

Solutions for LNG Facilities



Introduction

The first shipment of natural gas was transported to shores in 1944 in the form of liquefied natural gas (LNG). Today natural gas is used in more than 63 million homes and is utilized for a variety of purposes including electricity generation and petrochemical feedstock.

The use of LNG is a proven, reliable, and safe process, and natural gas is quickly becoming the world's cleanest burning fossil fuel as it emerges as the environmentally preferred fuel of choice. It is for this reason that LNG facilities are put under more pressure than ever to meet the world's natural gas demand. Keeping your plants running at an efficient pace is vital to production and condition monitoring plays a critical part in this process. Condition monitoring provides a proactive approach so that maintenance can be planned, eliminating unscheduled outages and optimizing machine performance. In addition, condition monitoring helps to avoid breakdowns with subsequent secondary damage and loss of production revenue meaning that today's LNG

facilities simply can't afford to not have a reliable condition monitoring solution.

Bently Nevada has been monitoring the condition of a wide variety of machinery assets in facilities like yours for more than 50 years, using sophisticated technology that has been installed around the world in more than 80% of all global LNG locations. Our comprehensive portfolio of systems and services addresses the full spectrum of condition monitoring and machine protection applications associated with today's LNG production facilities.

Whether it's continuous protection on the rotating and reciprocating machinery, portable data collection systems on numerous assets, wireless vibration monitoring on cooling fans, or software to monitor the thermodynamic efficiency of highly critical turbo machinery, we have a comprehensive portfolio of systems and services that help you protect your machinery, monitor its condition, and optimize its operation and maintenance.

Your challenges

As the demand for LNG increases worldwide, LNG facilities face an abundance of challenges. While operational efficiency and availability is key, reliable delivery and the prevention of unplanned downtime is critical.

Our asset management solutions can help you meet many of your most critical challenges, such as:

- Extending the time between planned outages
- Reducing duration and scope of planned outages
- Maximizing an asset's useful life while minimizing its maintenance and operating costs
- Minimizing unplanned outages
- Reducing fuel costs

- Protecting highly critical machinery against mechanical failures
- Extending condition monitoring to all levels of criticality
- Assuring delivery of product to end users without delay or financial impact
- Enabling staff to employ an effective condition based monitoring process
- Commit to production targets with full confidence in your plant's mechanical integrity

In the pages that follow, we will show you exactly where our solutions can be applied and the benefits that they deliver in a typical LNG facility.

Bently Nevada Industry Experience in the Global LNG Market

 **PARTNER OF CHOICE**

 **FIRST**
Global Export Production Train | 1964

 **FIRST**
HDGT Driven Train (CoP Process) | 1969

 **FIRST**
Super Train (AP-X Process) | 2009

 **FIRST**
Floating Liquefaction Conversion | 2018

 **OUR EXPERIENCE**

50+ years Since 1964, coinciding with the industry startup



*As of 06/2019

 **OUR IMPACT, PEACE OF MIND**

Production Capacity
■ 347 of 400 MMPTA global supply chain, 87% of market

Liquefaction Facilities
■ 96 of 111 Trains protected and managed, 86% of market

Producing Countries
■ 20 of 22* Territories with direct service support, 91% of market

*Libya & Yemen – evaluated periodically



The business case

Machinery protection and asset condition monitoring systems are an investment that pays back quickly and in numerous ways. Today, such systems have moved from simply “good engineering practice” to “good business practice.” And for good reason—they have proven their value time and again in not just the LNG industry, but nearly every industry that depends upon its machinery’s availability and output to meet its business goals.



Payback through protection

Our solutions help protect your machinery from catastrophic failures and their costs.

For more than 50 years, the Bently Nevada name has been recognized for its industry leadership in machinery protection and condition monitoring. Today, with more than one million channels of machinery protection installed worldwide, customers have made us the proven choice for machine protection. We not only protect your machinery, but our legendary product quality, deep application expertise, and highly competent locally available service help protect your condition monitoring investment as well.



