EVOLUTION OF A MECHANICAL SEAL CONDITION MONITORING SYSTEM

by

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Frank Olmos, Field Service Engineer at BW/IP International, Inc. (formerly Borg Warner Industrial Products), graduated from National University with a B.S. degree in Computer Science, in 1984. He joined Borg-Warner Mechanical Seal Division in 1981. His technical activities have included mechanical seal design and testing, electronics design and testing, along with the installation and troubleshooting of various mechanical seals and auxiliary equipment. He is also responsible for the design, implementation and analysis of the seal monitoring system used on mechanical seals.

ABSTRACT

Mechanical face seals have been used in fluid handling equipment for many years, with a long history of reliability and safety. Most users of mechanical seals, however, tend to have a few critical service areas where process operating conditions, changes, design, or installation problems, result in excessive leakage. The costs of these repeat situations result in high maintenance dollar expenses, and a solution to these repeat problems can result in large savings through increasing the meantime between failures. The actual operating conditions in the seal chamber are frequently not known by the users. Process variables such as pressure, temperature, injection flow, and equipment wear or mechanical vibration problems, have a direct influence on seal performance. Process or operational upsets which cause seal leakage are frequently hard to detect. The development is documented of a seal monitoring system which was designed to measure and record actual operating conditions at a field site. A methodology to analyze the recorded data to determine how the system operating conditions influence seal performance is included. A case history of actual field use of the monitoring system are reviewed.

INTRODUCTION

Mechanical seals, unlike motors, bearings, gear boxes, and other types of rotating equipment, operate in an environment that can be variable and influenced by many factors. A few of the factors which have an influence on the seal environment are as follows:

- Changes in pump flow rate due to automatic controllers responding to process demand or manual adjustment of valves by operators.
- Changes in NPSH caused by pressure upsets in the suction supply source, liquid level changes in towers, or pressure and temperature changes in the process stream.
- Changes in fluids or fluid properties due to process or atmospheric changes, or batch processing.
- Changes in cooling flow to the seal caused by orifice washout, heat exchanger failure, filter plugging, or worn out seal chamber throttle bushings.
- Changes in mechanical vibration, due to misalignment, bearing wear, or dynamic balance.

On less critical applications, changes in these conditions may have only a small effect on seal life. In some applications, however, shifts in these conditions can cause repeat or unpredicted failures. On critical services, or where unexplained failures occur, an important factor for or in predicting seal problems and finding solutions through analysis is the data on the actual seal operating conditions. Generally, this actual data is difficult or impossible to obtain.

In order to gather the data needed to analyze seal operating conditions, a mechanical seal condition monitoring system was developed. This system measures and records the seal operating system environment and allows for real time monitoring of the seal conditions and saves the data obtained for use in system analysis at a later date.

The mechanical seal monitor is a self contained mini computer with a built in memory. The monitor is powered by self contained batteries and is UL listed intrinsically safe for use in hazardous operating locations. Instrumentation for monitoring seal performance is built into the seal end plate. The monitor is installed at the pump site and connected to the seal end plate instrumentation receptacle with an electrical cable.

DESCRIPTION OF SEAL MONITOR SYSTEM

The seal monitor is a programmable minicomputer with 128K bytes of storage memory (RAM). The monitor is powered with self contained lithium batteries and the unit is UL listed as intrinsically safe for use in Class I, Group C, D. Class II, Group E, F, G, hazardous locations. The system is designed to be installed at a pump site within 10 ft of a specially configured seal end plate. The monitor is connected to the seal end plate by a 10 pin connector through which the following data is transmitted.

- *Mechanical seal face temperature* is monitored by the use of a thermocouple which is placed in the stationary face member of a mechanical seal about 0.050 from the seal interface. The thermocouple is positioned so that it records actual seal inner face temperature during static or dynamic operation of the rotating equipment.
- *Stuffing box temperature* is measured by a thermocouple which is placed through the seal end plate, in order to have access to the seal fluid cavity (Figure 1). Monitoring with this thermocouple enables the system to record actual seal fluid environment temperature at all times.
- *Stuffing box dynamic pressure and static pressure* is detected by a pressure transducer which is threaded and sealed

into a hole in the seal end plate. This hole also penetrates the seal fluid cavity and allows the transducer to transmit both dynamic pressure pulses and static pressure signals to the seal monitor system.

