

New Developments in Microcor Technology

Allan Perkins
Rohrback Cosasco Systems Inc,
11841 E Smith Ave,
Santa Fe Springs, California, 90631, USA.
Fax: +(1) 562-949-0123
E-mail: aperkins@rohrbackcosasco.com

ABSTRACT

Microcor®¹ technology is an advanced electrical resistance measurement for corrosion monitoring that was first developed during the late 1990's and implemented in the field in early 2000. Since that time, the improved performance has been widely adopted worldwide as the new standard for metal loss measurement in on-line corrosion and erosion monitoring applications where it operates in conjunction with process control systems for better corrosion and asset management. Experience with the system performance is reviewed, along with new developments into wireless transmitters that are fully integrated into a new generation of wireless distributed process control systems.

1. INTRODUCTION

This new technology created a major improvement over the previous metal loss measurement technology which was important in its own right. More importantly, the one to two orders of magnitude improvement in its speed of response has finally turned this metal loss measurement into a full process parameter. Since its introduction in 2000, significant changes in SCADA (Supervisory Control and Data Acquisition) and DCS or PCS (Distributed Control System or Process Control System) system communication configurations have occurred, with TCP/IP protocol over Ethernet becoming more and more prevalent. Now, further network evolution, integration with the business networks and wireless communication systems are again changing the system architectural concepts and economics.

2. WHAT IS MICROCOR TECHNOLOGY?

Microcor technology is an advanced form of electrical resistance measurement of metal loss for corrosion and erosion monitoring. Its development commenced in the mid 90's originally as a magnetic inductance method of measuring metal loss when processing corrosion coupons. From there, it was developed further into a magnetic inductance probe for direct measurement of metal loss similar to electrical resistance corrosion probes. In this form, a new electronic transmitter was designed that

¹ Microcor is a registered trademark of Rohrback Cosasco Systems Inc.,

produced a much higher resolution than previously attainable with conventional electrical resistance probe systems. As the new system further evolved, changes to the probe were made which finally made the technique more like electrical resistance than magnetic inductance as the sensing method. The end result was a system that gave an 18 bit (2^{18}) metal loss resolution, or one part in 262,144. This compared with a resolution of just one part in 1,000 or 10 bit resolution (2^{10}) for similar electrical resistance probes, producing an resolution improvement factor of 262 times. Subsequently, much of the field development of the system was made with the joint assistance of Saudi Aramco to further refine the probes and the system to ensure the improved performance translated into the field and would operate successfully in all environments and especially in source service, where electrical resistance probes had always proved to be a problem due to bridging of probe element connections by conductive iron sulfide deposits.

Improved resolution alone does not automatically guaranty improved overall performance. It is no good to increase the resolution 1000 times if the noise also increases a 1000 times. The increased resolution must be accompanied by an increase in the signal to noise ratio in order to get an overall improved sensitivity. Figure 1 is a graph of the resultant real-world field performance showing an improvement ranging between 40 and 100 times in sensitivity over conventional electrical resistance depending on the application. Figure 2 shows a comparison of signal to noise ratio between an electrical resistance probe and electronics configuration on the left and the Microcor probe and electronics on the right. Both are from probes with a 5 mil probe span, and on the same scale of metal loss.

The improved performance was derived from four main areas. First, the electronics was directly connected to the probe. Secondly, the probes were designed for exceptionally good thermal conduction between the measurement and reference elements. Thirdly, the usable probe designs were limited in the resistance ratio range that was required to be measured. This eliminated the once signature electrical resistance probe configuration of the wire loop both on geometry and thermal characteristics. Finally, the flush probes were designed to avoid a short path length between the ends of the probe elements to avoid iron sulfide bridging in hydrogen sulfide service. This improved design for sour service operation is good for oil and gas operation, but has the disadvantage of further reducing the resistance of the probe measurement element. This then raises the performance requirements of the electronics even further.

3. FIELD INSTALLATION & ELECTRICALLY HAZARDOUS AREAS

Oil and gas industry plants are generally designated electrically hazardous areas, and require electrical and electronic equipment to be third-party certified to not create an explosion if and when an explosive gas is present. Firstly, a gas explosion requires both oxygen and the explosive gas to be present together in the correct range of proportions. Secondly, the explosion also requires an electrical spark of sufficient energy, or a surface temperature above a certain value.

Different gases have different spark ignition levels and surface ignition temperatures. For any particular gas the ignition spark energy and surface ignition temperature are defined but not related. Typically the inside of a pipe or vessel under normal operation is not a hazardous area, as no oxygen is present. This may be different at start up and shut-down conditions.

Under North American standards oil and gas systems are designated Class 1 areas, in which there are two possible hazardous sub-categories, Division 1 and Division 2. Division 1 applies to a few areas where explosive gases may be present under *normal* operating conditions. Division 2 applies to the much greater number of areas where an explosive gas may be present only under *abnormal* conditions.

Under the European, the newer IEC classifications, and new North American Standard, these same areas are divided into three categories or zones instead of two. Zone 0 refers to areas where explosive gases are present *under normal operation for continuous or long periods*, defined as more than 1,000 hours per 10,000 hours (just over a year). See Table 1. Zone 1 refers to areas where explosive gases *are likely* be present under normal operation, defined as between 10 hours and 1,000 hours per 10,000 hours. Zone 2 refers to areas where explosive gases are only present under *abnormal* conditions, defined as less than 10 hours per 10,000 hours. Zone 0 and Zone 1 correspond basically to Division 1. Zone 2 corresponds to Division 2. The only difference is that in Zone 0, explosion-proof designs are not permissible whereas suitably certified intrinsically safe designs are allowed. North America is now adopting the Zone classification in parallel with the Division rating, with the intention of eventually replacing the Divisions rating and harmonizing with the European ATEX and IEC standards.