Payback through mechanical validation

Our solutions let you capture baseline machinery conditions, pre- and post-maintenance, giving you a reference for optimal decision making.

One of the most crucial times in the life of a machine is immediately after maintenance has been performed. We can tell you if “all is well” with systems that capture relevant data both before and after maintenance. You can instantly see if problems are present and make decisions accordingly. For many customers, the ability to knowledgeably continue with or abort the startup of a turbine-generator train can more than pay for their entire Bently Nevada monitoring system, in a single event.



Payback through predictive maintenance

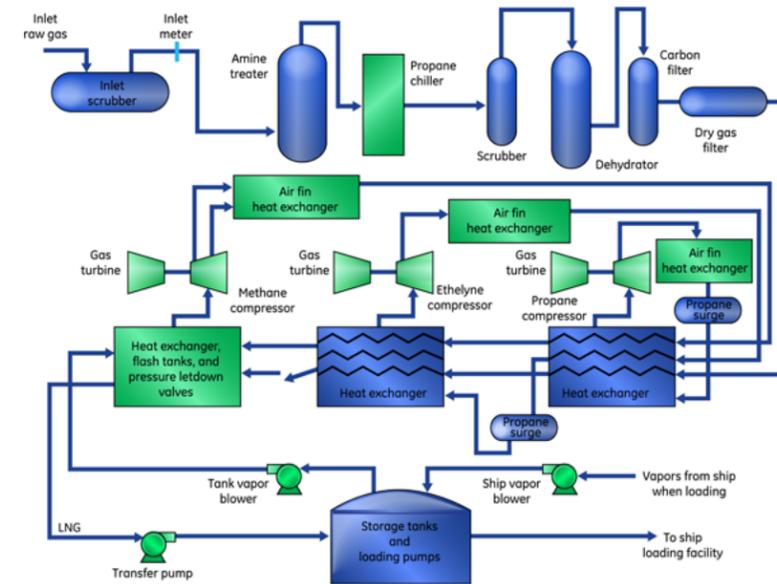
Our solutions deliver information that allows you to perform maintenance when conditions—not calendars—dictate.

Unplanned downtime can be detrimental to your plant operations. All LNG facilities operate at different production rates but by knowing the health of your assets, you can plan for repairs rather than react to failures. Employment of a condition monitoring solution in your plant increases availability and reduces downtime. Managing processes and equipment through predictive maintenance presents significant benefits. With the rapid evolution of technology, LNG facilities such as yours can obtain a higher level of intelligence while simultaneously monitoring plants and assets, reducing downtime and ultimately cutting costs by understanding operational risk for strategic decision making.

