Bently Nevada
a Baker Hughes business

NON-CONTACTING EDDY CURRENT SENSORS

THEIR APPLICATION FOR CONTINUOUSLY OBSERVING A ROTATING MACHINE SHAFT FOR PROTECTION AND DIAGNOSTICS

An ASME Historic Mechanical Engineering Landmark

Dedicated on June 20th, 2024, at 1631 Bently Parkway South, Minden, NV 89423

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SETTING THE STANDARD

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P. 13, Photo: Original BNC building rebuilt after 1976 fire, Google Maps

P. 13, Photo: Don Bently's office in old Dangberg building, courtesy of Roger Harker

P. 13, Photo: Bently Nevada Offices from 1976 to 2000, courtesy of Douglas County Historical Society

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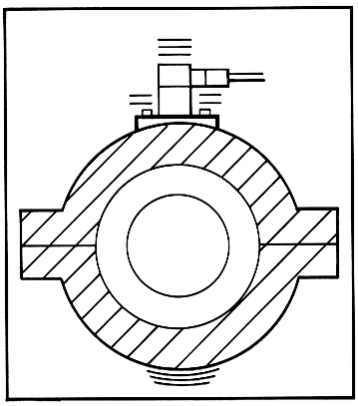
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990

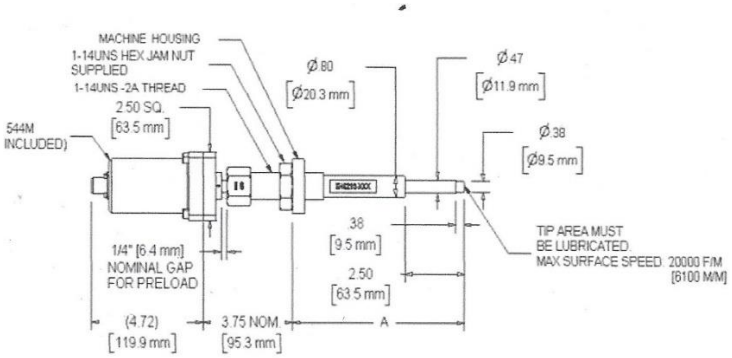
Prior Art of Vibration

The history of vibration analysis for machinery diagnostics first started with the human brain and one's senses. Knowledgeable operators and maintenance personnel could hear and feel the vibration in a rotating shaft from a bearing casing, or feel excess heat it gave off using their fingernails, a screwdriver, or broom handle. These inferred measurements were only qualitative and depended upon an operator's experience and memory.

Later, external velocity vibration sensors mounted on bearing casings were used to measure the amplitude of casing vibrations and this method helped identify severe problems, hopefully, before failure.



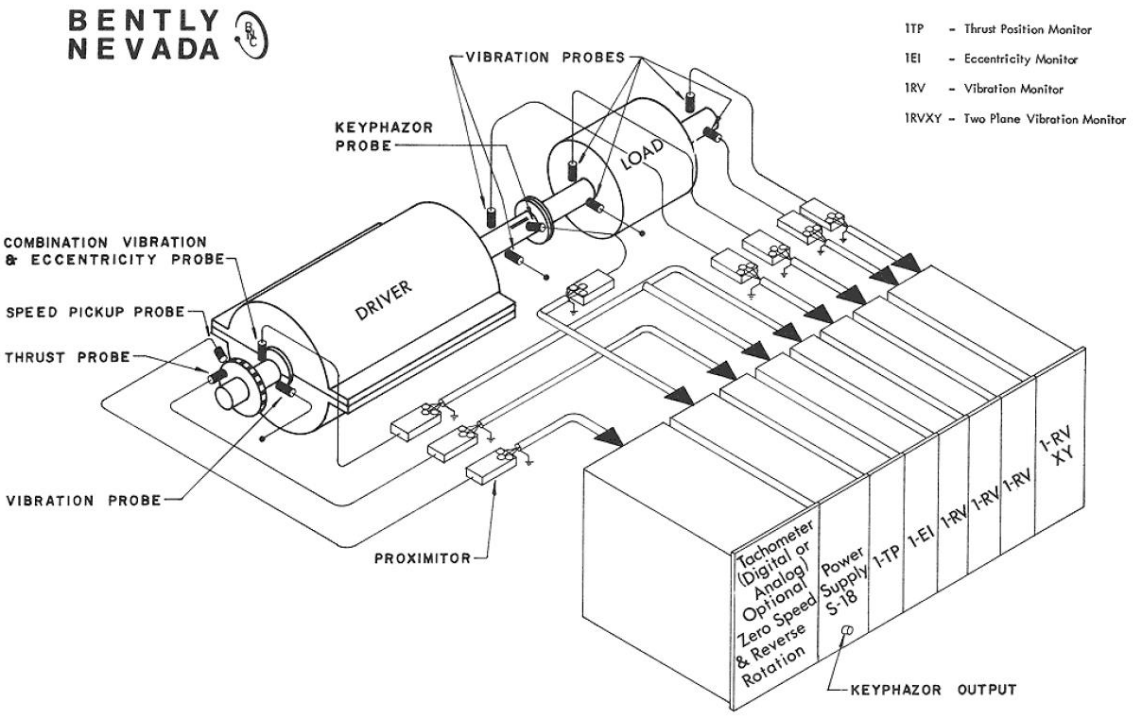
"Shaft-rider" instruments could be used on moderate speed equipment by coupling a sensor directly to the shaft surface. They were installed within the bearing area to provide lubrication to the tip of the sensor as the shaft rotated past it. A mechanical stop prevented the rod tip from marring or scoring the shaft. As the rider tip does itself wear from this contact, a visible indicator provided a check of tip wear. The disadvantage of this solution was the contact with the shaft itself and that it was only viable at lower operating speeds.



