

White Paper

Streamline API 691 Compliance and Reduce Automation Risks



Streamline API 691 Compliance and Reduce Automation Risks Simultaneously

Safety is paramount in process industries such as refining, petrochemical, and chemical. One major challenge facing these industries is developing effective and efficient strategies to achieve safe operating conditions given the inherent existing machinery and automation risks.

Risks are intensified by industries' fast-paced evolution and by the ever-increasing complexity of equipment, the use of equipment in untested applications and extreme environments, and the lack of experienced operations and maintenance resources. Reliability engineers, maintenance managers, and risk managers face these conditions every day. They recognize that these conditions coupled with tighter regulatory requirements and increased scrutiny (due to highly publicized industrial accidents) make it imperative that owners and operators have full control and visibility of critical assets that generate significant risk.

A standard to focus on higher risk machinery

Typically, standard best practices have been created as needed by process-equipment suppliers and by the companies that use process equipment. To formalize best practices related to higher risk machinery, an updated American Petroleum Institute (API) 691 Standard for Risk Based Machinery Management is being developed and finalized. API 691 is currently in draft form with the initial release expected soon.

The upcoming API 691 standard focuses on the higher risk machinery in facilities and supplements existing API machinery standards. API 691 applies primarily to rotating equipment, auxiliaries, and related system components such as pumps, gas turbines, and gearboxes for applications at great risk of loss of containment of hazardous process materials.

Its recommendations and requirements do not replace existing local, regional, or federal regulations. By adopting API 691, facilities gain a comprehensive outline of a risk-based approach to manage higher risk machinery assets throughout the equipment life cycle, supplementing current standards.

The standard contains elements for identifying high-risk machinery; for managing machinery risks in design, manufacturing of components, installation and commissioning, and operation; and for defining how to develop and execute maintenance and reliability strategies.

According to the standard, risk includes two factors: the probability of failure (POF) and the consequence of failure (COF).

Risk = Probability (POF) X Consequences (COF)

POF = likelihood that a failure will occur considering current condition and equipment design, and failure modes and mechanisms with high risk.

COF = effect of the failure taking into account the process safety and environmental events, flammable events, toxic releases, and high-energy releases (over-speed, rotating element failure).

The standard outlines the approaches and methods to address both POF and COF factors.

Directly impact risk by improving reliability

Both risk factors (POF and COF) are positively affected by improving and managing equipment reliability. In fact, if you address reliability, you also affect energy efficiency, HSSE compliance, process automation in general, and overall company performance and profits.

Key to improving reliability is the Reliability Value Chain (Figure 1-1), a practical concept illustrating that reliability is a chain of activities that reach across an organization. The Reliability Value Chain centers on a reliability strategy in which data and Information evolve into actionable knowledge through tools and techniques. This paper focuses on one such tool: Pervasive Sensing™, which provides information such as condition indicators and process parameters (shown in the lower right quadrant of the chain).

Figure 1-1. A complete Reliability Value Chain improves reliability by bringing out actionable knowledge based on complete data and relevant information.



Experience shows that reliability increases when potential machinery problems are found early through data and information. The subsequent actionable knowledge provides time to plan and schedule corrective actions to reduce the severity and outcomes of undetected failures or breakdowns. Soon — with the new API standard in place — there is the potential to garner upper-management support for addressing concerns that have existed for a long time, and to set an appropriate level of attention on higher risk devices.

Although specifically targeting the reliability of high-risk assets, the methodologies outlined in API 691 can and should be applied to a broad range of rotating assets for greatest impact by reducing risk associated with loss of capital investment due to equipment and property damage; by reducing risk due to loss of production; and by cutting excessive operating, maintenance, and repair costs.