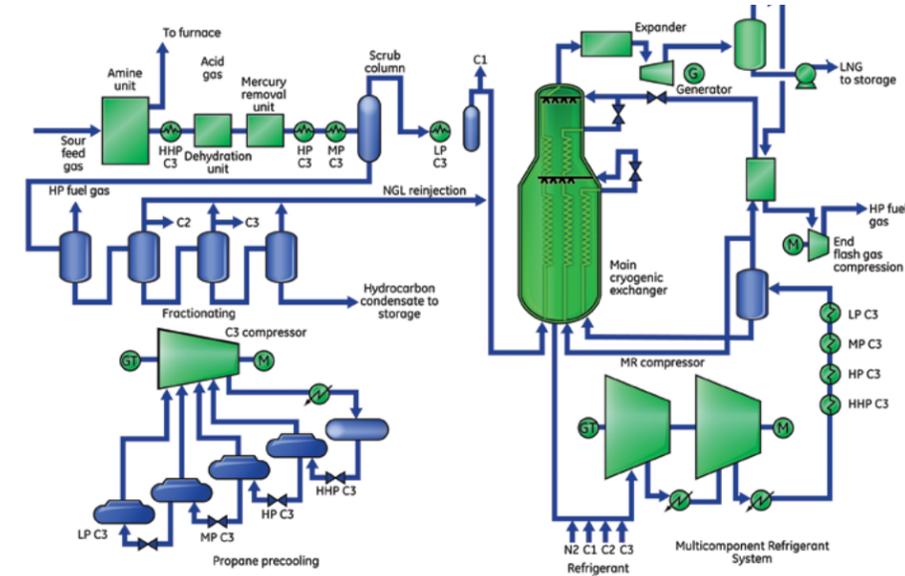
Examples of LNG liquefaction process

Bently Nevada has installed condition monitoring solutions in facilities such as yours for over 50 years. Below are just two examples of liquefaction processes used in many LNG facilities today where Bently Nevada has long been regarded as the partner of choice for machinery protection and monitoring.

ConocoPhillips Optimized Cascade® LNG Process†



APCI Propane Precooled Mix Refrigerant Process



† Image courtesy of ConocoPhillips

Integrated condition and performance monitoring applications for LNG facilities

S1 System 1 condition monitoring software platform

- Trends/plots/graphs
- Decision support advisories
- Cell/e-mail/notifications
- Alarms
- Status messages
- Spreadsheets
- Thermodynamic
 - Performance data
 - Emission data
- Planning and scheduling
- Integrate CMMS
- ERP
- Reliability
- SCADA systems

- Vibration data
- Mechanical data
- Process data
- Lubrication data
- Electrical data
- Corrosion data
- Thermography data
- Documents/drawings
- Machinery protection systems
- Wired monitoring systems
- Wireless monitoring systems
- Portable data collectors
- Process control systems historians
- Manually input data
- 3rd party data server

Legend (recommended solutions)

- Continuous Data Acquisition and Protection
- Periodic Data Acquisition
- Performance Monitoring

LNG liquification facility

Compressors

- Refrigeration Compressors
- Boil Off Gas Compressors
- Overhead Stabilizer Compressor
- Regen Compressor
- Domestic Gas Compressor
- Fuel Gas Compressors
- Air Compressors
- Acid Gas Compressors

Generators

- Gas Turbine Generators
- Expander Generator

Pumps

- Lean Solvent Charge Pumps
- Condensate Export Pumps
- Hot Oil Circulating Pumps
- LNG Loading Pumps
- LNG Transfer Pumps
- Cooling Water Pumps
- NGL Product Pumps
- Lean Solvent Booster Pumps
- Fin-Fan Coolers
- Motors

Gas feed facility (onshore/offshore)

Compressors

- Centrifigual Compressors
- Reciprocating Compressors
- Screw Compressors
- Gas Turbine Power Generation
- Pumps
- Motors
- Fans