These hazardous areas also have further gas group sub-categories based on the spark ignition levels and the temperature ignition levels based on the gas typical of the group of the gases present in the area. In North America these are designated by letters A, B, C, D, E, F, and G, A being most explosive. In the European and IEC standards, the corresponding classifications are IIC, IIB, and IIA, with IIC being the most explosive gases.

In an explosion-proof design, an explosion is permitted to occur inside the equipment enclosure if an explosive gas mixture should ever be present, but the enclosure design prevents its propagation to the area outside to produce a general explosion. By comparison, an intrinsically safe design does not require a explosion-proof enclosure, but instead requires the electronic circuits, input and output connections to the electronics have additional multiple redundant protective components such that even if one or two fault conditions develop in the electronics, no part of the circuit can create a spark with sufficient energy to cause ignition, and no part can generate a temperature high enough to produce an explosion.

Figure 3 shows a typical field installation of the probe and transmitter. This is a hard-wired installation. An explosion-proof design of the equipment was used instead an intrinsically safe design, as it afforded greater flexibility and lower installation costs.

The explosion-proof design provides an inherently heavier duty design for ruggedness and allows up to 32 transmitters to be connected on a single multi-drop power and communication cable. By comparison, intrinsically safe design transmitters are limited to no practically no more than four transmitters per cable because current and voltage limiting barriers are required on each cable from the safe area out to the hazardous area. Hence, much less cabling and safety equipment is necessary for the explosion-proof designs.

4. SYSTEM ARCHITECTURE

In its simplest configuration the corrosion transmitters are hard-wired back to a server in the central control room where ICMS3-Amulet®² Corrosion Management software collects and manages the data through a SQL Server database. Here the measured metal loss data is computed into corrosion rate data using typically the last 24 to 48 hours of data. Process data for correlation with corrosion upsets is transferred from the DCS and corrosion rate data is sent from the corrosion server to the DCS.

Separate servers are used for the corrosion and related data because of the generally longer timescale over which data is analyzed. Typically, for a process control system data more than two days old is transferred to an historian as it is little used and is not relevant to the current process control. Corrosion on the other hand is a generally slower process although corrosion upsets can occur quickly. Consequently, days, weeks and months worth of data need to be accessed quickly and easily for review. Process control computers are not optimized for this purpose. In addition, corrosion issues can be more complex and require more investigation and analysis than the standard process data. Typically this is done by corrosion technicians, and corrosion specialist who typically may not be resident at the plant. All of the corrosion related data needs to be available over the company intranet for easy access by these corrosion specialists as well as local inspection and operations personnel.

A hard-wired configuration of metal loss transmitters is shown in Figure 4. Figure 5 shows that the same configuration is used when mixing the metal loss probes and transmitters with electrochemical probes for corrosion rate and pitting in water systems or for galvanic probe measurements in water injection systems. This system architecture is fine for smaller plants, where the 1200m (4000ft) limit of cable runs is sufficient.

For larger scale plants, it is now common to use multi-mode fiber optic links to provide transmission from the control room to the plant of up to 3 km (9,800 ft), where fiber optic converters and repeaters are used to convert to hard-wired links for the local cable runs to the transmitters, thereby providing up to 1,200 m (4,000 ft) on each of multiple radiating cable runs to the transmitters. Multimode fiber optic cables have lower cost transmitters since they used low cost LED's. Single-mode fiber optic cables can also be used. These fibers are of smaller diameter and use higher cost laser transmitters. This combination permits high data rates to be transmitted up to 120 km on a single fiber cable. In addition, fiber optic cables provide complete immunity to electrical noise interference, and electrical isolation from end to end.

Upstream on-shore corrosion and erosion monitoring installations will typically use hard-wired, or a combination of hard-wired and multi-mode fiber optic links in the main processing plant areas, the remote headers, the main manifolds and locally at the well sites. However, to interconnect the well sites, over the wide areas involved high speed dual ring single mode fiber links are common. The dual ring provides redundancy and protection from a failure or damage of the fiber and any one point in the ring.

When we commenced installing these systems back in 2000, the input and output connections to the system were mostly serial ports, RS 232, RS 422 and later RS 485. A typical configuration is shown in Figure 6. The TCP/IP Ethernet connections were only between the servers in the control room and for

² Amulet is a trademark of Corrosion and Condition Control Ltd

connection to the company's intranet. Subsequently, with the use of Ethernet extending further and further into the field, the field end converters became RS 485 to TCP/IP and the whole communications network for all of the process controls and corrosion transmitters became Ethernet and Industrial Ethernet. Industrial Ethernet uses the same communications protocol and the normal Business Ethernet, but also uses within the TCP/IP the ability to attach priorities to different messages. Critical process control loops, such as flow and pressure control loops require fast response, and have carefully tuned time-sensitive parameters set. For these loops the variability of data transfer times with the standard business TCP/IP protocol would be a problem. The industrial Ethernet allows higher priorities to be set for these critical control loops to ensure data communication response times are not compromised. For corrosion monitoring response times are not critical by comparison, and do not require the enhanced capability of the Industrial Ethernet higher priority settings. However, as the standard process controls move over to an Industrial Ethernet backbone, it becomes more critical to ensure that the bandwidth of the system is not compromised.

