reviewed to reflect the potential for any retained fluids to initiate corrosion processes in the pipeline.

Upon completion of assessment with CorrosionWATCH, a review of pipeline operating procedures is advised to ensure maintenance activities are appropriate for operating conditions in the pipeline system. Optimization of activities is anticipated in many systems.

Corrosion Control Measures

Various forms of corrosion control are available for the pipeline operator. The most common include use of pipeline liners or application of corrosion inhibitors. When replacing corroded pipeline segments, use of nonmetallic materials is possible in many applications. Specialists should be consulted prior to the implementation of any program and to review selection of the most economic alternative.

External Corrosion Assessment

CorrosionWATCH provides full data storage from the pipeline design including records of external pipeline coatings and levels of cathodic protection applied to the pipeline during operation. While no specific assessment has been developed for external corrosion prediction, cathodic protection surveys can provide indication of areas of coating damage or external pipeline corrosion for inspection. External corrosion defects can be monitored using the data storage features of CorrosionWATCH.

Ongoing Assessment

Periodic updating of production rates, pressures, and temperatures is advised. CorrosionWATCH will review the significance of the changing conditions against the setting in the auto alert. If a significant variation in output is identified, CorrosionWATCH will notify the technical person responsible to ensure the control program can be reviewed to reflect the change in conditions.

Understanding the Corrosion Assessment View

The correlation of system parameters to the incidence of corrosion failure permits the use of predictive assessment of system conditions to indicate the location of highest susceptibility to corrosion failure along a pipeline or among a group of pipelines. The methods used in CorrosionWATCH are based on experience of the makers of this program and the correlative studies done during the development of the logic sequences.

The importance of correlating the system conditions with the incidence of pipeline corrosion or failure in each individual system cannot be under-emphasized. The requirement for continual improvement and correlation of assessment techniques is essential for the reliable use of CorrosionWATCH as a predictive tool in each production system.

Corrosion assessment involves the numerical assignment of values for different operating conditions as a measurement of the severity of the conditions. Operating conditions are reviewed in each of several categories including water wetting, stagnant water pocket formation, corrosion rate potential, etc. Numerical values are assigned to reflect each of these parameters in individual lines. The summation of these values reflects varying levels of likelihood that corrosion failure will result in a pipeline.

Evaluation of the potential for internal corrosion occurrence in a pipeline begins with assessment of operating conditions. The flow conditions in the pipeline and the characteristics of fluids produced through the pipeline are of particular importance in determining the likelihood that internal corrosion will occur.

Flow Modeling

A thorough understanding of the flow of media through the pipeline is required. Flowing conditions often change along the route of a single pipeline and localized conditions can make some areas along the pipeline more likely to experience corrosion than other areas. Identification of these flow conditions and locations along the pipeline with high susceptibility to corrosion is one the primary functions of CorrosionWATCH.

Basic Flow Patterns

CorrosionWATCH uses a two phase flow model (gas and liquid) to estimate the basic flow patterns of liquid and gas moving through the pipeline. Seven basic patterns of flow reflect the way that the process fluids move in the pipeline:

- **Single Phase** - The pipeline is completely full of either liquid or gas.
- **Stratified** - This occurs at low gas and liquid velocities. The liquids tend separate from the flow and collect along the bottom of the line. Stratified conditions exist when there is litle turbulence associated with the liquid phase or the liquid/gas interface. Significant liquid holdup may occur in low lying areas when this flow pattern is present.
- **Wave** - At moderate gas velocity and low liquid velocity, wave flow results. This flow condition is characterized by the formation of "waves" on the surface of the interface between the liquids and gas as the velocity of the gas phase increases. The increased gas velocity reduces the relative amount of liquid found in the pipeline but liquid holdup may still reach 25% of the pipeline volume.
- **Mist** - At high gas phase and low liquid phase velocity, the liquid phase will be distributed within the gas phase as a mist or spray. The liquid hold up in this pattern is relatively small (< 5%).
- **Bubble** - At low gas and moderate liquid velocities, gas can be present in the system as "bubbles" in the liquid phase. Liquid holdup in this conditions is high, as the majority of the pipeline will contain liquid in this flow pattern.
- **Slug** - At moderate gas and liquid velocity, intermittent movement of liquid and gas phases occurs. The slug pattern characterizes the alternating production of gas and liquid phases that occurs when gas velocity exceeds that found in the bubble flow patterns. The collections of liquid at the base of inclined segments along the pipeline often moves up the inclined segment of the pipeline in this manner. The alternating nature of this flow can result in only periodic movement of the liquid. The amount of liquid holdup can vary with higher liquid loading indicating fluid movement is more frequent and lower liquid volumes indicating the slug formation is less frequent.
- **Dispersed Bubble (Froth)** - When gas velocity is low and liquid velocity is high, the gas phase becomes distributed in the liquid phase. Liquid holdup volumes are very high and the liquids tend to dominate the characteristics of the flow.