Vibration Innovation

The revolutionary solution to the previous shortcomings was found with “Shaft Orbit” machinery protection and diagnostic systems that used non-contacting eddy current sensors and transducers. This allowed continuous observation of shaft movements within the bearing providing amplitude, phase, and frequency of vibration over the full range of operating speeds. Bently Nevada Corporation (BNC) developed what the industry would later call the “Bently equipment.” Non-contacting eddy current sensors oriented in the X and Y directions provided signals to the transducers which became known as "Proximitor" signals and a "Keyphasor®" signal viewed on an oscilloscope became the state-of-the-art in vibration analysis systems in 1967.

In 1970 American Petroleum Institute (API) adopted proximity transducers for shaft vibration acceptance testing as API Standard 617.



TYPICAL MACHINE PROTECTION SYSTEM

This standard covers the minimum requirements for axial compressors, single-shaft and integrally geared process centrifugal compressors, and expander-compressors for use in the petroleum, chemical, and gas industries services that handle air or gas. Thus, Bently Nevada became a standard in the oil and gas industry.

In 1976 API Standard 670 became the industry standard and described the minimum requirements for a machine protection system (MPS), including measuring radial shaft vibration, casing vibration, axial shaft position, shaft rotational speed, piston rod-drop, phase reference, overspeed, and critical machine temperatures (such as bearing metal and motor windings). It covers requirements for hardware (transducer and monitor systems), installation, documentation, and testing. Incorporation of the Bently Nevada Proximity Transducer System allowed BNC to become the vibration standard servicing critical equipment in pulp & paper, aerospace, and power generation industries.

The advantages over prior art were; continuous monitoring of the shaft movements, non-contacting sensors allowed for higher shaft speed rotations, shutdown protection levels, and increased diagnostic analysis.

The plethora of BNC products and service are the global standard design, analysis, and operation of rotating machinery for mechanical engineering.

Non-Contacting Eddy Current Sensors

An eddy current sensor or 'probe' is a tightly wound wire encapsulated in a molded plastic and tuned for each specific installation need. They come in a variety of sizes (diameters) from 5mm, 8mm, 11mm, up to 50mm, depending on each application's required measurement distance. The eddy current sensor performs two basic functions:

First, as a tuned oscillator which generates a radio frequency (RF) signal. This signal produces the low-energy electromagnetic field around the probe tip.

Then, the eddy current sensor performs as a special demodulator circuit which conditions the RF signal to extract a usable displacement signal from the feedback. When a conductive material is present in the RF field, the alternating electromagnetic field induces small eddy current flows in the surface of the shaft. The penetration depth of the eddy current depends on the material's conductivity and permeability. When the shaft (or conductive material) is within the linear range of the probe, eddy current flows in the surface of the shaft material and the RF will have lower amplitude. Probes are installed to keep the gap between the shaft and the probe tip in the middle of the linear range, so when the shaft vibrates towards or away from the probe, it remains in the range that the transducer can see. This means that the eddy current is now generated on the shaft surface.

Finally, when the shaft vibrates the shaft gets close and away from the probe causing the RF to be modulated with the same vibration amplitude. Eddy currents are employed in various types of machinery, such as, gas turbines, centrifugal compressors, expander compressors, gas or process air compressors. Types of failures detected include radial shaft vibration, axial shaft position, piston rod-drop, shaft rotational speed, overspeed, and phase reference.