Process control over Ethernet is designed with more bandwidth than typical business systems. In business systems the Network is normally sized for about 10 to 20% of the maximum bandwidth that the computers that are attached to it could use. This is acceptable as in the worst case the system slows down a little and e-mails take a few more seconds or minutes to arrive. In a process control system, those delays can be unacceptable. Consequently, the Process Control Networks are designed to be able to handle the full capacity of the system under maximum capacity conditions, to ensure proper operation of the system under all operating conditions. For the same reasons, Network redundancy is also much more of an inherent requirement in Process Control Networks where the highest reliability is required.

Figure 7 shows a typical newer configuration with the Industrial Ethernet now extending to the field end of the system. The system is now nearly all Ethernet. At the Control room end the Process Control has its own redundant Network configuration and is connected to the companies Business network through a firewall to provide added security to the process control system. The diagram shows the ease with which it was possible to combine the internal corrosion monitoring, the external cathodic protection monitoring, and the SCADA RTU (Remote Transmission Unit) into the same communication network and interconnect the various servers at the central location.

The advantage for the corrosion specialist is that all of the relevant data is delivered to his desk in a manner that simplifies correlation of the data along with the integrity management criteria to produce a more coherent and cost-effective system.

5. WIRELESS PROCESS CONTROL

The return on investment of these new rapid response on-line corrosion monitoring systems has been demonstrated clearly on many occasions. For example, see NACE 2001 Paper 01319 where investment in a wired on-line monitoring system on an Amine system produced an estimated return of between \$0.3M to \$3M on just one of three trains for a total investment across the plant of \$0.2M. One of the most important factors here was the correlation of corrosion upsets with other process parameters and manually input data achieved with the Corrosion Management System. Pro-active use of such an on-line corrosion management system also commonly achieves savings in Corrosion Inhibitor use of 15 to

20%, and frequently higher. Such economic cases need to be better presented to management whose focus is primarily on ROIC (Return on Invested Capital). Frequently, corrosion monitoring takes a lesser priority than other process control functions even though the corrosion monitoring helps protect a highly expensive plant asset to an extent much greater than does much of the process control system.

Such economic advantage has been easily achieved with many hard-wired systems. However, now a new development has helped to move the economic break-even point to an even lower level in a number of plant applications. This is with the use of wireless process monitoring networks.

A major oil producer recently estimated that the cable installation cost to install ten on-line corrosion monitoring points on an offshore platform was \$100,000, or \$10,000 per point. Now, for a \$1200 increase in transmitter costs a wireless monitoring point may be installed removing the need for cable to the monitoring point completely. Rohrbach Cosasco has partnered with Emerson Process Management and their Smart Wireless system to produce a Smart Wireless Microcor Transmitter.

The wireless corrosion transmitter is shown in Figure 8. A complete re-design of the transmitter was required for the wireless system because of the low power consumption that was required for battery operation. The radios have also been specially designed for low power since they must be continuously active. Most of the standard process transmitters have been or are being re-designed for wireless network operation to allow the battery pack to last for 5 to 7 years before replacement is required. Metal loss corrosion transmitters require more power in general due to the relatively high energization required when reading the probes. For the corrosion transmitter we installed a slightly larger battery pack and have a projected battery life of 2 to 3 years, which is compatible with the probe replacement time. The re-designed transmitter was required to have lower power consumption by a factor between 5 and 10 to provide the necessary battery life. This was achieved along with an improvement in the measurement performance and thermal noise rejection.

A further modification was required in converting from the wired to the wireless metal loss transmitter. Currently, the wired systems measure metal loss and the corrosion rate is computed at the central corrosion server using variations of linear regression to calculate corrosion rate over a period of typically 12 to 48 hours depending on the system. Graphs of metal loss and corrosion rate from a typical wired metal loss transmitter are shown in Figures 12 and 13. The Microcor wireless transmitters have the ability to compute corrosion rate from metal loss on-board the transmitter, so that both metal loss and corrosion rate are transferred from the transmitter direct to the process control system. This configuration provides for easier integration of the transmitters into a standard DCS system, where the added features of a separate corrosion server are not required or are not economic.

The transmitter base station, or gateway, is shown in Figure 9. The overall typical wireless system architecture is shown in Figure 10. Each wireless gateway is capable of handling up to 100 transmitters. The wireless network is a self-organizing 2.4 GHz mesh network. This important feature allows the radios to act as relay stations for other transmitters as well as transmitting their own data. See Figure 11. The range of the radios in a relatively dense plant environment is between 300 and 900 ft. With the mesh network the overall range of the system is extended, since it is only necessary for the each transmitter to reach an adjacent transmitter nearer to the gateway than itself. The configuration is ideal for process plant applications. Both wired and wireless systems can be mixed as required or to accommodate legacy systems.

The wireless gateway provides both Ethernet and serial Modbus output, see Fig 11. This enables the wireless network to be part of an Emerson process control system, be integrated into any other manufacturers DCS system, or to be added to any new or existing Microcor corrosion monitoring system.

Extensive re-design was made to the wireless mesh radio network in order to provide the highest level of security, which has become a major concern for process control systems. There was natural concern with the possibility to pick up and interfere with the radio communication network. The radio network has five layers of security.

Authentication	-	Authenticate sender and receiver
Verification	-	Verify that the data is valid
Encryption	-	Encrypt the data
Key Management	-	Periodic changes to encryption keys managed automatically
Anti-Jamming	-	Avoid Interference and blocked communication spaces

The self-organizing network uses 128 bit encryption, user definable key rotation and frequency hopping spread spectrum. It also does not support TCP/IP based communications. The gateway uses Secure HTTP and SSL-enabled connections for Ethernet communications with the host system. All other ports remain closed.