LNG tanker

Compressors

- Air Compressors
- Boil Off Gas Compressors
- Fuel Gas Compressor

Auxiliary equipment

- Engine
- Blowers
- Power Generation
- Fans
- Motors

Pumps

- Fuel Transfer Pump
- Transfer Pumps
- Water Pumps
- Ballast Pumps

Re-gasification

Compressors

- Boil off gas compressors
- Instrument air compressors

Pumps

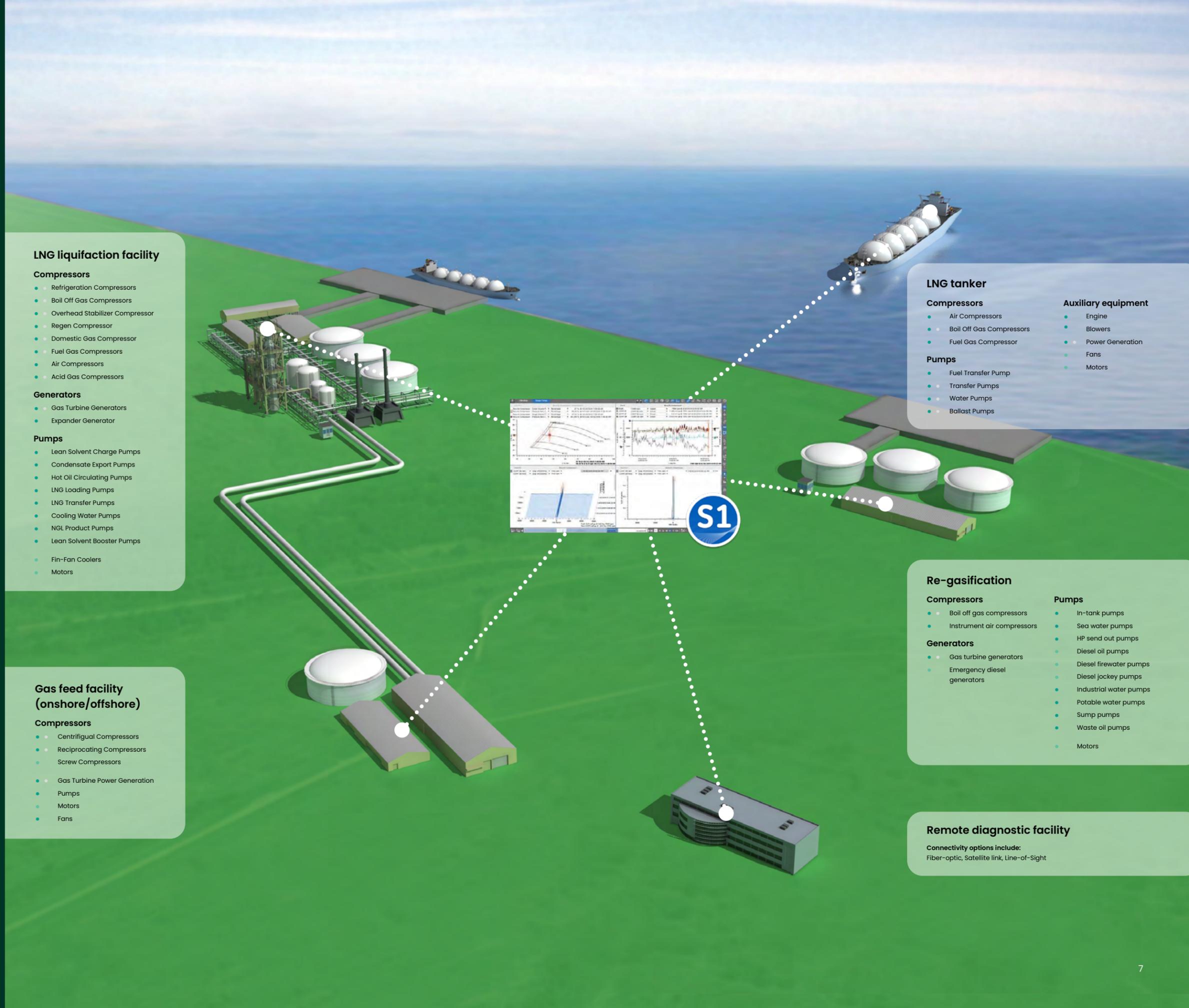
- In-tank pumps
- Sea water pumps
- HP send out pumps
- Diesel oil pumps
- Diesel firewater pumps
- Diesel jockey pumps
- Industrial water pumps
- Potable water pumps
- Sump pumps
- Waste oil pumps
- Motors

Generators

- Gas turbine generators
- Emergency diesel generators

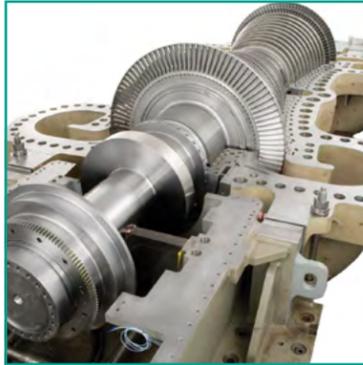
Remote diagnostic facility

Connectivity options include:
Fiber-optic, Satellite link, Line-of-Sight



Measurable results, tangible value

Plant-wide value through condition monitoring occurs asset-by-asset. Our solutions for LNG facilities encompass not just your most critical equipment where downtime is the dominant economic driver and can reduce or even halt plant output, but also your less critical assets where maintenance and labor costs are of primary concern. Below are just a few examples of the dozens of different asset types we can address.