Shaft *sensor* *transducer*

XY proximity probes

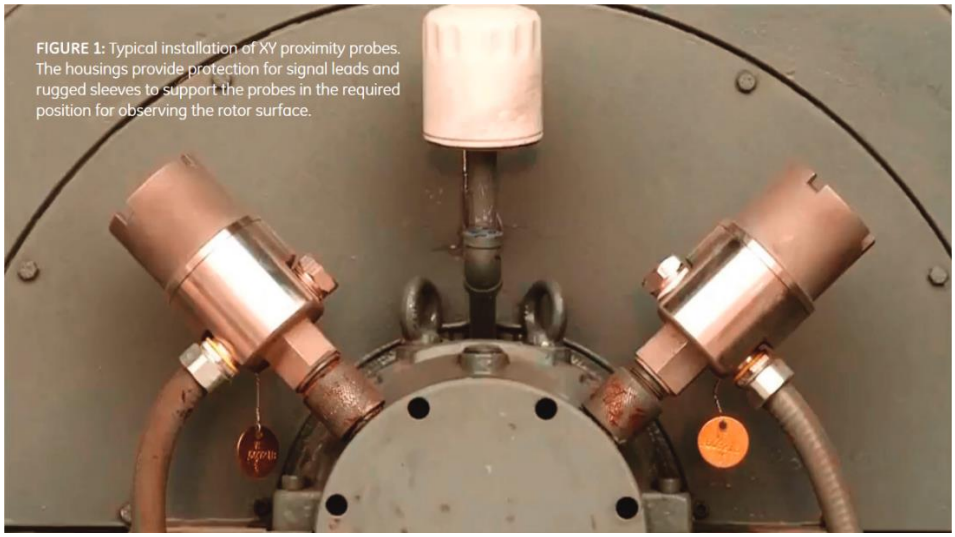
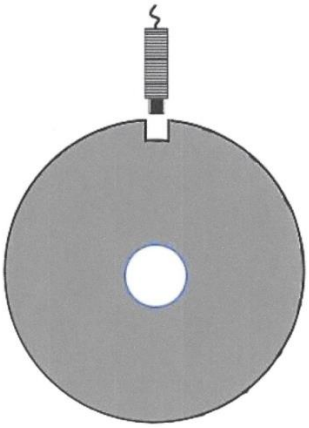


FIGURE 1: Typical installation of XY proximity probes. The housings provide protection for signal leads and rugged sleeves to support the probes in the required position for observing the rotor surface.

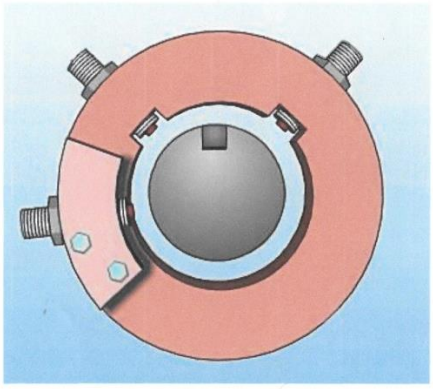
An example of the installation of XY proximity probes with a 90-degree offset (±45° from vertical) avoids interference with the horizontal split line of the bearing housing, since the upper half is removable from the machine casing. A vertical probe would also interfere with whatever is installed on the top of the housing, such as here a pair of lifting lugs and a filter associated with the lubrication vent system.

Keyphasor® Transducers

The Keyphasor®, or blank-bright spot measurement, uses a notch in the rotor to provide a reference point for shaft rotation. The Keyphasor® event is analogous to a timing mark in a car engine and provides a repeatable, accurate reference point for phase, rotative speed, and timing measurements.



Keyway Notch or Projection



Typical Probe Installation

Proximitor Transducers

The "Proximitor" name was coined in 1965 as an abbreviation of "proximity monitor." This transducer converts the eddy current sensor output (i.e., probe response) in to a signal for the use of the monitoring system. The Proximitor is technically an "oscillator-demodulator" that "drives" the probe as part of a tuned resonant RF circuit and demodulates the response to provide a highly linear proportional voltage that corresponds to the distance from the measured surface to the probe tip. Pictured below are the early 3000 series Proximitor, model 20885-01, and the new 3300XL series Proximitor with the distinctive Bently Nevada blue can that has been improved over the years.

X-Y Monitor Rack System

The 5000 Series monitoring system, produced from 1967 to 1980, was Bently Nevada's very first standard monitoring system and displays the vibration as detected. Prior to that, all systems were essentially custom designed based on specific customer requirements.

Rack size: 24" wide, 12" high, 17" deep, and about 40 pounds. The 5000 Series was replaced by the 7200 Series in 1975.