These new wireless systems offer flexibility of use and economies not previously achievable. For example with corrosion monitoring, it is sometimes a problem to find the most effective monitoring location. Alternate access points are often available for probes but moving the electronics with an on-line system is inconvenient and may be costly. A wireless solution makes this much easier to accomplish. Addition of monitoring points to an existing wired or wireless network can also be implemented much more easily.

6. EVOLUTION IN MICROCOR PERFORMANCE

The first generation of this transmitter was limited in the range of probe resistance and probe temperature over which it could operate. This was part of the result of the improved performance that was achieved. Configuration modules in the transmitter had to be changed when moving to a new alloy other than carbon steel. The second generation permitted all alloy ranges to be covered without deterioration in the reading sensitivity and signal to noise ratios. Figures 12 and 13 show the typical sensitivity of these metal loss techniques in field operation. This sensitivity and response brings the corrosion rate measurements to realm of process control even in largely or exclusively hydrocarbon service where electrochemical techniques do not operate.

Figure 14 shows the type of data from the on-line electrochemical Corrat³ transmitter, which monitors corrosion rate by Linear Polarization Resistance (LPR) and incorporates solution resistance compensation for a wider range of operation. See ASTM G96-90 (2001) e1 Standard Guide for On-Line Monitoring of Corrosion in Plant Equipment (Electrical and Electrochemical Methods). In addition, pitting tendency is also measured by an electrochemical current noise signal that has been used for many

³ Corrat³ is a registered trademark of Rohrback Cosasco Systems

years in this instrument with good success. The measurement is usefully qualitative for a tendency to pitting. Actual quantitative measurement of pitting rates is currently not possible with any plant electrochemical methods. It had been hoped that Electrochemical Noise measurements would prove to be more quantitative and less qualitative, but this has not proved to be the case. Additionally, in the Oil and Gas Industry the typical hydrocarbon content quickly renders even measurements in water phases ineffective and noisy due to the hydrocarbons filming over the electrodes.

Figure 14 shows the output from an on-line Corrat probe and transmitter in the liquid area of an Amine absorber system. This graph shows the effect of a corrosion upset which is also accompanied by an increase in pitting tendency. Normally, in relatively uniform corrosion the electrochemical current noise between the electrodes is relatively low compared to the corrosion rate. The left hand side of the graph in Figure 14 shows this condition. The black trace shows the corrosion rate. The red graph shows a lower value and typically near to zero. This is typical of stable conditions and uniform corrosion. On May 31 to June 1, the graphs are reversed during the corrosion upset. Here, the corrosion rate increases but the red pitting tendency increases even more and is erratic and unstable. This is typical of pitting and heavy corrosion that has been detected and proven by analysis of the probe electrodes to show pitting in some of these upset conditions.

Amine systems are a good example of where electrochemical probes can be used in the liquid regions of the system, provided iron sulfide deposits do not bridge probe electrodes. However, these cannot be used in the vapor phases of the system. Typically, the electrochemical probes require a little more maintenance to keep the system operating in good condition. If the pitting information is not critical, it is often easier to use the high resolution metal loss probes even in water and water based systems, since they generally require less maintenance.

Metal loss measurements by standard electrical resistance methods had been slow in response, prior to the development of the Microcor advanced metal loss measurements. This new technique has closed that gap substantially and brought rapid response to hydrocarbon and non-aqueous environments. Figures 12 and 13 show this improved response. Figure 12 also shows some of the second order effects of process and or outside diurnal temperature changes. All metal loss probes are temperature compensated to a first order by the use of a reference element. In fact, they could not function without this reference element since the resistance of a probe element is dependent on temperature and its thickness. Probe design is an important part of minimizing these second order temperature effects. Further work is in progress to further reduce these second order temperature effects.

7. SUMMARY

The increased sensitivity of this Microcor high resolution metal loss measurement has made a significant improvement in corrosion monitoring for on-line applications and finally taken it into the realms of a process parameter, especially in hydrocarbon services where electrochemical methods are generally not applicable. Further evolution of the technique is in process to further improve the signal to noise ratio by second order correction of some of the residual temperature noise. Added to this evolution, is the addition of what may yet become a revolution where wireless operation establishes itself in process control in the same way as wireless systems have been, and are being, adopted in every other area of digital electronics. The convenience and installation cost advantages will make further implementation

of on-line corrosion monitoring much more likely and help to make corrosion measurement and management finally much more integrated with overall process control and management where it belongs.