Gas Turbines

Bently Nevada has provided machinery protection and condition monitoring for gas turbines for decades. Our comprehensive solution combines protection with state-of-the-art condition monitoring hardware and software for trending high-resolution data capture surrounding an alarm, as well as high-resolution data capture during startup, shutdown, and overspeed conditions. By combining this functionality with additional Bently Nevada modules such as Thermodynamic Performance monitoring, Predictive Emissions Monitoring System (PEMS), and Decision Support capacities, we will help you manage these assets with full confidence.



Centrifugal Compressors

Centrifugal compressors are a critical component to LNG facilities. Bently Nevada solutions have successfully protected and managed these assets for decades. Our solution set combines the protection from our 3500 System (or latest Orbit 60 platform), with the management capabilities of System 1. Our modular approach allows you to select the solutions to meet your needs. Examples include Thermodynamic Performance monitoring and Decision Support capabilities. In particular, monitoring the performance and health of dry gas seal systems on these compressors is an ideal application for System 1 Decision Support analytics engine.



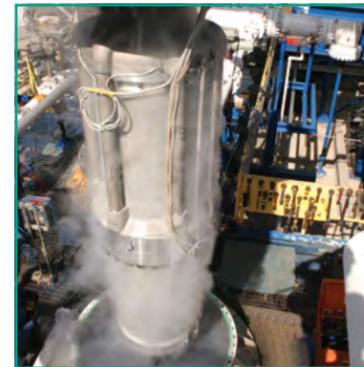
Electric Motors

AC Motors—both fixed or variable speed—require a variety of specialized protection and condition monitoring solutions depending on criticality, horsepower, duty, and the type of machinery they drive. For highly critical motor driven applications, such as cryogenic pumps, compressors, cooling fans, etc., condition monitoring techniques may include vibration, temperature, speed, and phase measurements. An innovative approach for motors, especially those that are difficult to access or are submerged is AnomAlert! Motor Anomaly Detector. This solution utilizes motor current and voltage transformers to build an operational model, from which real time condition and incipient fault symptoms can be assessed. The user interface will automatically advise on electrical AND mechanical anomalies associated with the motor and the driven load. Corrective action to the electrical supply, stator, rotor, bearings, or abnormal load from clogged filters, for example, is available from AnomAlert.



Fin-Fans

LNG facilities may include hundreds of Fin Fans (often referred to as Heat Exchangers or Air Coolers). Given the criticality of these assets, Bently Nevada recommends the use of our Trendmaster Dynamic Scanning Module (DSM). The DSM is an online periodic condition monitoring device that is capable of connecting to thousands of sensors (including vibration, temperature, speed, and process variable information). The acquired static and dynamic data is then sent to System 1 for trending, alarming, and advanced vibration diagnostics. If desired, the DSM is capable of sending static data directly to a third party system such as a DCS. In addition to the DSM, Bently Nevada offers various options for continuous monitoring, predictive maintenance, and protection of Fin Fans, including portable vibration analysis which has proven to be a valuable tool for monitoring these assets.



Pumps

Pumps are plentiful and absolutely vital to the operation of LNG facilities. Unfortunately, pump failures can impact more than just maintenance costs and production losses—they can result in failures that may be catastrophic to your operations and staff. Our solutions for monitoring pumps detect and address the mechanical and Thermodynamic Performance conditions that—when left unchecked—can lead to seal leaks, bearing destruction, and other costly malfunctions. To ensure that an economical yet appropriate solution exists for the spectrum of pumps, we offer portable instruments, conventional wired systems for online monitoring, and innovative new wireless technology that makes the benefits of online monitoring economically feasible for a larger percentage of your assets while reducing installation costs.

