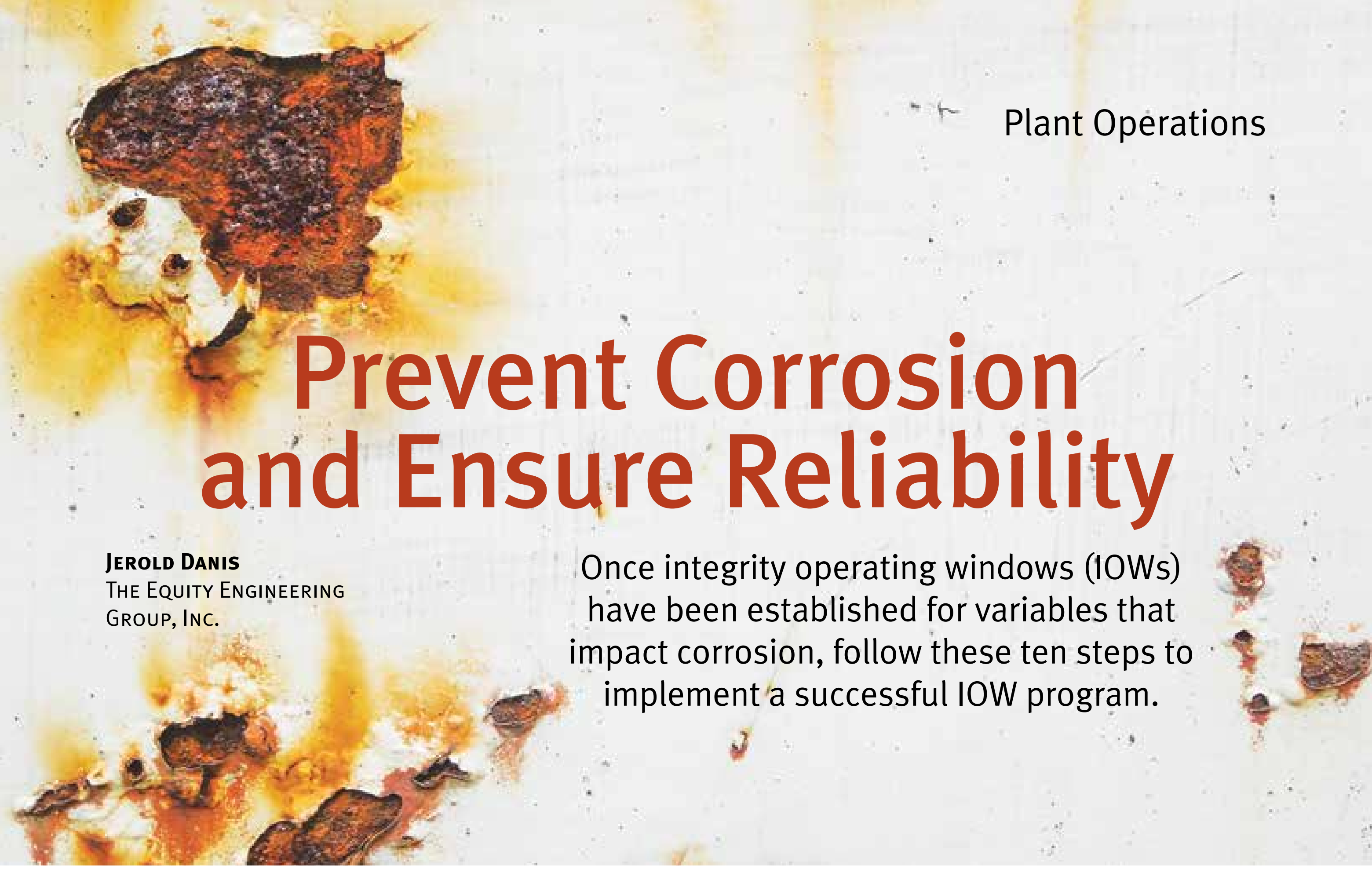

Prevent Corrosion and Ensure Reliability

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Once integrity operating windows (IOWs) have been established for variables that impact corrosion, follow these ten steps to implement a successful IOW program.

Most refineries and many of their process units are operating well beyond their design lives. Systematic unit inspections and, when required, repairs or alloy upgrades have helped to extend lifespans. Ensuring continued reliable operation is possible through stewardship of key operating variables, which can minimize the potential for unplanned downtime due to corrosion *(1, 2)*.

