Predicting Relief Valve Reliability – Results of the API Risk-Based Inspection and AIChE/CCPS Equipment Reliability Database Groups

by

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Coincidentally, API and CCPS, in conjunction with the same contractor, have been undertaking synergistic efforts to provide reliability information that is beneficial to companies with respect to making relief valve selection and test decisions. The API effort is focused on the methodology that enables optimization of service schedules. The optimization algorithms consider the costs of maintenance and the potential risks of delaying maintenance. The CCPS goal is to obtain the highest-quality defensible equipment reliability data available in industry for use in any analyses that benefit its participants. Supporting the goals of risk based inspection in the area of relief valves is one example. These respective efforts allow users to sort large data masses by variables of interest to any given application. In combination, they can be used to provide added value and accuracy for very little added effort. As a result of these projects, the members of these committees have data and software that allow users to: (a) provide a logical framework for reliability data collection, (b) select the best relief valve for an application, (c) assess the best way of configuring the relief device (e.g. with/without spare, with/without rupture disk), and (d) establish the most cost-effective maintenance schedule.

1.0 Introduction

There are synergistic activities taking place in the process industry that are addressing the reliability of relief valves (and many other equipment types). One of these is the API Risk-Based Inspection (API RBI) effort; the other is the Center for Chemical Process Safety - Process Equipment Reliability Database (CCPS PERD) project. Both projects are being supported by a consortium of about 20 companies, and are being developed by a common contractor.

The current state of industry relief valve reliability information is not adequate. The available literature is often inconsistent in definition, contradictory in results, and in large part consists of

data collected for non-oil/chemical industries. There is a need for something that is better, defensible and usable.

The mandates of the API and CCPS groups are somewhat different; however, the overriding goal of both is to promote greater safety, lower costs and reduced losses through the acquisition and application of quality information derived from equipment reliability data. This paper describes the focus and benefits of each of these efforts independently, and the synergies offered by integrating the two.

2.0 The API RBI Project

2.1 Project History

Historically, the bases for a process equipment inspection program have been one or more of the following: (a) experience of the plant inspection planner, (b) code and regulatory requirements, (c) limitations imposed by external requirements, such as a fixed turnaround time. While each of these is generally based in reason, the first two at least are also generated by people who may be motivated to be overly conservative. Less commonly, there are unique features to a particular operation that lead to risks that are higher than the "experts" expect. The result is that inspection resources are misallocated, with unaddressed risks and/or wasted and ineffective inspection efforts.

In 1993, a group of American Petroleum Institute (API) member companies sought to develop a methodology that would provide objective input to the inspection planning process. The purpose of this effort was not to subvert the plant expert, or codes, but rather to provide support where gaps in knowledge exist, and to provide a defensible, technical basis for decision-making and risk analysis.

The result of this multi-year effort are a protocol that is described in detail in API Publication 581, and software that reflects the methodology embodied in this standard. The work in API 581, plus some more recent additions, have resulted in an RBI method that includes modules for pressure vessels, piping, atmospheric storage tanks, heat exchanger bundles/shells, process heaters, and other equipment.

The API RBI protocol is in use in many companies. For those companies in the committee, its use has resulted in measurable reductions in risk, but also direct inspection savings of over $100 million dollars, with median project paybacks of about 10:1. An added benefit is that the protocol is "open source" through API 581. So the users can understand and be comfortable with the methodology that literally may effect peoples' lives. For the same reason, the API method is arguably the one that is most defensible to regulators.

2.2 The Relief Valve Module

The relief valve module is a relatively recent addition to the API RBI protocol. It is based on the available public data, plus some committee data. In general there is reasonable confidence in the

results produced by the protocol. However, both the literature and plant data indicate large differences in reliabilities in what, on the surface, appear to be similar services. Also, API RBI assesses six failure modes that can have significant safety or economic impact (failure to open, opens above set pressure, stuck open, fails to relieve required capacity, opens spuriously, leakage) - historical data for some of these is very sketchy.

3.0 The CCPS PERD Project

There have been several efforts over the years to develop public equipment reliability databases. Each of these have fallen into one or more of the following categories:

- Contributors to the database not in the onshore process industry (IEEE, OREDA)
- Effort not based on obtaining consistent, "quality" data (we would rather not mention names)
- Data based upon published works of others

The CCPS Process Equipment Reliability Database, PERD, protocol has been designed to both learn from the experiences of past industry initiatives and to address any problems that have been identified in a rigorous and methodical fashion. The CCPS PERD initiative grew out of the process industry, but technical foundation, data relationships, and procedures developed are equally applicable to industries such as electronics, pulp and paper, power generation, steel, etc. Specific industries can filter out data from industries not deemed to be comparable. "Quality" data is assured through the following:

- using a documented and certified data quality management system
- using software that assists validation of the data as it is recorded
- establishing fundamental failure modes for equipment and their definitions via a rigorous functional analysis procedure
- building data recording requirements around failure mode definitions that are objective, not subjective

Industrial support is fostered by making flexible software available. Equipment can be added or deleted whenever desired, and data can be collected for those failure modes important to the user. Users can tailor their data management system to meet their needs at any time. Thus a site can support the database to the extent that resources exist and a perceived value supports the use of those resources.