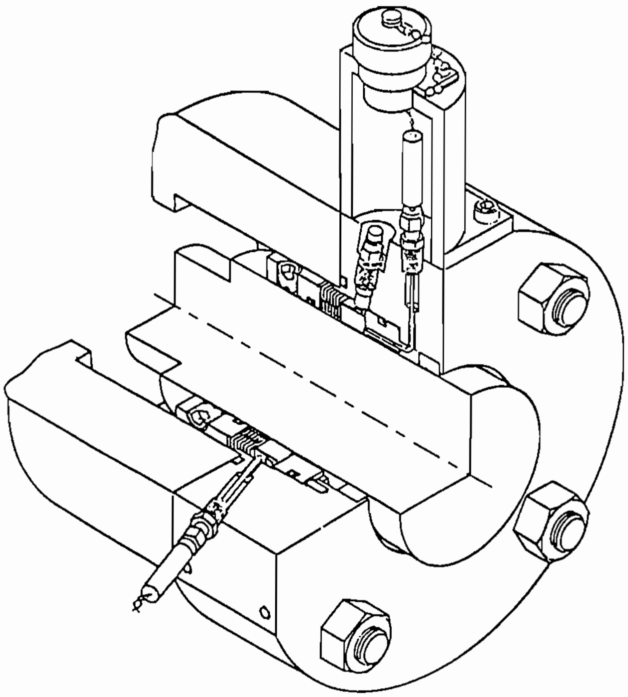

Figure 1. Seal Fluid Cavity.

MONITORING AND ANALYSIS

The seal monitor's microcomputer organizes the data and performs preliminary analysis. This data is stored in a semiconductor type memory, based on the various trigger limits programmed into the seal monitor just prior to the initialization of the unit. A plugin (five pin) port is provided in the seal monitor system for programming and offloading of recorded seal data.

The seal monitor system is programmed for each separate application for which it is used to collect data. Based on a complete job application analysis by a trained operator, a parameter file is designed which will record data at a frequency suited to the objective of the seal monitor application. For example, data set points or trigger limits, can be established for each operating condition monitored (Figure 2). Normally, operation within these ranges would not be critical to seal performance. However, operation outside of these trigger limits is considered justification for recording. The seal monitor system is programmed so that it will record data when it exceeds these threshold trigger limits. Furthermore, the seal monitor may be programmed to capture real time data at any interval desired.

Programming of the seal monitor is accomplished by a serial interface from a personal computer to the five pin port on the seal monitor.

There are three ways that captured data is recorded, and each is used in a specific way to support analysis. They are referred to as statistical data (synchronous), real time data (asynchronous), and dynamic pressure.

• *For statistical data (synchronous)*, incremental averages are maintained for face temperature, stuffing box temperature, and static pressure (Figure 3). This data is read by the seal monitor on a continual time basis, however, the data points are

SEAL MONITOR --- PARAMETER INITIALIZATION UTILITY

Seal Monitor HW #:	1	Status:	HARDWARE DOES NOT EXIST
Initialization Date:	7/02/87	Location:	CUSTOMER ID
Initialization Time:	9:25:25	Pump #:	ID TAG

Data File (START-DATE-2-PUMP-CHARACTERS.3-LOCATION-CHARACTERS): 070287ID. CUS

TRIGGER VARIABLES	TRIGGER (X - YES)	LIMIT
High Seal Face Temperature (C)	X	99
High Bulk Fluid Temperature (C)	X	99
High Differential Temperature (C)	X	18
Unstable Temperature Oscillations (C)	X	8
Low Static Pressure (PSI)	X	96
High Static Pressure (PSI)	X	898
High (MAX-MIN) Dynamic Pressure (PSI)	X	4
Integrated Dynamic Pressure (PSI-SEC)	X	4

Dyn-Pres Data/Block (@ 2048 HZ):	128	Asynch. Data/Block (@ 2 HZ):	503
Asynch. Trigger Check Intvl. (MIN):	3	Synchronous Data Intvl. (SECS.):	1203
Asynch. Min. Storage Intvl. (MIN):	60	Self Test Time Intvl. (MIN):	33

Figure 2. Seal Monitor—Parameter Initializing Utility.

recorded as an average of the readings, taken over any time interval established in the initialization program, (Example; three minutes). Consequently, this serves to compress data in which long term trends and cycles can be evaluated.