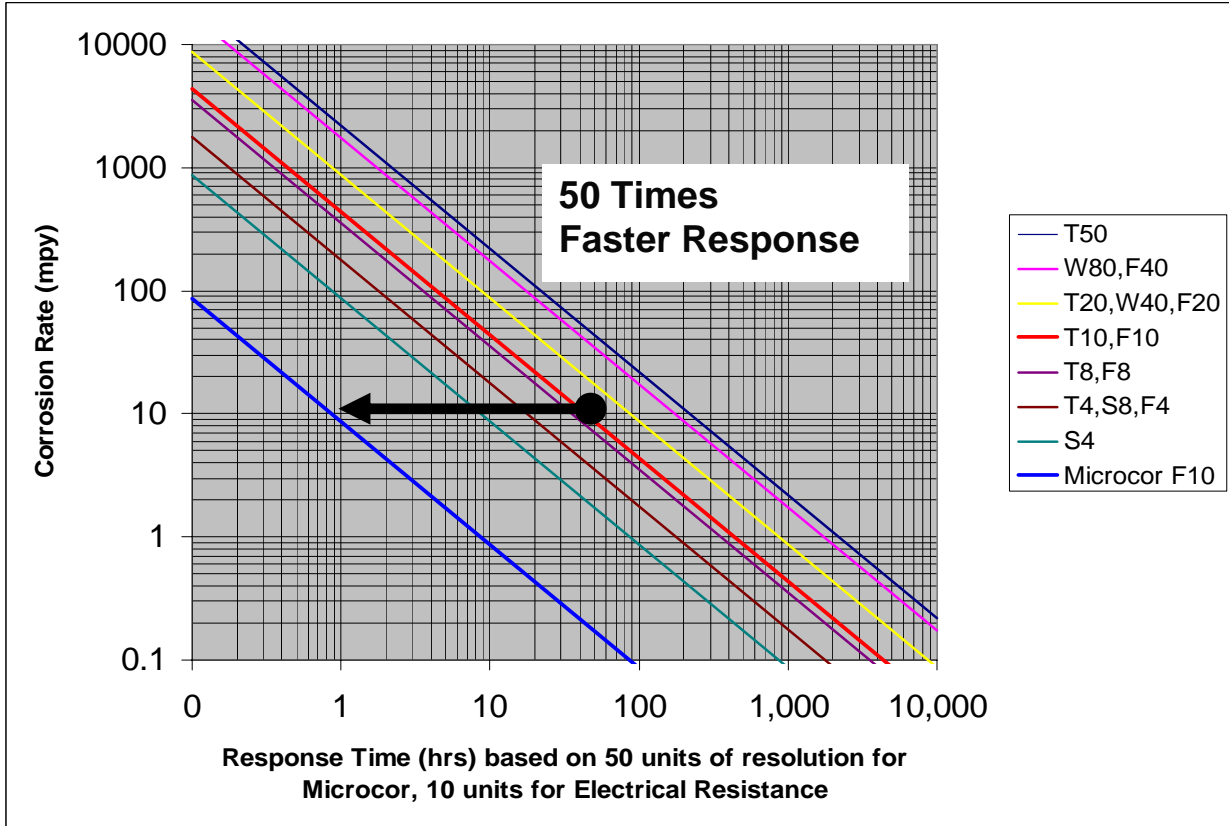


Figure 1 Comparative Sensitivity

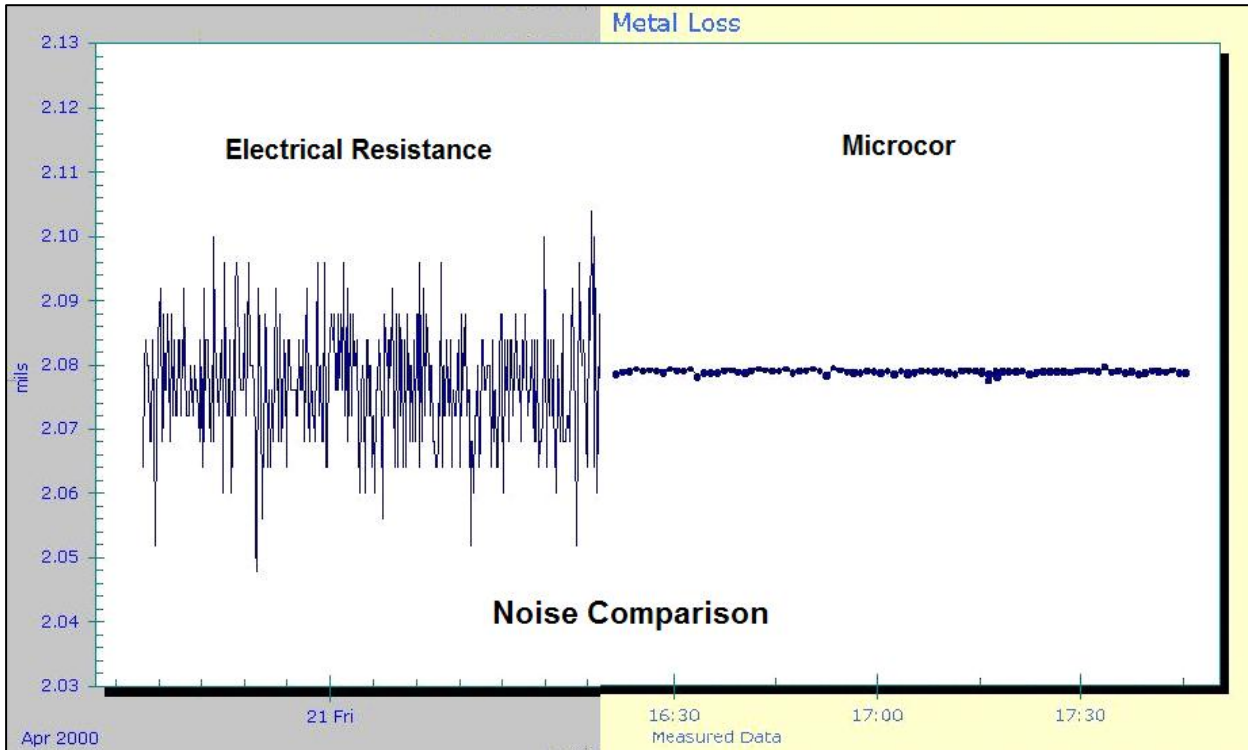


Figure 2 Comparative Signal to Noise



Figure 3 High pressure retrievable upstream probe and transmitter, and medium pressure process plant probe and transmitter