Attaining a comprehensive risk-management system

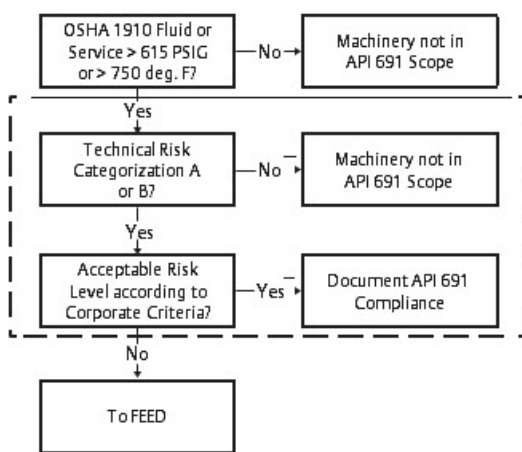
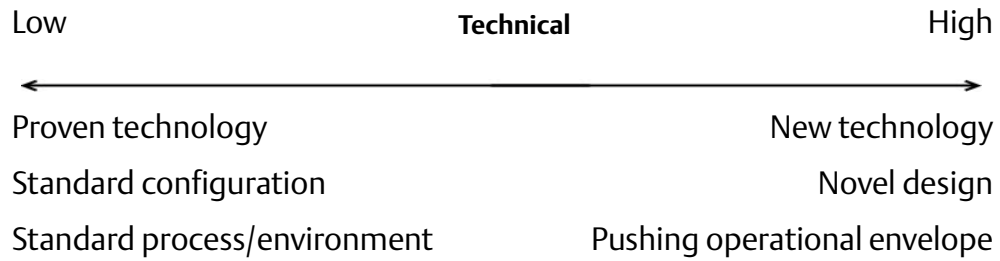
API 691 defines a comprehensive risk-management system including procedures for implementation; program maintenance and reassessment; roles, responsibilities and training requirements; and documentation of the risk analysis (scope, boundaries, assumptions and mitigating actions). Also included are data requirements; acceptable risk limits and thresholds; a management-of-change process; and audit requirements.

In addition, an organization's risk-mitigation process must:

- Identify risk levels above tolerable limits
- Identify scenarios at each stage of an asset's life cycle (from feasibility and concept selection through operation and maintenance)
- Identify POF and COF scenarios to understand risk drivers by identifying potential risks and establishing mitigation controls
- Select and test mitigating actions
- Document and implement the selected mitigations

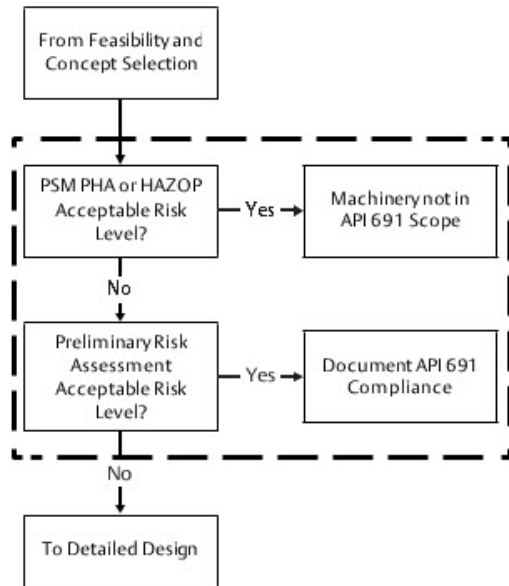
The API 691 recommendations include flowcharts and decision trees that guide users through the decision-making process. The following sections show the decision flow involved in the various phases of asset life cycle, and outline the methodologies that must be incorporated into the process in each phase.