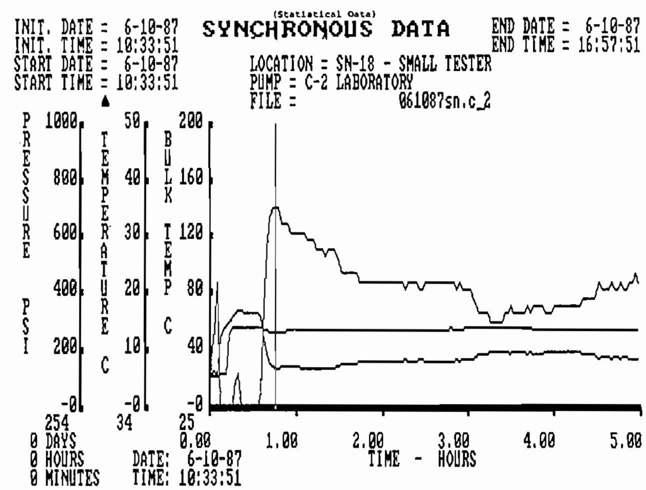

Figure 3. Synchronous Data.

• *Real time data (asynchronous)* is taken by the seal monitor for face temperature, stuffing box temperature and static pressure (Figure 4). This data is continuously compared to thresholds limits which are established for each application and are entered into the initialization program. The seal monitor records "real time" data in two ways; real time data is recorded based on a time frequency (Example: 60 min) established in the initialization program, and the seal monitor records between these time frequencies *only* if the established trigger limits are exceeded.

• *Dynamic pressure* pulsations are continuously compared to trigger limits established for each application (Figure 5). The seal monitor reviews dynamic pressure in two ways. Data is taken over an established interval of time (Example; 90 minutes), and, if trigger limits are not exceeded, the seal monitor does not record during this time. At the end of each established interval, if trigger limits are not exceeded, data is recorded. This ensures that *some data* is available for analysis.

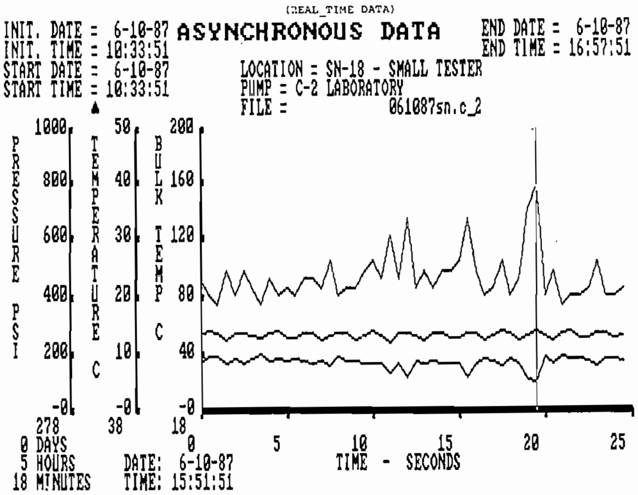

Figure 4. Asynchronous Data.

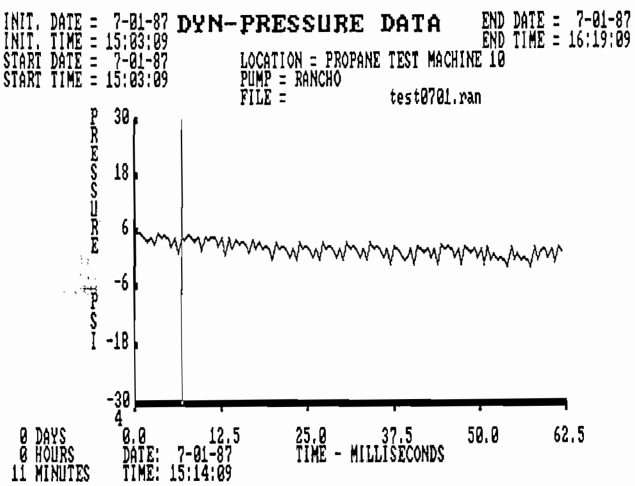

Figure 5. Dyn-Pressure Data.