Wetting Tendency

CorrosionWATCH estimates the potential for hydrocarbon wetting using the fluid characteristics identified in the input data and the liquid phase velocity through the area of liquid holdup along the pipeline. The tendency to form oil wet surfaces is calculated on the basis of the ability of the hydrocarbon liquid phase to

suspend the water phase. This is based on the physical characteristics of each phase and the level of shear stress found at the interface level expected to result under actual flowing conditions.

The calculations are based on the determination of the “Critical Velocity” required of the hydrocarbon phase to suspend droplets of the water phase from the oil/water interface. When the hydrocarbon velocity is insufficient to suspend the water phase, the water phase forms a separate distinct layer and water wetting of the lower portion of the pipeline results.

The assessment of wetting is adjusted to reflect actual experiences within the system - based on the emulsifying tendency displayed by the produced hydrocarbon.

Water Phase Flow Characteristics

Internal corrosion in multiphase pipeline systems has been most severe when stagnant pockets of water form along the bottom of the pipeline. The formation of a distinct water phase in the pipeline assures water wetting of the surface of the pipeline but may or may not reflect a high potential for pipeline corrosion.

Highly dynamic conditions, specifically in the presence of H2S can often result in low corrosion rates. However, low water phase movement rates often result in increased rates of corrosion as anodic and cathodic areas form and the corrosion process is initiated. The lack of movement in stagnant packets of fluid contributes to deposition of suspended solids and may result in changing corrosion mechanisms accelerating corrosion rates due to the local environment created in the based of the water pocket.

Review of the Effect of Water Chemistry

As the pressure and temperature of produced fluids change across the system, the corrosiveness of these fluids is also changed.

The acidity of the produced fluids can be calculated by widely accepted means and is reflected in the calculated pH produced by CorrosionWATCH. The lower the pH, the more corrosive the system is expected to be. High corrosion rates are commonly experienced when pH drops below 6. A pH between 6 and 7 may cause mild acidic attack. When the pH is above 7, corrosion is not expected to be a significant problem.

The scaling tendency of the produced fluids can be estimated along the pipeline. As seen with pH, changing pressure and temperature across the system will change the amount of dissolved minerals the produced water can carry. When fluids are under-saturated, corrosion may occur. When the produced fluids reach saturation or if a supersaturated condition exists, corrosion is less likely and scale formation may occur.

Expected Corrosion Mechanisms

The assessment of internal corrosion of the pipeline system must include assessment of the mechanism by which corrosion is expected and an understanding of the deterioration that is most likely to occur. In many cases, corrosion mechanisms can accelerate corrosion rates or produce localized conditions tha may not be reflected in the bulk of the produced fluids.

Developing the inspection plan or the control corrosion program requires and understanding of what is causing the deterioration and where the pipeline must be protected.

Settling of solids, the presence of bacteria, or presence of elements which can affect formation of stable corrosion product films must be evaluated in conjunction with flowing conditions to determine the effect along each pipeline. Corrosion mechanisms evaluated in CorrosionWATCH include:

- Oxygen pitting
- Acid attack - isolating H2S pitting
- Acid attack - localized CO2 attack
- Crevice corrosion
- Micro-biological influenced corrosion (MIC)
- Sulfur included pitting attack
- Methanol related attack

Calculating Corrosion Rate

The complex nature of corrosion makes accurate rate prediction difficult, and localized effects often hinder prediction of corrosion rates.

CorrosionWATCH estimates a corrosion rate that may exist based in acidic attack in the pipeline system. The acidic attack rate reflects relative corrosivity of the produced fluids under the given conditions. The calculated corrosion rate is devised considering the natural buffering provided by water chemistry, acid gas loading (O2, H2S, and CO2), operating pressures and temperatures.

The corrosion rate should be correlated with the corrosion rates experienced in actual system operating history and a correction function is provided for this purpose.

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