Feasibility and concept selection



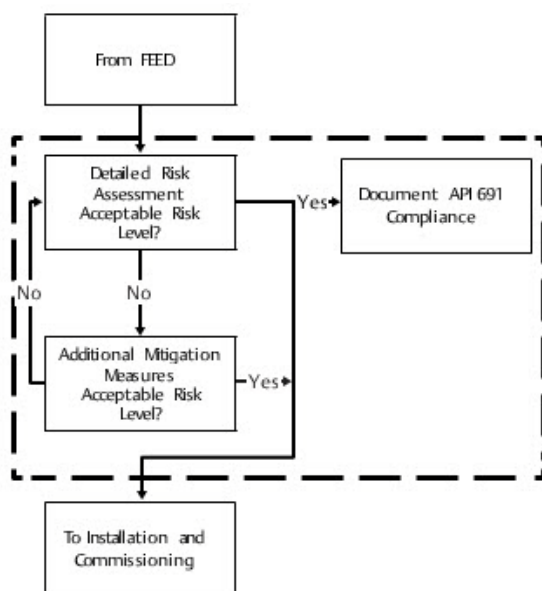
- Allows focus to be placed where greatest risk exists
- Defines levels of sophistication in design techniques required at the component/subcomponent level (e.g. Finite Element Analysis, Rotor Dynamics Analysis)
- May require prototype development and testing before FEED can commence

Front-End Engineering Design (FEED)



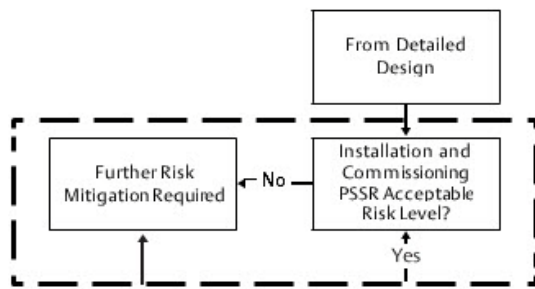
- **Asset Business Strategy** - Determine constraints posed by ESH regulations, utility availability, manpower, workforce competencies, maintenance cost/RAV needs, output capacities etc.
- **RAM-1 Modeling** - Done at the system/unit/plant level to define ability of proposed design to operate at acceptable risk levels and understand major contributors to potential loss
- **Preliminary Risk Assessment** - Identify probability and consequence of large scale potential hazards for critical equipment; facilitates “designing out” failure modes
- **O & M Strategy** - Determines requirements for training, spares philosophy, machinery condition monitoring and protection systems, data collection system, integrity operating windows
- **Process Verification** - Requires validation of assumptions around pressure losses and safety margins to avoid “overdesign” that results in inefficient operation
- **Condition Monitoring** - Define requirements for on-line sensors as well as P & ID reviews for appropriate valving, gages, warm-up lines, knockout drums, etc.
- **Manufacturing Qualification** - Requires equipment manufacturers to be ISO 9001

Detailed design



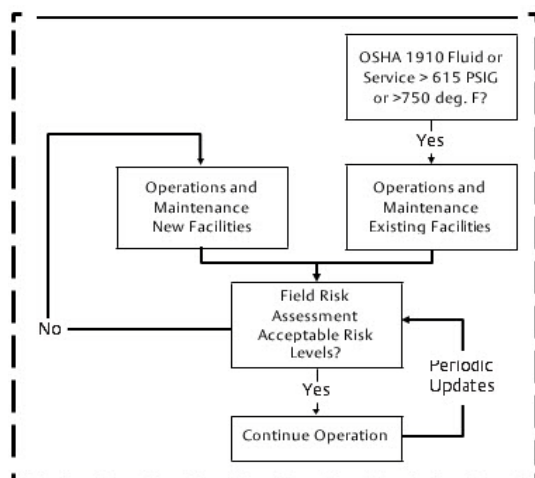
- **Detailed Design Specifications** - Augment relevant API Standard with considerations from FEED elements
- **Design FMEA** - Identifies operational assumptions, installation specs, operating limits (IOW), required maintenance activities, startup/commissioning requirements
- **Risk-based Machinery Selection** - Requires vendors to have produced equipment operating in equivalent or more severe service for >2 years
- **Boundary Definitions** - Specific machinery details are added, technical information gathered, and detailed FMEA done on process-safety critical equipment

