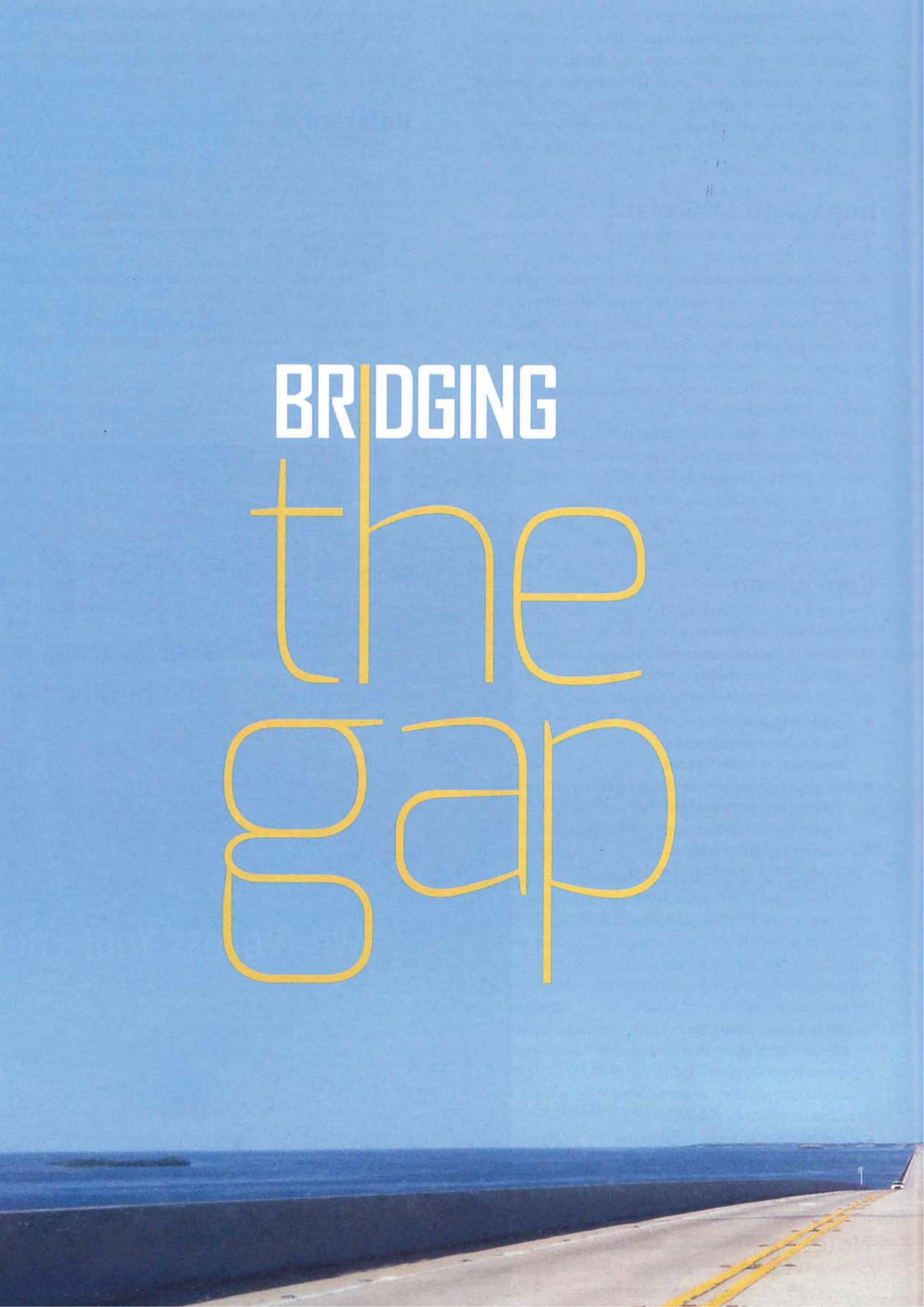
BRIDGING the gap



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discusses the relationship between safety protection and condition monitoring.

In the process industry it is still common that users strictly separate safety protection equipment from condition monitoring. Machine operators frequently face a time consuming troubleshooting based on minimum diagnostic data e.g. from the DCS system. For many years, flight data recorders have been a common standard in the aviation industry to perform post incident analyses of aircraft accidents. Such transient data recorders are also available for machinery protection systems. The captured data can be used to improve the traditional snapshot monitoring program and support cost efficient condition monitoring purposes without waiting for an analyst to come.

Maintenance strategies

When operating rotating equipment, different maintenance strategies are applied. The simplest method is to run a machine until it stops due to a failure, taking the risk that a comparably small damage can cause expensive consequential damages. When wear processes in the machine are well understood and the timely progress of wear is known, worn parts should be replaced shortly before their lifetime is reached to maximise use of the wear potential and prevent component failures (preventive maintenance). However, the lifetimes of components of reciprocating compressors, such as valves and bearings, are not subject to linear wear, which makes it difficult to decide on the best time to replace a component based mainly on operating hours. Maintenance decisions on components that are experiencing non-linear wear out are challenging and can not be made time based. They require monitoring of certain parameters that allow judgement on the component's condition and an estimation of the best time for replacement. This is named predictive maintenance.