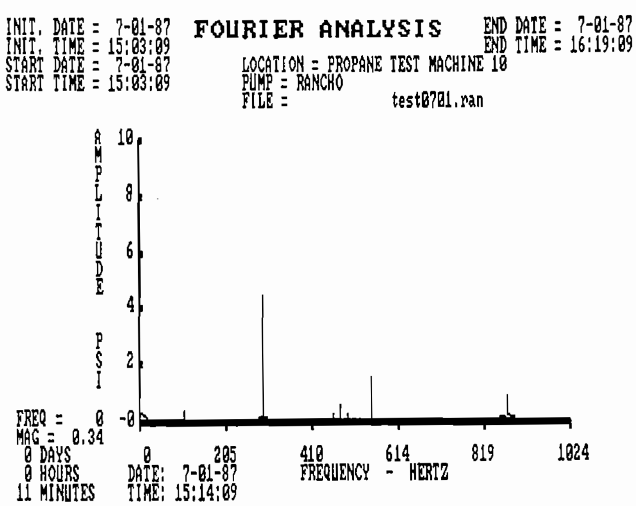

Figure 6. Fourier Analysis.

An additional feature of dynamic pressure is that an engineer is able to analyze collected pressure data by using a fast fourier transform analysis program (Figure 6). This allows an engineer to look at the frequency spectrum which contributes to pressure pulsations, and can, in most cases, be traced to its source.

Once installed, the seal monitor collects meaningful data on all conditions of the seal operation and records any changes in the seal environment that may have an effect on seal performance.

Data transmitted to a personal computer from the seal monitor, statistical data, real time data and dynamic pressure, are correlated by a time clock feature built into the seal monitor system. The data presents a historical picture in time, and captures events which may lead to poor seal performance.

Reviewing screens of data on a properly programmed PC, an engineer compares information to previous lab and field tests to provide a diagnosis of operating conditions and seal health. Reports are returned to the user with, if appropriate, recommendations which may vary from changing or controlling the seal environment to recommending a seal design change or a change in materials.

CASE HISTORY
PAPER AND PULP SERVICE

Casing press: 2-75 psig
Stuffing box press: 2-75 psig
Seal type/size: Bellows type, 10 in diameter
Fluid: water and pulp
Monitor serial number: 15 and 27
Casing temperature: amb. 300°F
Refiner type/size: 16,000 hp pulp refiner
API Piping plan: 32
Vapor press: 285 psig
SP GR: 1.0
Flush temperature: amb. 100°F
RPM: 3600

PREFACE

Historically, the seal previously installed in this equipment varied in performance life from a few hours after start up to several months. The silicon carbide stationary face exhibited chipping and cracking; chipping and wear were observed in the carbon rotating face when removed. Determination of this erratic seal performance and a solution to this problem was the primary objective of this seal monitor installation. Evaluation focused on the following:

- Monitoring seal performance both short and long term.
- Monitoring fluid conditions in the seal cavity both short and long term.
- Determining the effect of any fluid changes in the seal cavity on seal performance.

The seal monitor is designed to evaluate relational data by capturing actual data points. The graphs are based on stored data points, which can be pulled out for any given time frame. Trigger limits are set for an instantaneous snap shot of changing relationships. If the equipment stayed within the set operating parameters, the seal monitor only recorded data on a set time frame. The snapshots outside the trigger limits was the information the designers wanted to evaluate.

MONITOR REPORT TIME FRAME

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Initialize:	Time: 7:05 :07	Date: 4/14/88
Start Up:	Time: 7:13 :07	Date: 4/14/88
Disconnect:	Time: 13:01 :07	Date: 4/28/88
Total Time Monitored:	14 Days	
	Set Up #1	*Set Up #2*
Interval	24 hrs.	30 days
Real Data	15 min.	3 hrs.
Synch Data Checks	30 sec.	6 min.
Face Temperature	125°F	125°F
Bulk Temperature	99°F	115°F
Differential	25°F	10°F
Pressure	2-70 psig	2-65 psig
Vibration Pressure	5-30 psig	5-30 psig

NORMAL OPERATING RANGE (2 GPM FLOW)

NORMAL OPERATING RANGE (2 GPM FLOW)

	Box Pressure	*Face Temp.*	*Bulk Temp.*
Tail Idle	10	94°F	89°F
Drive Idle	10	102°F	99°F
Tail Steaming	35	96°F	89°F
Drive Steaming	35	102°F	99°F
Tail Refining	59	110°F	100°F
Drive Refining	59	125°F	107°F

Under normal operating conditions, seal face temperature remains within an acceptable limit of 130°F. The drive end mechanical seal runs 15°F hotter than the tail end, due to additional compression from shaft growth.