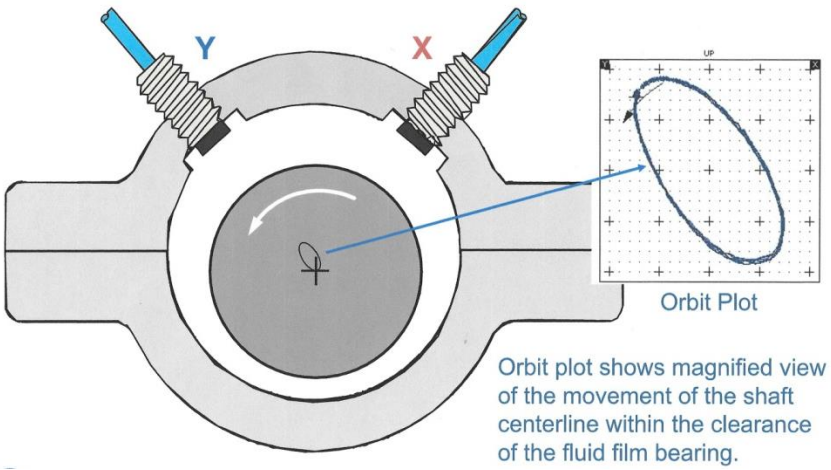
Analysis / Diagnostic System

In an A/D System, vibration is analyzed to provide prediction and protection of the rotating piece of equipment. Early oscilloscopes for radial vibration were made by Tektronix in Beaverton, Oregon for Bently Nevada. The model at right, the BN Mod 709V, was a modification of a Tektronix 5110 model oscilloscope and made with a robust traveling case for field use.

Orbit

The orbit is the two-dimensional path traced by a shaft's centerline as it vibrates. When a Keyphasor® phase reference signal is available, the orbit also includes the familiar "bright-blank" or "blank-bright" spot, denoting where the Keyphasor® event occurs during the orbit.

More than any other data presentation format, the orbit embodies Bently Nevada's contribution to industry because it shows the exact motion of the shaft as it vibrates inside the machine. Prior to Bently Nevada's introduction of the proximity probe, this observation was not practical or accurate. As such, the orbit is a fitting symbol for Bently Nevada, and is a dominant part of our familiar logo.



The Evolution of Bently Nevada Products

1950s New technology in search of an application

In his earliest experiments, Bently used miniature vacuum tubes. But recognizing the advantages of solid-state components, he quickly adapted the more reliable transistors that were becoming available by the mid-1950s. His early transducer systems began to be used by major Original Equipment Manufacturers (OEMs) in their research and development labs but were not yet being applied to plant equipment in the field. In the earliest days, Bently did everything himself with no additional employees. His philosophy was that if he built a useful product, sales would follow. He wasn't focused on a particular industry but created designed-to-order "distance detectors" that were used to make very precise bench-top distance measurements in laboratory settings. Sales channels were via mail order only.

1953 Bently encountered eddy current proximity transducer technology while working as a control systems engineer in the aerospace industry. His employer was not interested in his suggestion to use electronics for control surface position feedback.

1954 Bently developed basic circuit designs for transistorizing the eddy-current proximity transducer – which was originally pioneered by GE in the 1930s using vacuum tube-based circuits.

1955 Bently left his aerospace controls career and his pursuit of a doctorate degree to found Bently Scientific in his garage in Berkeley, California.

1960s Revolutionizing the way the world monitors machinery condition

During the 1960s, Bently hired people to help him with his business, starting with 5 employees in 1961 and reaching 150 by 1969. His machinery-focused view was that his products allowed better measurements as his probes could go "where the action is" inside the machines. His transducers were used increasingly by turbomachinery OEMs and in the hydrocarbon processing industries. The product line expanded to include proximity transducers, continuous monitors and portable test equipment. Sales shifted from mail-order to mostly partner representatives "reps." A factory-direct sales force was launched in 1967 in Houston, USA.

In the early 1960s, BNC transducer systems were often used in conjunction with third-party monitors that were not always set up properly. After dealing with several instances where the third-party monitor system was causing problems, Bently decided to start making monitors himself. This allowed BNC to offer a complete instrumentation system – from the probe in the machine, all the way to the monitor that processed the transducer signals.

1961 Bently Nevada Corporation (BNC) relocated to airport building in Minden, Nevada.

1962 First thrust position and radial vibration transducers delivered to large Original Equipment Manufacturers.

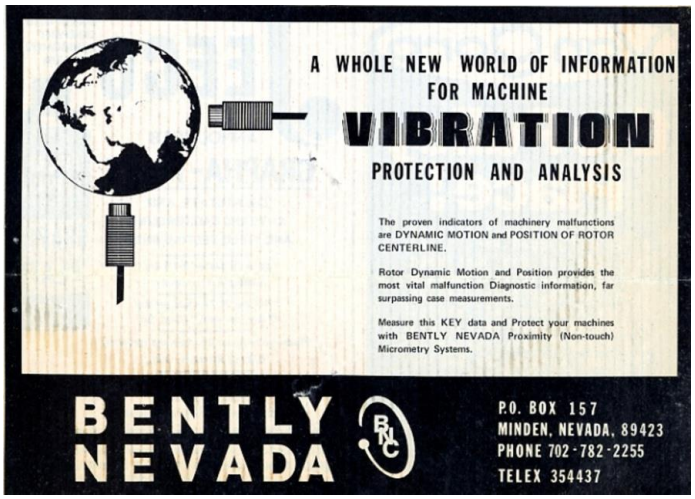
1964 First rotor kit (RK-1) launched.