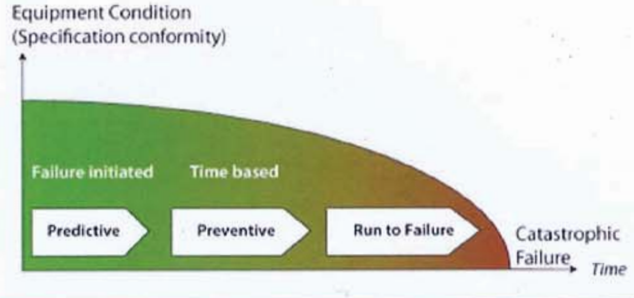

Figure 1. Basic maintenance strategies.

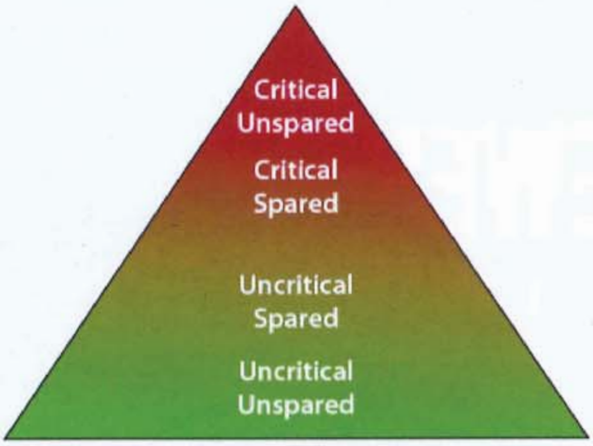

Figure 2. Proportion of machinery in the four categories of criticality.

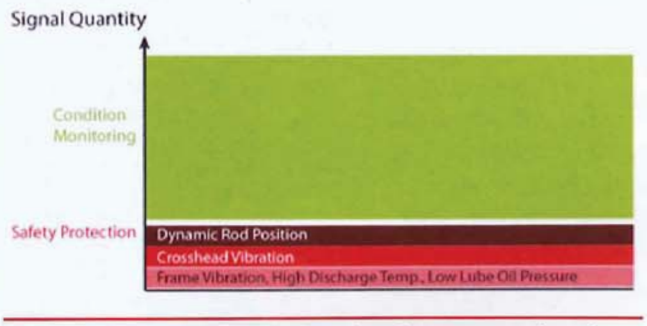

Figure 3. Typical methods of safety protection for reciprocating compressors.

Table 1. API 618 4th Edition: Minimum alarm and shutdown requirements for reciprocating compressors

Condition	Alarm	Shutdown
High gas discharge temp for each cylinder	X	X
Low frame lube oil pressure	X	X
Low frame lube oil level	X	--
Cylinder lubricator system failure	X	--
High oil filter differential pressure	X	--
High frame vibration	--	X
High level in separator	X	X
Jacket water system failure	X	--

Which maintenance strategy is applied depends mainly on two parameters:

- The criticality of the machine.
- The availability of a spare compressor.

The total population of machines can be grouped in four main categories:

- Category I: Critical, unspared.
- Category II: Critical, spared.
- Category III: Uncritical, spared.
- Category IV: Uncritical, unspared.

Generally, the more critical a machine, the less acceptable it is to run it to failure or to rely on preventive maintenance. An unexpected failure with a machine shutdown has a negative effect on the production or safety. The availability of a standby compressor will reduce the requirement for predictive maintenance, but has no effect on the level of safety that is required.

The gap between protection and condition monitoring

Uncritical and spared reciprocating compressors especially are still operated without or with a minimum of protection. Whereas most of the critical compressors are equipped with at least basic protection such as frame vibration, low lube oil pressure and discharge gas temperature. The number of primary damages is large and full coverage of all these would require an almost indefinite amount of monitoring parameters. Therefore, a compromise between 'limitation of consequential damage' and 'amount of protection parameters' is widely practiced. In short: depending on the degree of the acceptable damage, the protection parameters are determined.

An overall guideline on the essential protection parameters can be obtained from the API618. However, this should be considered as the bare minimum and does not reflect all recent experiences of the industry.

Frame vibration is typically considered a parameter that provides basic information on the mechanical condition of the compressor. However, in the past years it has been widely accepted that frame vibration is not sufficient for mechanical safety protection. Monitoring vibration impacts on the crosshead slide has been recognised as a far better method for detecting all major mechanical problems of the motion work. Recent experience has also shown that piston rod failures can only be prevented by monitoring dynamic piston rod position (piston rod run out). Only if a piston rod failure is considered an acceptable damage is crosshead slide vibration sufficient for mechanical protection.

Protection systems are typically based on simple, but reliable, RMS parameters e.g. RMS vibration. Some of the values are transferred to DCS systems, but most recommended protection parameters such as low frame lube pressure or low suction pressure are not useful to provide any diagnostic information for preventive or even predictive maintenance.