Installation and commissioning



- **Validation of Risk Mitigation** - Mitigation actions defined in Detailed Design are tested during commissioning; detailed commissioning plans are developed, passed by the OEM to ensure they are consistent with the Design FMEA and executed
- **Operational and Performance Testing** - Integrity operating windows are verified and actual performance against design is confirmed
- **Field Functional Safety Testing** - Software and hardware
- **Capture Baseline Data** - Baseline readings are recorded such as vibration, final alignment, bolt torques, piping alignment offsets, and performance against curves
 - Pre-Start Safety Review conducted
 - Processes and procedures validated
 - Turbine and motor “solo run”
 - Compressor inert gas testing
 - Instrument calibrations verified

Operation and maintenance



- **Field Risk Assessment** - Identify and mitigate any risk changes from previous assessments or conduct an initial assessment (if brownfield)
- **Gap Closure** - Review risk assessment and FMEA for sensing and condition Monitoring needs (retrofit brownfield assets)
- **Risk Mitigation** - Document strategies and tasks to mitigate risks noted above (including maintenance and spares strategies, SOPs, data sheets and documentation, and 10-year inspection requirements)
- **Operation** - Operational procedures and related audit protocol, incident Investigation and RCFA, MOC, and emergency response procedures should be in place
- **Decommissioning** - Hazard review is done to ensure removal does not create a hazard
 - Drawings updated, power sources disconnected, piping purged and removed

API 691 requirements are substantial. Compliance with the standard will require considerable operating discipline. By using Pervasive Sensing strategies, organizations more quickly and efficiently become compliant with and stay compliant with API 691. In the process, the organizations also significantly reduce risks and costs.

Using Pervasive Sensing strategies as a path to API 691

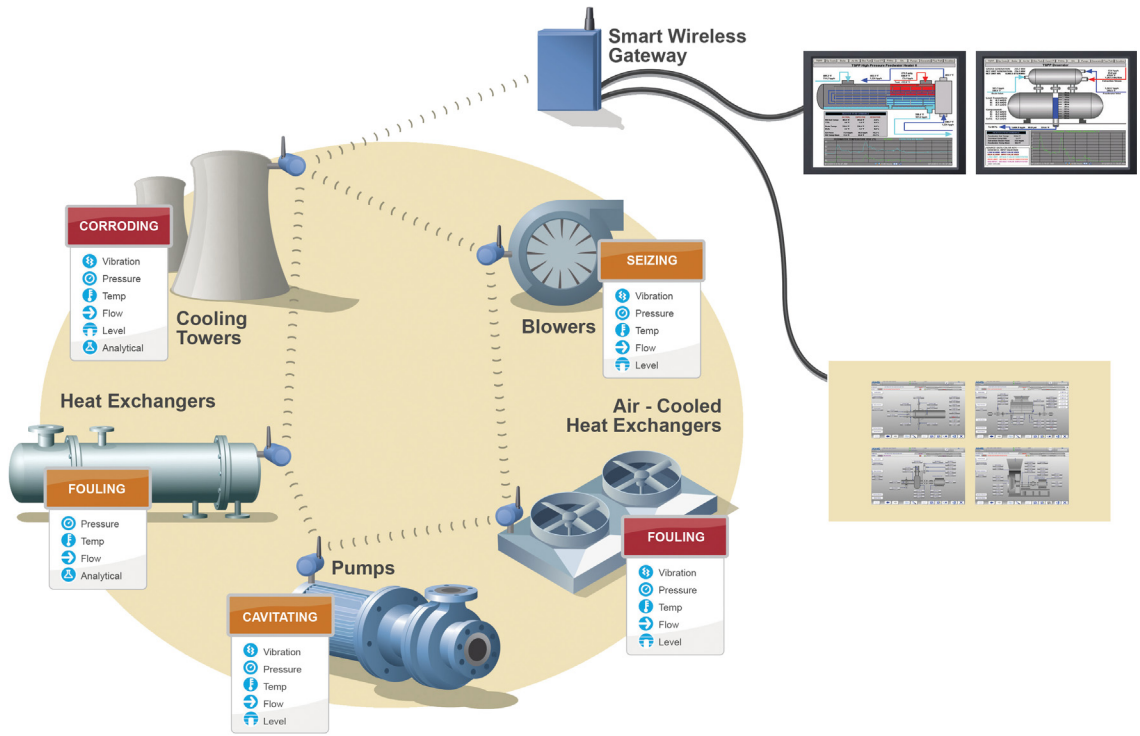
By implementing the Reliability Value Chain (Figure 1-1) and specifically by using advanced sensing pervasively throughout your facility and transforming the data and information into actionable knowledge, you can quickly avoid problems before they lead to process interruptions, cause HSSE issues, or degrade energy usage.