1965 3000 series transducers launched. First field representative office opened in Ohio.

1966 BNC entered monitor production. TK-3 "wobbulator" introduced for instrument loop checking and calibration verification.

1967 Standardized 5000 series monitors launched. Beginning of the systems focus.

1968 "Wherever sales are available, service will also be available." New office opened in Louisiana.



BN Advertisement, c.1968 depicting XY probe pair and use of familiar shaft orbit design around BNC as company symbol.

1968 the 1205 HP Oscilloscope was used with the RotorKit for demonstration and training purposes.

1968 Orbit design as BNC logo. The orbit is actually the "Lissajous figure" that is produced on a two-channel oscilloscope when the signals from the X and Y probes are input to the horizontal and vertical signal inputs. The orbit represents the movement of the rotor centerline within the small clearances of the bearing.

1969 First international BNC office opened in the Netherlands. First customer training class at the airport facility. Course focused on installation & calibration of transducer systems.

1970s Protecting Your Machinery

During this decade, Bently's focus was to grow the core business and to become machinery diagnostic experts – not just machinery data collection experts. He increased employee count from 200 in 1970 up to 1000 in 1979. Main industries served continued to be OEMs and hydrocarbon processing industries (HPI), with a deliberate entry into protection systems for power generation. Product line additions included seismic transducers, bearing temperature monitors, and first steps to digital monitoring systems. Sales channels shifted from mostly representatives to mostly factory-direct sales force. The total number of field offices reached 24, with half in the USA and half in various international locations.

1970 American Petroleum Institute (API) adopted proximity transducers for acceptance testing (API 617). First dual probe system delivered to large heavy duty gas turbine installation. 1700 series monitor introduced.

1971 Deliberate entry to power generation segment.

1972 First Turbine Supervisory Instrumentation (TSI) offering via 7000 series system. Proximity transducers were recognized as an improvement over old "shaft-rider" systems.

1974 7200 series monitors launched.

1975 7200 series transducers launched; first software system. 9000 series monitors introduced.

1976 200,000th probe shipped. API 670 1st edition adopted by industry. Airport facility destroyed by fire.

1977 BNC adopted Material Requirements Planning (MRP) and Capacity Requirements Planning (CRP) programs.

1978 Mechanical Engineering Services (MES) launched. Would later become known as Machinery Diagnostic Services (MDS).

1980s Protecting and Managing Your Machinery

Turbomachinery OEMs, Oil & Gas (hydrocarbon processing and offshore platforms) and Power Generation remained the core industries served during this decade. BNC moved beyond probes and monitors to include online Condition Monitoring (CM) software. Basic research at Bently Rotordynamics Research Corporation (BRDRC "Bird Rock") enhanced the company's understanding of machinery behavior. The company grew from 1000 employees in 1980 to 1250 by 1989. The product line expanded to include API 670-compliant systems, ADRE, DDM/TDM software, custom products, and early portable data collectors. Sales channels continued to migrate away from representatives to the factory-direct sales force. Total field offices exceeded 50 by 1989 with just over 30 being located internationally.

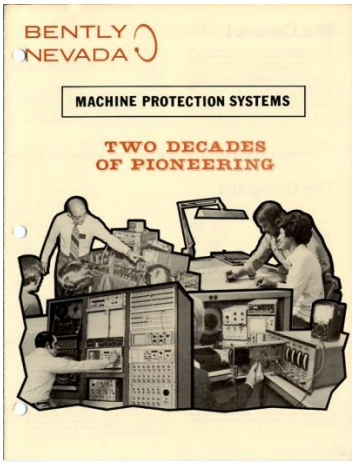
1980 ORBIT magazine launched. ADRE launched. Custom Products department introduced.

1981 Personal computers (PCs) introduced by IBM. 250th TSI system installed.

1982 BRDRC formed to contribute to the field of rotordynamics knowledge and to advance the technology of electronic instrumentation for monitoring the mechanical performance of rotating machinery. Computerized Smart Monitor launched to integrate protection & management for first time.

1983 Data Manager software introduced.

1984 "Turnkey" Design & Installation Services (D&IS) launched to increase scope and expand TSI retrofits. First portable data collector introduced.



BN Advertisement from the 1980s

1986 Dynamic Data Manager (DDM) introduced.

1987 Transient Data Manager (TDM) launched.

1988 3300 Series Monitors launched.

1989 1,000,000th Bently Nevada transducer sold.

1990s Protecting and Managing All Your Machinery

Bently's goal was to remain focused on turbomachinery OEMs, power generation and hydrocarbon processing, and to expand into more general industrial facilities as well. The Trendmaster 2000 system was designed to accommodate monitoring needs where a permanently installed scanning system was appropriate. First performance monitoring software was added to the line. Sales channels expanded to a total of 80 offices in 42 countries, using factory direct sales force wherever possible

1990 Trendmaster 2000 introduced. 3300 probe series launched. First generation "expert system" developed.

1991 D&IS sales exceeded $3 million.

1992 DDM2/TDM2 SW debuts. 2201 monitors launched.

1994 1800 and 990 transmitters; 3500 monitoring system introduced.