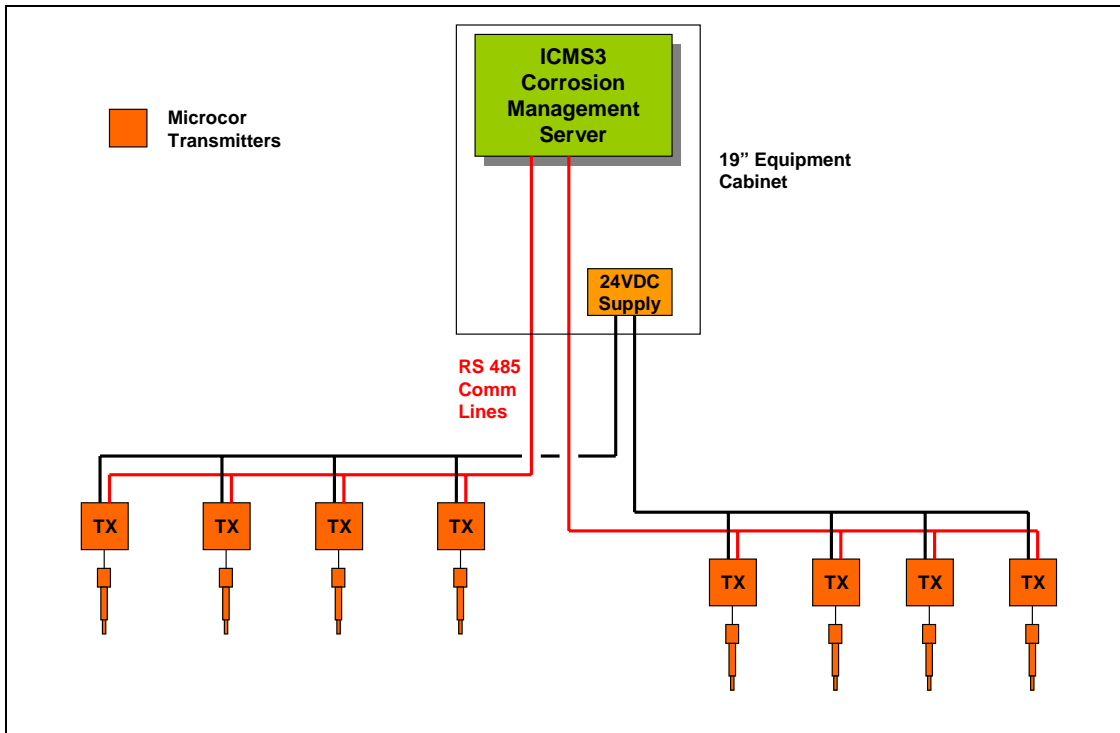


Figure 4 Hard-wired Architecture with Microcor metal loss transmitters

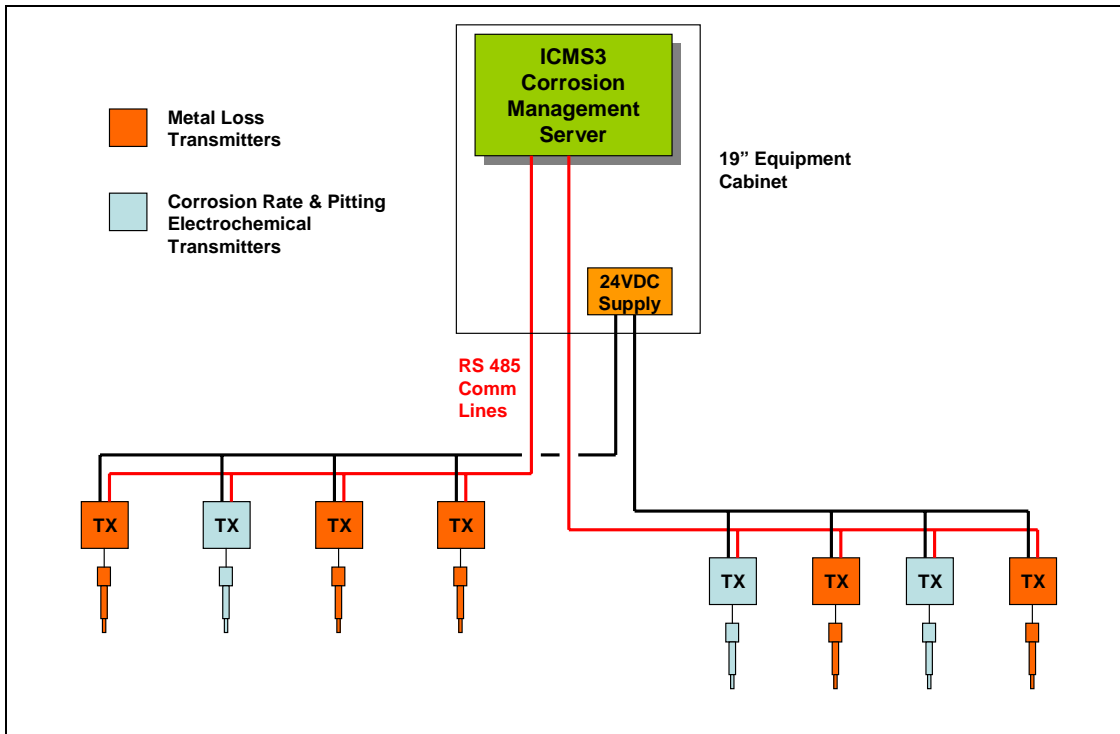


Figure 5 Hard-wired Architecture with Metal Loss and LPR/Galvanic Probe Transmitters