Pervasive Sensing applications use a wide range of sensors to unlock data from your assets and processes. These applications use available familiar devices that are non-intrusive to install and easy to use. In addition, software applications and embedded sensor intelligence can now interpret and integrate the collected data and convert it to information which will allow for more precise understanding of risk and identification of mitigating actions. Open architecture applications make it easy to access any data source for monitoring and analysis purposes, allowing companies to respond promptly to potential problems and have better insight for improved and timely decision-making.

While utilizing applications on even a few areas of the plant has proven to quickly improve the area being monitored, deploying Pervasive Sensing applications across the entire facility enables continuous monitoring to detect conditions in day-to-day operations. This helps to pinpoint areas where risk is increasing and can dramatically improve the reliability, HSSE and energy efficiency of the entire plant, as well as enabling quick alignment to the API 691 methodologies.

For example, Emerson packaged solutions known as “Essential Asset Monitoring” (Figure 1-2) have been created through the use of Failure Modes and Effects Analysis (FMEA) and Reliability Centered Maintenance (RCM) for a wide range of common systems to ensure a comprehensive monitoring solution is deployed to address all known failure modes. To implement this comprehensive monitoring at the field level, sensors can be deployed using wireless technology to reduce installation time and cost with minimal process disruption.

Figure 1-2. Essential Asset Monitoring provides visibility of abnormal situations, enabling avoidance of process interruptions.



Case study: User Improves Pump Reliability and Eliminates Fires

Manual vibration measurements and visual inspections can be time consuming and may not be performed often enough to catch and avoid certain problems. In addition, manually collected vibration data is not easily used to display trends in combination with process data. This means that facilities are not maximizing opportunities to avoid downtime, plus they are missing out on data that can improve future uptime.

In the average refinery, chemical or petrochemical plant, as many as 90% of process pumps are manually monitored or not monitored at all.

Recently by using Essential Asset Monitoring pump monitoring applications, a United States refinery improved the safety of their pumps. They did this while generating significant cost savings and reducing maintenance costs — by shutting down equipment before larger failures occurred. Although at the time of this example API 691 was not in play yet, the approach taken positions this refinery to be in alignment with the standard when it is released.

Through a PHA (Process Hazard Analysis) the refinery determined that approximately 120 pumps were a layer of protection short.

The pumps operated at above auto-ignition temperature and typically had low MTBF. They could upgrade equipment to make it more reliable, but that is usually very costly. The alternative is to implement a monitoring technology that would alert them of a problem, allowing them to shut that piece of equipment down before catastrophic failure could occur. Detecting vibration before it worsens and fails a seal can potentially prevent product from escaping the pump and creating a vapor cloud, a fire, or injury to personnel.

When they implemented CSI 9420 Wireless Vibration Transmitters, they could detect problems sooner than they typically had in the past through portable vibration rounds. This allowed the plant to plan maintenance activities better, to shut down equipment before catastrophic failure occurred and thereby reduce maintenance costs, and to protect their personnel and assets better by preventing equipment fires.