1998 Performance Manager 2000 launched. Initial concepts for System 1 software discussed.

1999 System 1 software developed with updated portable data collector. ARC Advisory Group (www.arcweb.com) originated the term "Plant Asset Management (PAM)" to describe systems specifically intended to enable the full scope of asset management functions in a plant.

2000s Plant Asset Management (PAM)

In the early 2000s, Bently constructed a new headquarters facility in Minden to take the place of several separate buildings. Bently's strategy was to expand PAM offerings within the core business, and also with "new" verticals such as metals & mining, pulp & paper, water & wastewater. The product line added increased emphasis on thermodynamic performance monitoring. After acquisition by GE, sales channels were still factory direct where possible, with Bently Nevada specialists integrating with generalists within the broader GE organization.

2001 ARC report named BNC as the industry leader in the Plant Asset Management (PAM) category.

2002 GE acquired BNC. By the time Bently Nevada was sold to GE Energy in 2002, the company had 1800 employees worldwide, operated in more than 40 countries, and had global sales exceeding $250 million USD.

Donald E. Bently and his team pioneered the successful commercial use of the continuous monitoring non-contacting eddy current proximity transducer to measure shaft vibration in rotating machinery. This led to the development of shutdown protection for equipment and vibration data acquisition through diagnostic processing systems and related services. This created the foundation for a new discipline within mechanical engineering of the diagnostics of machinery malfunctions.

Don Bently was born on October 18, 1924, in the farming community of Muscatine, Iowa. Mr. Bently served in the armed forces as a Seabee during World War II and later attended the University of Iowa, receiving a B.S. in Electrical Engineering in 1949, followed by an M.S. in Electrical Engineering the following year.

After graduation, he went to work for the flight controls department of North American Aviation in Los Angeles where he assisted with research on the use of electronic sensing technologies for aircraft control systems. It was here that he first encountered eddy-current position sensing technology, but at the time his employer concluded that there was limited use for the eddy-current technology, as hydraulics were then the standard in aircraft controls. Bently, however, felt the technology showed commercial promise elsewhere and received permission to use it in his own endeavors. In 1956, he left aerospace to start a small business, while pursuing a Ph.D. degree at University of California, Berkeley. The business, Bently Scientific Company, built and sold eddy-current distance sensing products by mail order, operating out of his garage in Berkeley.

Looking to expand his company Don drew a 200-mile circle around Berkeley to find the ideal place to relocate. He found the Carson Valley, a small rural community much like the farming community of his youth that would support his love of agriculture and ranching with room to expand, and he moved the company to Minden, Nevada 15 miles east of Lake Tahoe.

In October 1961 he renamed his business Bently Nevada Corporation (BNC), and began building his team. Don Bently served as its CEO until February, 2002 when General Electric purchased BNC.

Don received many awards over this career including 1992 Honorary Foreign Member of St. Petersburg Academy of Engineering in Russia, 1997 N.O. Mylestad Award from ASME Design Engineering Division Technical Committee on Vibration & Sound, 1999 ASME's R. Tom Sawyer Award, and in 2000 the ASME Frederick P. Smarro Award.

Don passed away on October 1, 2012 in Carson Valley, Nevada at the age of 87.

… and his team:

Roger G. Harker started as a summer engineering intern in June 1964 and became employee number 3 in June 1966. Roger designed and built the first 5000 series monitor system that enabled the company's successful entry into the high-speed machinery protection market in 1967. He was also heavily involved in the development of the Keyphasor®, or blank-bright spot measurement, using a notch in the rotor to provide a reference point for shaft rotation during the early years.

Roger was President of BNC from 1986 to 2002. He emphasized that the path to success for any business is to make effective strategic decisions to "do the right things." This core principle allowed BNC to become very successful in the field of machinery protection, condition monitoring, and diagnostics.

Roger was also instrumental in the adoption of eddy-current senor systems by the American Petroleum Institute. He was a member of their Subcommittee on Mechanical Equipment from 1986–2014 and also a member-at-large for the ASME International Gas Turbine Institute from 2000–2006.

Philip C. Hanifan was employee number 4, hired June 2, 1967. He designed proximity sensors, tachometers, tunable filters, digital vector filters, monitoring systems & various other BNC products until being named Engineering Lead in 1972.