Table 1 - Probability of Explosive Conditions
Class 1 – Flammable Vapors or Liquids

USA & Canada Only	Division 1		Division 2
Europe, IEC, & new USA & Canada	Zone 0	Zone 1	Zone 2
Explosive Gas Mixture Presence	Continuous or Long Periods	Likely	Unlikely or Abnormal
Gas Presence in hours per 10,000 hours	>1,000	10 to 1000	<10
Probability of Gas Presence	1/10 to 1	1/1000 to 1/10	< 1/10
	10^{-1} to 10^0	10^{-3} to 10^{-1}	$< 10^{-3}$
Intrinsic Safety Permitted Faults			
Instrument NOT to generate an explosive source	With 2 Faults [ia]	With 1 Fault [ib]	Under normal operation
Faults to generate explosive source	3	2	1
Assumed Probability per Fault	$1/10,000$ or 10^{-4}		
Probability of Instrument Failure	10^{-12}	10^{-8}	10^{-4}
Probability of Explosive Conditions Per 10,000 hours (1.14 yrs) = Prob of Gas x Prob of Fault	10^{-12} to 10^{-13}	10^{-9} to 10^{-11}	$< 10^{-7}$
Probability of being struck by lightning in USA per year (8760 hrs)	3.6×10^{-6}		
	Reference: National Lightning Safety Institute		