4.0 Goals and Capabilities of Each Effort in Relief Valves

4.1 API RBI

The goal of the API RBI relief valve module is to help maintenance planners determine the optimal time to perform a service test. This is done by estimating the risk of leaving the RV in service up to whatever test option dates are available, and comparing this risk to the costs of doing the test at that time. The software allows the user to input as many as 35 design, installation, application and test variables. Of these, only 10 are required fields (e.g. set pressure,

discharge line diameter, process chemical, service severity); any optional fields not filled in are inferred using internal algorithms.

The outputs of the analysis are the associated risks that can result from specific failure modes. Six failure modes of particular interest to risk based inspection, a sub set of the fundamental failure modes identified and documented by CCPS PERD, are shown in Table 1.

Table 1
Relief Valve Failure Modes

API RBI	CCPS PERD
Complete Failures	
Fail to open	Fail to open
Stuck open (fails to reseat)	Fail to close (reseat)
Spuriously opens	Spuriously opens
	Equipment rupture
Partial Failures	
Opens above set pressure	Opens above set pressure
Fail to relieve req'd capacity	Fail to relieve req'd capacity
	Opens below set pressure
	Fails to completely reseat
Leakage	Seat leakage
	External leakage
	Opens too slowly
	Erratic opening

These outputs include the following types of risks/costs:

- damage caused by release of material to atmosphere
- damage to equipment being protected
- losses due to equipment shutdown
- value of lost products

The risks/costs are summed, and assigned to one of four risk severity categories (e.g. high, medium-high, medium, and low).

4.2 CCPS PERD

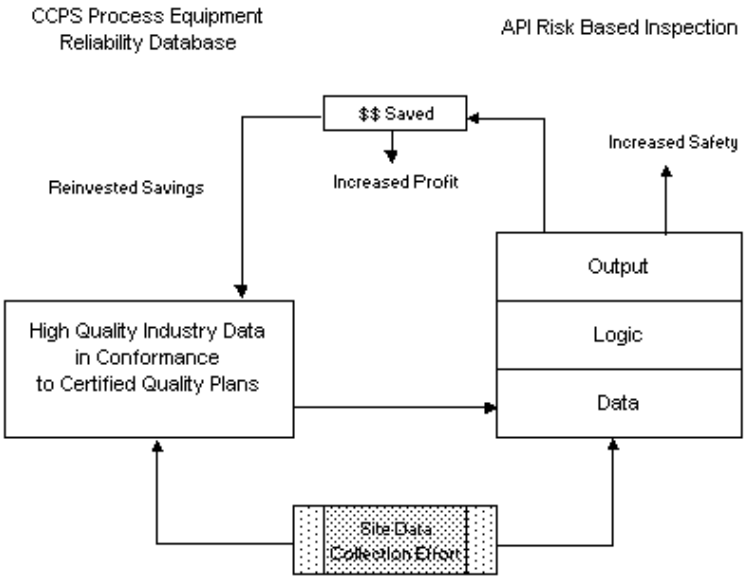
The CCPS PERD is a resource for "classical" reliability or risk assessment studies. It returns reliability and availability numbers for a desired relief valve type and application, providing median, high and low estimates for a stated confidence level. The software allows the user to fully describe a relief valve and its application, providing the user to enter up to 70 "inventory" data input fields; of these, only 8 are required. In contrast to API RBI, though, no inferences are made about any optional fields for which data has not been provided.

The outputs from a PERD query can be filtered using any of a number of filters in a standardized report, or can be sorted by any of the inputs by exporting the raw data and sorting it in "native" software mode. Reliability/availability values can be retrieved for each of the API RBI failure modes as well as others previously indicated in Table 1. Cost/risk data are not specific outputs. However, information on these is solicited as inputs, and can be retrieved as outputs, again in "native" software mode.

5.0 Potential Synergies

Each of these efforts provides tremendous value to participants directly (optimized maintenance, better reliability data) and indirectly (cost-saving tools for data collection and management, lower risks). Each can be used to support the other as well. Figure 1 shows the synergistic relationship of how the two initiatives interact.

Figure 1
Synergies Between CCPS and API Relief Valve Efforts



Keying on the data link, the most obvious benefits to cooperation between the efforts are the following:

- combining data collection needs, so that for very little added cost, the value of both projects can be had for the effort of one
- collection of high quality, objective data from CCPS PERD that can be used to validate and improve the failure rates used in API RBI by individual users

- inducing API RBI users to provide additional data to CCPS PERD that they might not otherwise take the effort to collect

To these ends, efforts have been made to make the data collection definitions and required fields the same, or similar enough so that one set of data can be mapped to the other.

We expect that within the next several months, a large amount of data will be available from CCPS PERD. This data can be used by companies that are members of both CCPS PERD and API RBI to replace the standard algorithms in the API RBI protocol, to improve the accuracy of analyses within their companies.

The general use of CCPS PERD data by non-PERD participants is not allowed. However, it is envisioned that the API RBI group could submit a proposal to CCPS PERD for data use. For example, API RBI may request data on relief valve reliability for the purposes of validating their models. Upon approval by CCPS, API would conduct their analyses, on the condition that the resulting report be made available to the CCPS PERD members free of charge. Alternatively, CCPS PERD data may be incorporated in API RBI at such time as CCPS publishes a data book for public use. In either case, we can look forward over the next few years to having, for the first time, meaningful relief valve data for the process industry that allow defensible value added activities to be performed.

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