Piston rod position is a parameter that is directly 'located' at the gap between protection and condition monitoring. The two different parameters: vertical piston rod position to indicate rider ring wear, and piston rod runout indicating the mechanical health of the piston rod and its connections, come from the same sensor and signal. It is economical to use both parameters, one for protection and one for condition monitoring. However, in most applications only one parameter is used, either for protection or for condition monitoring.

How can the gap be bridged?

Bridging the gap means using monitoring sensors and their continuous information stream for both purposes. This is more economic and increases the quality of both protection and condition monitoring. One way to bridge the gap is to record high frequency signal data for detailed analysis in a device, attached to the protection system. The aviation industry introduced flight data recorders decades ago; however, it is only used in post mortem analysis. But why should recorded data only be used when damage has occurred?

Using the protection sensors for condition monitoring purposes is one option; another option is increasing the frequency and signal quantity of monitoring sensors and continuously recording the data for on demand diagnostic approach.

Reciprocating compressor diagnostic condition monitoring is typically based on:

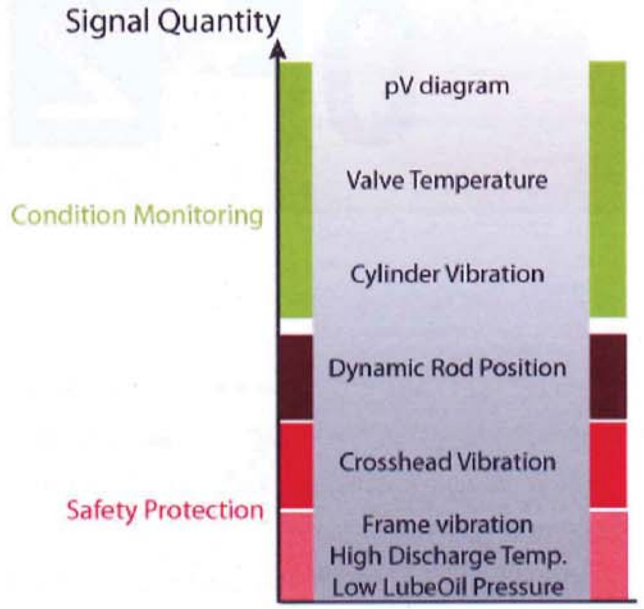

Figure 4. Typical levels of safety protection and condition monitoring for reciprocating compressors.

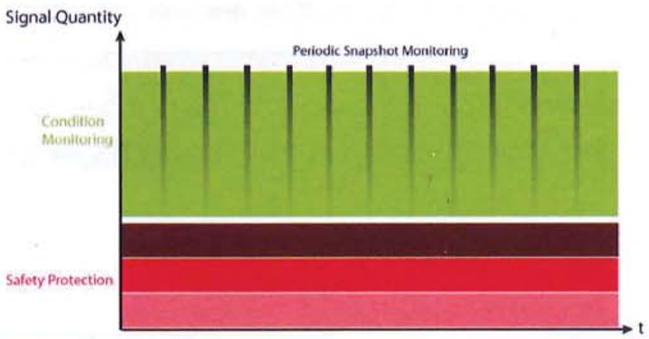

Figure 5. Stretching the diagnostic quality.

- P-V diagram analysis.
- Cylinder vibration.
- Vibration monitoring of crankshaft bearings.

Primarily, information on the condition of components such as suction/discharge valves with comparably high failure rates is collected. This is often done with periodic snapshot monitoring in order to save investment cost for sensors, cables and diagnostic systems. However, trended data provides continuous information with a much higher diagnostic quality as compared to a periodical snapshot data collection (offline monitoring).

The diagnostic quality of condition monitoring data is defined by two variables:

- Quantity of signals/sensors.
- Time the signal is available/frequency of the recordings.

The diagnostic quality of offline monitoring cannot be improved by increasing the number of monitored sensors indefinitely. Adding some of the offline sensor positions to a permanent data recorder will add diagnostic quality, because it allows on demand access to online data and gapless trended data. The information always results from the same sensors and can be obtained without a risky activity of personnel in the field operating a portable data collector. This is a particular advantage offshore, where the deployment of people is always a matter of logistics.

Cost benefit compared to condition monitoring systems

Online monitoring is often considered too costly for uncritical and spared machines. Cost is generated in six areas:

- Sensors.
- Field wiring.
- Data acquisition systems.
- Computerised server and monitoring systems.
- Monitoring and diagnostic software.
- Analyst know how.

Online data recorders have a competitive price advantage in three out of six points:

- Field wiring.
- Computerised server and monitoring systems.
- Monitoring and diagnostic software.

These three areas typically cause more than 60% of total investment. This underlines that permanent data recorders may provide a significant upgrade in diagnostic quality at an economic scale.

Today, modern protection systems offer the opportunity to be expanded by high frequency data recorders. The data acquisition platform is common, but the data recording does not interfere with the protection function. In case of a machine shutdown all important instrumentation is available for on demand analysis. While portable offline data collection often comes too late such data is recorded gapless and therefore is always available for the critical moment in time. This way, answers on what has caused the shutdown can be obtained immediately and the gap between condition monitoring and protection can be overcome. HE