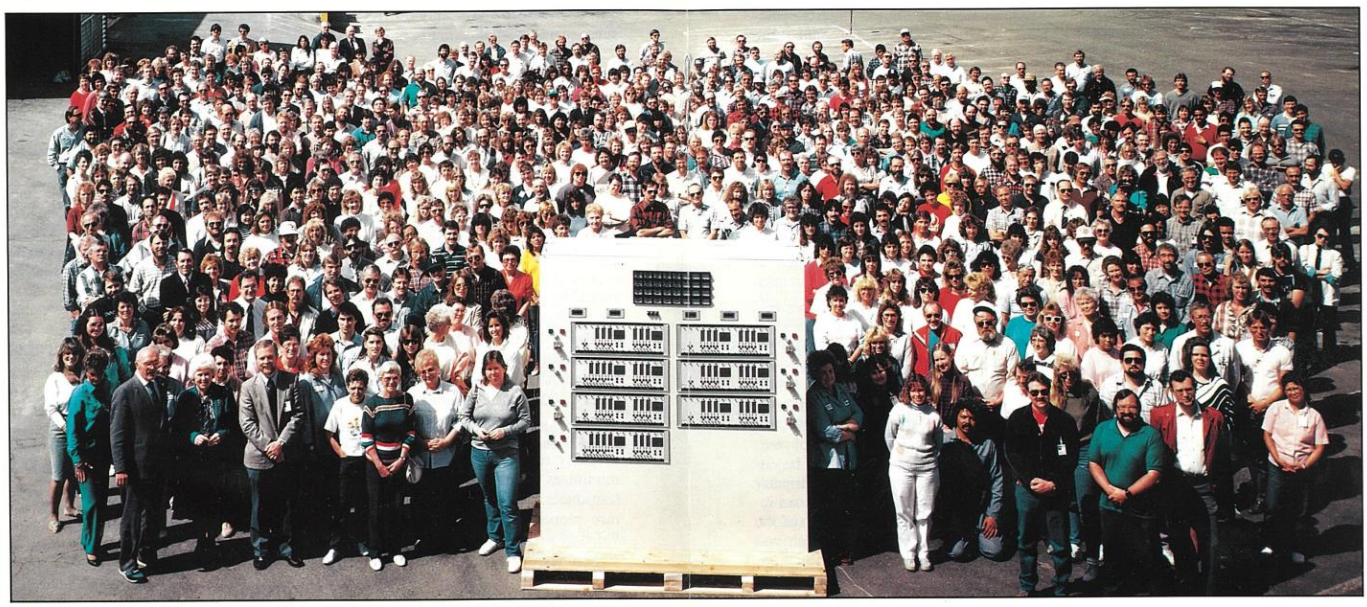
In 1976 the BNC airport facility in Minden experienced a serious fire, after which Phil was named Manufacturing Lead. Here he introduced the Material Requirement Planning (MRP) system to BNC manufacturing. He has also led Custom Products Engineering, Engineering Services and along with David H. Biggs and John K. Little was awarded U.S. Patent 5,019,814 for "Wireless Data Coupling System and Method."

With the acquisition of BNC by GE in 2002, Phil's contributions were recognized with a GE Edison Award as Bently Nevada Chief Technologist status in 2004.

Phil continued to contribute to Bently Nevada's success until retiring on June 2, 2021, after a 54-year career.

Many others were critical to success:

These are thousands of local Nevadans who have worked in production and other departments that made the innovations in eddy-current sensors possible at BNC. Don Bently had the vision to recruit incredible engineering talent, both men and women, from universities and bring them to Minden. He also made sure to recruit local talent worldwide in over 50 countries to operate the Bently Nevada business and provide services to their home countries. Another key to success was the training of over 200 new engineers in our Bently Nevada New Engineer Training program that started about 1980. Many of those engineers have moved on to become CEOs, Chief Engineers, and Research Directors, at respected technology companies in the United States.



Bently Nevada's new 3300 System was developed by using the knowledge and expertise gained in over a quarter century of machinery monitoring. The goal was to build a system that would become the new standard. Ease-of-use and field-programmable options were engineered into the design.

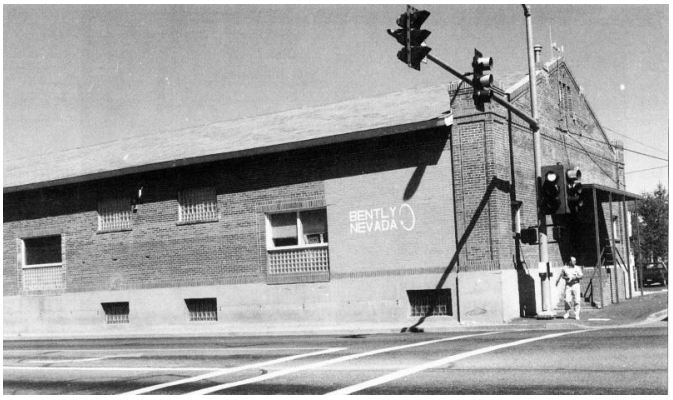
Technicians suggested ways to make it easier to install, test and service. Production personnel helped streamline our manufacturing techniques. This commitment adds up to a superior, reliable product that does more for our customers and costs less.