REDUCED FLOW RANGE TEST (½ HOUR MANUAL)

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End	*Water Flow Brooks*	*Water Flow Universal*	*Box Pressure*	*Face Temp.*	*Bulk Temp.*
Tail	2.25	2.00	60	104	96
Tail	1.75	1.50	49	102	96
Tail	1.00	1.00	48	109	115
Tail	.75	.75	47	109	115

Reduced flow during refining did not significantly effect seal face temperature or performance. The bulk temperature illustrated a greater swing than the seal face temperature.

SYSTEM PRESSURE SWING

SYSTEM PRESSURE SWING

A) Normal 4/20/88 8:33

Time	*Box Pressure*	*Face Temp.*	*Bulk Temp.*
0 hrs.	59	102	98
4 hrs.	14	96	89
9 hrs.	59	102	98

B) Upset 4/19/88 17:33

Time	*Box Pressure*	*Face Temp.*	*Bulk Temp.*
9 hrs.	62	107	102
10.5 hrs.	31	104	94
11.5 hrs.	8	195	223
12.5 hrs.	59	109	99

The seal monitor picked up instantaneous swings and long term swings which elevated the bulk temperature above 220°F at a pressure of eight psig. The fluid in the bottom of the box is turning to steam. The expansion, which is approximately 1600 × the volume, could be creating some of the problems on both the seal and the bushing.

DYNAMIC PRESSURE

The data that was captured from recordings taken at the pulp mill showed no sign of erratic fluid vibrations that would effect seal performance. Dynamic pressure using mean stuffing box pressure as a reference point from which plus or minus swings are recorded. The dynamic pressure never varied more than a couple of pounds. This translates into a smooth running refiner.

CONCLUSION

The seal design operates properly even outside the design parameters. Pressure swings and reduced flow rates do not affect seal performance. Seal face temperature remains constant and bulk temperature will rise with reduced injection. There are upsets in the operation of the refiner, which can severely damage the seal faces. The liquid in the box is changing from water to steam. This occurrence has been recorded at three separate time intervals. Normal pressure swings do not affect face temperature or bulk temperature. This upset conditions does affect both. The time frame of the upset is approximately one hour. Based on lab testing, interruptions of the seal water injection might be experienced.

Prior to this installation, seals in this service were lasting approximately five months due to a loss of cooling fluid in the seal cavity. Now that this problem has been resolved, with proper cooling, optimum seal performance can be expected for a minimum of four years.

INSTALLATION AND COMMERCIAL USAGE

In order to conduct a proper mechanical seal analysis (operational records, maintenance procedures and records, and any other pertinent data that related to the mechanical seal installation), the customer must provide pump information such as product being pumped, product temperature, suction pressure, discharge pressure, stuffing box pressure, specific gravity, and a description of any auxiliary equipment used in conjunction with the mechanical seal installed on the rotating equipment. The minimum analysis period is two months to view any changes or interruptions in the rotating equipment that would possibly signal an upset in the mechanical seal performance.

Costs will vary depending on nature of service, which has direct relationship to conditions in which the seal monitoring system must capture data from the rotating equipment. The costs for the seal monitoring system in an average industrial installation ranges form $2000 to $4000, respectively. A field engineer must be at the site with the seal monitoring system and watch the varying performance of the rotating equipment that is being analyzed for approximately three days. In this time period, the field engineer is making any final adjustments to trigger limits in the seal monitor software, while capturing fast snapshots of real data to perform a preliminary seal monitor analysis. When the seal monitor system has been properly installed, the seal monitor can be left unattended for a period of 30 days, during which time it is recording data continuously.

ACKNOWLEDGEMENT

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