The American Petroleum Institute (API) Recommended Practice 584, “Integrity Operating Windows,” provides a basis for a program to monitor variables critical to reliability *(3)*. However, little information is readily available to help ensure successful implementation of an integrity operating window (IOW) program once the variables and their limits have been identified. This article presents a stepwise approach to facilitate IOW program implementation.

The need for integrity operating windows

Many refinery units are operating at higher throughputs and, in many cases, with feed slates that differ significantly from the original design. Over the past few decades, for example, units processing crudes have had to contend with increasing levels of sulfur and naphthenic acid. More recently, light tight oils from shale have introduced feed changes that can also contribute to unexpected corrosion.

Changes in refinery operations extend well beyond the upfront crude vacuum distillation unit. For example, crudes with higher nitrogen and sulfur content can promote the formation of higher levels of ammonia and hydrogen sulfide (H_2S) in hydroprocessing and fluid catalytic cracking (FCC) units. Ammonia and hydrogen sulfide can combine to form ammonium bisulfide (NH_4HS), which can cause sour-water corrosion. These contaminants can also impact units at the back end of the refinery, *e.g.,* amine units, sour-water strippers, and sulfur plants.

Slight fluctuations in operating conditions can also impact reliability. Changes to variables such as charge rate, operating temperature, pH, velocity, hydrogen partial pressure, and contaminants (in the unit feed or from process upsets) can accelerate corrosion rates and increase the potential for unplanned downtime.

API 584 prompts refiners to develop an IOW monitoring and sampling program for variables that impact corrosion. These programs have various names, including material envelope statements, material operating envelopes, and reliability operating limits. IOW programs are often conducted with the assistance of third-party consultants, such as metallurgists or those familiar with both damage mechanisms and methods to mitigate these mechanisms. Guidelines are available to assist in addressing risk and corrosion damage mechanisms, such as API 580/581 and API 571 *(4–6)*.

The development of an IOW program can be performed as a stand-alone initiative or it can be conducted as part of a risk-based inspection (RBI) assessment of the particular operating unit. RBI assessments are forward-looking reviews that extend from the date of the study beyond the next planned turnaround to the end of the subsequent unit run. The entire RBI effort is based on assumptions about the operating conditions during that period. The IOWs act as

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controls on key variables during this time, ensuring that conclusions reached during RBI remain valid during actual unit operation. IOWs can also be incorporated into fitness-for-service (FFS) assessments, which are typically conducted for a particular time period based on expected operating and degradation conditions.

A closer look at API 584

API 584 introduces a method to develop unit-specific control limits on variables that could contribute to corrosion. These control limits, which frequently have upper and lower boundaries, define the IOW for the specific variable.

API further classifies IOWs into three categories:

Critical limit IOWs. Exceeding a critical limit IOW, such as acidic pH in the overhead of a crude distillation tower, can cause rapid corrosion, so these IOWs are frequently alarmed.

Standard limit IOWs. Exceeding standard limit IOWs over an extended period of time can cause corrosion damage. In a crude distillation unit, for example, an increase in feed sulfur concentration can increase sulfidation corrosion rates above 500°F (260°C). However, in most cases, the rate of damage allows time to plan and implement a response to bring the variable back into an acceptable range.

Information limit IOWs. These variables are not readily controlled but simply trended, as they can contribute to future problems. For example, feed nitrogen contributes to the formation of ammonia, which can combine with chlorides and form ammonium chloride salts (NH_4Cl), which can cause pitting.

Steps for successful implementation of an IOW program

Once the IOW variables and limits have been determined, a comprehensive implementation plan can help to achieve timely results. Follow these ten steps to implement a successful IOW program.

1 Obtain management sponsorship

Support from upper-level management ensures the IOW program is prioritized by all relevant personnel, including operations, maintenance, and technical staff. Attempting to implement this program from the bottom up, *i.e.,* starting with the inspection or mechanical reliability departments, can cause frustration, friction, and wasted resources. Some refiners select a member of the leadership team, such as the technical or operations manager, to be the owner or steward of the site's overall IOW program.