Pictured is Ebara Cryodynamics' LNG pump test facility, Sparks Nevada, USA, featuring a nine stage submersible LNG Sendout Pump (265 m³/hr at 1722 m TDH, -158°C, 900kW). This pump is also at the heart of a South Korea LNG Terminal.



Reciprocating Compressors

Reciprocating compressors play an important role in the LNG process. Bently Nevada is proud to be a leader in the protection and condition monitoring of these unique assets. Our solution includes specifically designed sensors, 3500 protection and data acquisition modules, and System 1 condition monitoring software. This combination allows for the collection of both static and dynamic data for trending, high-resolution data captured on alarm, as well as diagnostic capabilities including: cylinder performance, rod load calculation, cylinder pressure, crosshead vibration, frame vibration, rod position, speed, temperature, and more. By incorporating our new Decision Support capabilities, you can automate the detection of complex malfunction types, such as cylinder valve leaks, pressure packing case leaks, loose pistons, loose cylinder valves, and many others so that machinery stake holders can proactively plan maintenance activities.

Bently Nevada service menu

Key benefits

Implementation services

Get it right the 1st time

- Ensure your assets are protected and monitored when you're ready to startup
- Avoid costly delays and rework
- One source to design, plan, manage, and execute the installation
- Avoid startup trips due to improper installation and configuration

Up to \$1M/day

Avoided cost from lost production, secondary process & equipment damage

100%

Service work guarantee
1 year warranty standard on service work

Proactive support

Keep your system healthy and optimized

- Prevent instrumentation related false trips
- Prevent and minimize potential data loss events
- Keep up to date and compliant with the best technologies available
- Access the expert support you need when you need it most

80%

Industry wide machinery alarms & events are due to instrumentation

>90%

Typical reduction in non-actionable alarms & events

Asset health and consulting

Actionable insights you can trust

- Understand your asset health to optimize outage and maintenance planning
- Plug in to our global network of machinery experts with remote monitoring
- Professional OEM agnostic machinery diagnostics when and where you need it
- Custom analytic development and tuning to pinpoint specific conditions

100% ROI

A single machine save often results in complete monitoring contract payback and more

5-10X

Cost reduction for well planned maintenance outage vs unplanned reactive outage

Cybersecurity¹

Stay ahead of evolving cyber threats

- Ensure your system is up to date and protected as threats continually evolve
- Identify and mitigate cybersecurity risks to your operation
- Keep your system both secure and accessible with advanced security technologies and architectures leveraging data diodes and database replication

29%

Patch management can reduce your attack surface up to 29%

243 days

Average time before detection that a system is compromised

Training and education

Critical skills that amplify your machinery management capabilities

- Enable your personnel to operate and maintain your monitoring and protection system
- Enable your operation to maximize the value of your system leveraging expert product and application training and knowledge

400+

Customer courses delivered each year in 10 languages and over 45 global locations

Why the Bently Nevada product line.

We have earned your trust. For five decades the Bently Nevada product line has supported the most demanding applications in multiple industries. And even as we protect and monitor your machinery, we constantly strive to refine and improve our offerings—and help enable your success.

We design and deliver solutions for all of your monitoring needs—including sensors, distributed and rack-based monitors, software, and supporting services—with the following goals in mind:

- Increased availability and production
- Lowered maintenance costs
- Reduced risk in terms of safety, environmental, and asset upsets

And we have impressive statistics to back up our extensive experience:

- Over 60 years of condition monitoring leadership
- More than 240 international patents issued, including over 150 in the U.S.
- Over 300,000 series monitoring systems installed globally
- Over 1 million protection points
- 1,800 System 1 customer sites globally



1. https://www.us-cert.gov/sites/default/files/documents/Seven%20Steps%20to%20Effectively%20Defend%20Industrial%20Control%20Systems_S508C.pdf