The refinery has not had a pump fire in over seven years. Personnel attribute that record to a good portable vibration program using Emerson CSI 2130 and CSI 2140 Machinery Health Analyzers and wireless vibration technology in the CSI 9420s.

Saving time and seeing benefits quickly with prepackaged solutions






Using API 691 as a base, you can develop a standard practice using Emerson’s suite of solutions to help in both addressing

and implementing the standard. You will obtain a full risk-based machinery management program that improves the speed of compliance and considers the scale of compliance, covering your assets that most need the standards and the accompanying detailed work.

Figure 1-3 shows a set of ready-to-implement solutions for monitoring essential assets such as pumps, heat exchangers, and blowers. The illustration shows that an essential-asset monitoring solution for pumps requires vibration and pressure monitoring—and recommends temperature, flow, and level monitoring.

With the knowledge gained from implementing these automated monitoring solutions, the plant will be better prepared to meet the recommendations for best-practice reliability. Combine this knowledge with the best practices experience embedded in the monitoring applications and monitoring hardware will help achieve the early warning of potential equipment problems, and allow detection of root causes.

Figure 1-3. Essential Asset Monitoring provides pre-configured predictive monitoring solutions for common asset types and conditions.

	EAM MODULE	VIBRATION	PRESSURE	TEMP	FLOW	LEVEL	ANALYTICAL
Heat Exchangers			●	●	●		●
Pumps		●	●	●	●	●	
Cooling Towers		●	●	●	●	●	●
Air - Cooled Heat Exchangers		●	●	●	●	●	
Blowers		●	●	●	●	●	

● = Required
● = Recommended

Economic value of essential asset monitoring solution

Inputs	
Refinery capacity in barrels per day	250,000
Refinery net margin per barrel refined	\$5
Refinery total annual maintenance spend excluding turnarounds	\$50,000,000
% of refinery total annual maintenance attributable to process pumps	7%
Anticipated reduction in process pump maintenance cost with diagnostics	30%
Anticipated reduction in lost production with process pump monitoring	30%
Operational benefits	
a. Refinery capacity in barrels per day	250,000
b. Net margin per barrel	\$5
c. Production capacity lost due to process pump failures	0.2%
d. Reduction in lost production with pump monitoring	30%
Annual Net Profit Improvement (a x b x c x 365 x d)	\$273,750
Maintenance benefits	
e. Annual maintenance budget	\$50,000,000
f. Refinery annual maintenance (e.) attributable to process pumps	7%
g. Reduction in average cost to repair if pumps didn't fail unexpectedly	30%
Annual Maintenance Costs Reduction (e x f x g)	\$1,050,000
Total annual profit improvement	\$1,323,750

The savings detailed in the table above are realized through reductions in unscheduled shutdowns and associated loss -production value, plus savings of the direct cost of unscheduled shutdown. And with Pervasive Sensing solutions, a plant will realize fewer off-spec products, less catalyst loss/deterioration, fewer equipment replacements, and lower labor costs (including cleanup, and operating and staff overtime).

In addition, with the deployment of these advanced monitoring methods, serious incidents and associated costs are reduced including external cleanup fees, reporting costs, and fines. Upsets to the process are also minimized, as are risks to personnel experienced when making monthly field readings.

Summary

The API 691 standards are coming, and now is the time to start to digest them and to begin laying out a strategy for compliance as the standard will put some teeth behind proper maintenance and reliability practices for high-risk assets. The standard defines practices for cradle-to-grave management and maintenance of assets, and drives utilization of best practices for monitoring and maintaining equipment. In addition to reducing business risk, there is ample evidence that best practices including advanced monitoring techniques are more cost effective than traditional techniques, and can easily pay for themselves many times over within a few years.


For more information on Essential Asset Monitoring, visit Emerson.com/Solutions/Essential-Asset-Monitoring.


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