Bently Nevada's 3300 Team circa 1990s

Published in the ORBIT magazine with the following quote, "When you buy from Bently Nevada, you buy more than a product. You buy a *commitment* from our entire company. You buy our proven record of *reliability*, extensive field *experience* and *excellence* in personal customer service."

Historical Buildings

Location of original Bently Nevada Corporation building (rebuilt after the fire on Sunday, April 11, 1976). 1132 Airport Road, Minden, NV 89423.



Don Bently's office was in the old Dangberg buildings purchased by BNC in 1969. "Building D", 1615 U.S. Hwy 395, Minden, NV, photo from the 1990s.

Bently Nevada Offices from 1976 to 2000. 1617 Water Street, Minden, NV 89423. The egg plant was added to the west side. Office space to the east side. Photo courtesy of Douglas County Historical Society – Photo #:0019-0005 Minden Butter Manufacturing Co. building 'presently' the Bently Corp.

Bently Nevada Corporation headquarters since 2001. 1631 Bently Parkway, Minden, NV 89423.

Acknowledgements

Special thanks must go to Roger Harker and Phil Hanifan for their willingness to share the history of the Bently Nevada Corporation from the earliest years through their many contributions to the business. They were a pleasure to work with. Others that have shared in preparing this document include Gary Swift, Steve Sabin, and Jerry Pritchard. Tonya Woods supported us and championed the creation of the Bently Nevada museum of artifacts. Without Tonya's help this ASME History & Heritage designation would not have been possible. I would also be amiss if I did not also recognize Joel Blumenthal, ASME Comstock Section President and the ASME Comstock Section for their willingness to support this endeavor. Last, but not least, thanks to Brenda Cullen, Curator at the Douglas County Historical Society, for her expertise and guidance. She shared the treasures which the museum has captured and allowed us to include some of the early photographs here. Thanks so much, Seena Drapala (Bently Nevada employee from 2003 to 2009)

Further Reading

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"Donald E. Bently," https://peoplepill.com/people/donald-e-bently

The History and Heritage Program of ASME

Since the invention of the wheel, mechanical innovation has critically influenced the development of civilization and industry as well as public welfare, safety and comfort. Through its History and Heritage program, the American Society of Mechanical Engineers (ASME) encourages public understanding of mechanical engineering, fosters the preservation of this heritage and helps engineers become more involved in all aspects of history.

In 1971 ASME formed a History and Heritage Committee composed of mechanical engineers and historians of technology. This Committee is charged with examining, recording and acknowledging mechanical engineering achievements of particular significance. For further information, please visit http://www.asme.org

LANDMARK DESIGNATIONS

There are many aspects of ASME's History and Heritage activities, one of which is the landmarks program. Since the History and Heritage Program began, 27X artifacts have been designated throughout the world as historic mechanical engineering landmarks, heritage collections or heritage sites. Each represents a progressive step in the evolution of mechanical engineering and its significance to society in general.

The Landmarks Program illuminates our technological heritage and encourages the preservation of historically important works. It provides an annotated roster for engineers, students, educators, historians and travelers. It also provides reminders of where we have been and where we are going along the divergent paths of discovery.

ASME helps the global engineering community develop solutions to real world challenges. ASME, founded in 1880, is a not-for-profit professional organization that enables collaboration, knowledge sharing and skill development across all engineering disciplines, while promoting the vital role of the engineer in society. ASME codes and standards, publications, conferences, continuing education, and professional development programs provide a foundation for advancing technical knowledge and a safer world.

HISTORIC MECHANICAL ENGINEERING LANDMARK

Non-Contacting Eddy Current-Sensors

1967

NON-CONTACTING EDDY CURRENT-SENSORS CONTINUOUSLY MONITORING A MACHINE SHAFT WITHIN THE BEARING PROVIDED A BREAKTHROUGH IN MACHINE MANAGEMENT, CONTROL AND PROTECTION. THIS INNOVATION ALLOWS MECHANICAL ENGINEERS TO CONTINUOUSLY OBSERVE SHAFT MOVEMENT WITHIN THE BEARING CLEARANCE (THE ORBIT). THIS ORBIT CHARACTERIZES THE AMPLITUDE, PHASE, AND FREQUENCY OF THE VIBRATION OVER THE ENTIRE OPERATING RANGE OF THE MACHINE. THIS INNOVATION WAS PIONEERED BY DONALD E BENTLY AND HIS BENTLY NEVADA ENGINEERING TEAM. THIS INNOVATION BECAME THE GLOBAL STANDARD FOR MECHANICAL ENGINEERS DESIGNING AND OPERATING ROTATING MACHINERY OVER THE FULL RANGE OF OPERATING SPEEDS.

ASME
SETTING THE STANDARD

The American Society of Mechanical Engineers—2024

Designation Ceremony held June 20th, 2024, at 1631 Bently Parkway South, Minden, NV 89423

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