2 Appoint a single contact

To ensure consistency across all process units, one person should be responsible for implementing the site-wide IOW program, and it should be their primary job assignment. This contact should ideally be an experienced process engineer, as these individuals are most familiar with operations, field sampling, and lab procedures. However, an experienced mechanical reliability engineer may also be suitable. A metallurgist is another option, but it is often better to use their expertise to support implementation rather than to drive the activities.

3 Install the required sample stations

If new sample stations are needed, these should be prioritized to address critical limit IOWs as soon as practical. If the facility's hot-work practices do not allow installation during operation, the required work should be added to the next turnaround plan. It is not necessary to wait for all sample stations to be installed before starting monitoring at other unit locations.

4 Recognize and accept the need for additional lab testing

It is likely that site-wide implementation of IOWs will increase demand on laboratory resources. While it can be tempting to limit the number of samples required by the IOW program, it is necessary to weigh the possible reduction in lab expenses against the cost of an unplanned (and possibly predictable) outage.

After extended sampling (perhaps two years or more), it may be reasonable to reduce the frequency of sampling. In addition to an evaluation of the risk, all stakeholders, including the unit IOW program steward, operating supervisor, chief operator, process engineer, and inspector, as well as the site materials engineer, should participate in this decision. Any decisions to reduce sampling should be documented via the management of change (MOC) process.

5 Develop baseline data

Initial samples should be taken to establish a baseline for the IOW. While there is no set rule for the sample size needed to obtain a valid baseline, some refiners have established a minimum of 12 data points as a reference for their baseline. To expedite baseline generation, IOWs that would normally require sampling once per week can be sampled more often, for example, three times per week for four weeks; then after the baseline is developed, the sampling frequency can revert to the normal weekly frequency. If an IOW requires daily sampling, this normal frequency can be used to establish the baseline in 12 days.

6 Define program ownership for each unit

Each operating unit should have an IOW program steward, such as the unit's chief operator or process engineer. Stewards periodically review the unit's data and participate in IOW stakeholder meetings. Stakeholder meetings should ideally be convened monthly, but should be conducted at least once per quarter. Action items from the meeting should be documented to include the responsible party and deadline for resolution of any required actions. Subsequent meetings should review any open items from the prior meeting and reestablish any needed followup. The management program owner or steward should be briefed on the results of quarterly meetings.

7 Establish the reporting frequency and distribution network

A single unit can generate extensive IOW data, which can quickly become overwhelming. To ensure the program is manageable, critical and standard limit IOWs should only be reported to stakeholders on an exception basis. Stakeholders should be automatically notified if this data trends above or below the established limits.

A report on all IOWs, regardless of IOW category, should be generated and reviewed by stakeholders at least quarterly. This review helps to identify variables that are approaching the established upper or lower control limits. The unit IOW program steward and the site metallurgist may want to review the data on all IOWs more frequently (*e.g.,* monthly) to ensure that the sampling program proceeds as planned.

8 Document actual responses to excursions

Suggested responses to excursions for both operations and inspection are typically found in the original unit IOW report. For example, the suggested operator response to low pH in the crude tower overhead accumulator might include confirming that the neutralizer injection pump is working, increasing the amount of neutralizer being injected, and/or increasing the amount of wash water being injected. The actual response to excursions should be documented in the operating log. This information can be useful in revising IOW program documentation.

The original IOW report might also provide guidance for inspection personnel to evaluate certain piping and equipment to identify localized corrosion in response to a specific event, such as a low-pH excursion in the crude tower overhead. The actual inspection plan prompted by this incident needs to be documented.

9 Make the program evergreen

The overall program should be periodically evaluated to ensure it accomplishes its intended goal of improved unit reliability. After every turnaround, a detailed review should be scheduled to determine if any unexpected damage was identified during the downtime that requires adding or revising IOWs. It can be tempting to eliminate some IOWs if no damage was noted, but this decision warrants careful consideration by all stakeholders to ensure that risk will not increase.

10 Train staff

It is critical to train staff on the importance of IOWs in mitigating corrosion. Some refiners have implemented unit-specific IOW and damage mechanism training for process engineers, mechanical reliability personnel, and inspection staff. This multidisciplinary approach engages all stakeholders in ensuring mechanical reliability.

As stakeholders leave or change, a mechanism should be in place to ensure that the new individual understands their IOW program responsibilities. An informal verbal exchange of information is likely insufficient. A better approach is to include IOWs in regularly scheduled formalized training for all new stakeholders. CEP

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