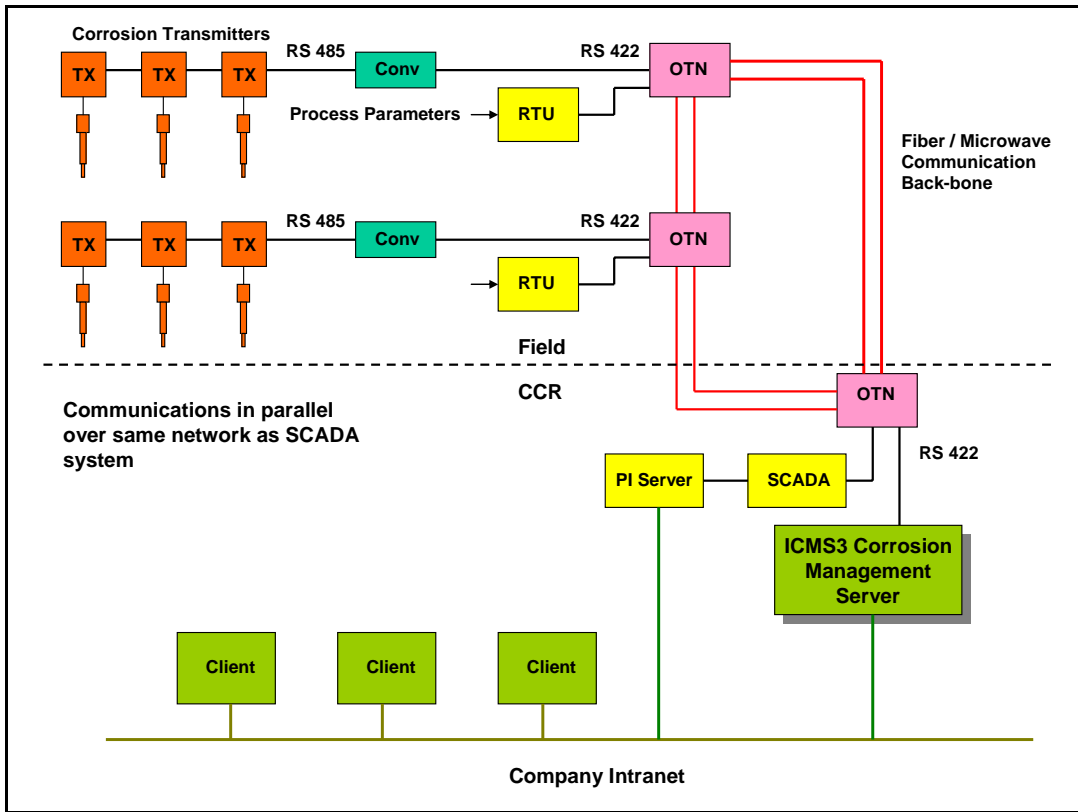


Figure 6 Typical Early Upstream Wired System Architecture

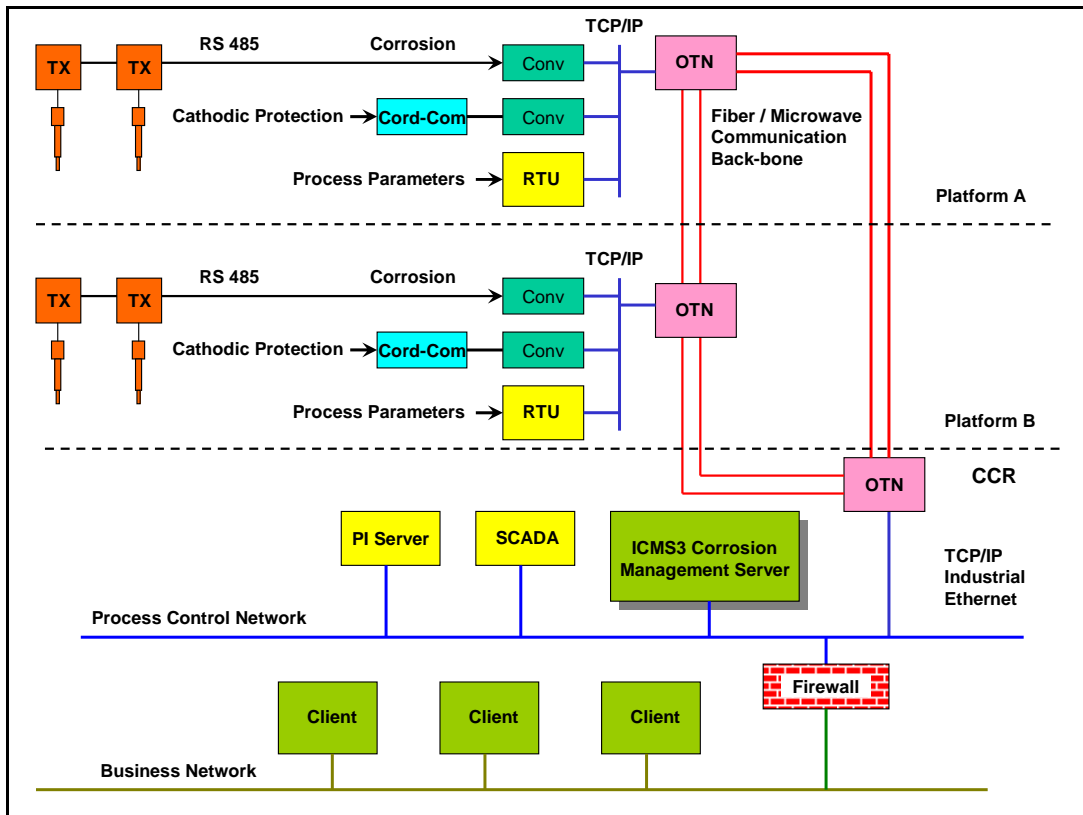


Figure 7 Typical New Configuration using Industrial TCP/IP on Offshore Platform



Figure 8 Wireless Microcor Corrosion Transmitter



Figure 9 Wireless Gateway

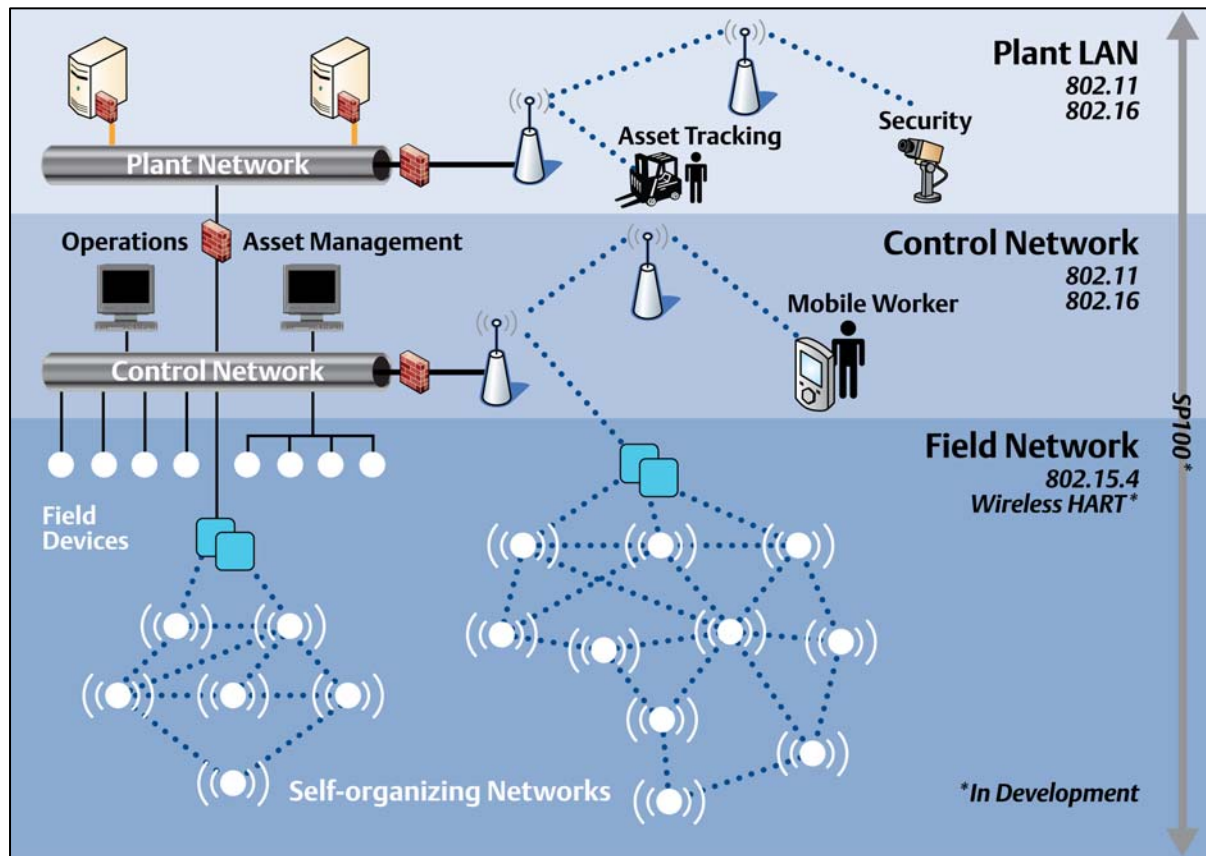


Figure 10 Smart Wireless System Architecture



Figure 11 Smart Wireless Network, Gateway and Interface



Figure 12 Corrosion Upset from Microcor Transmitter on Upstream Gas System

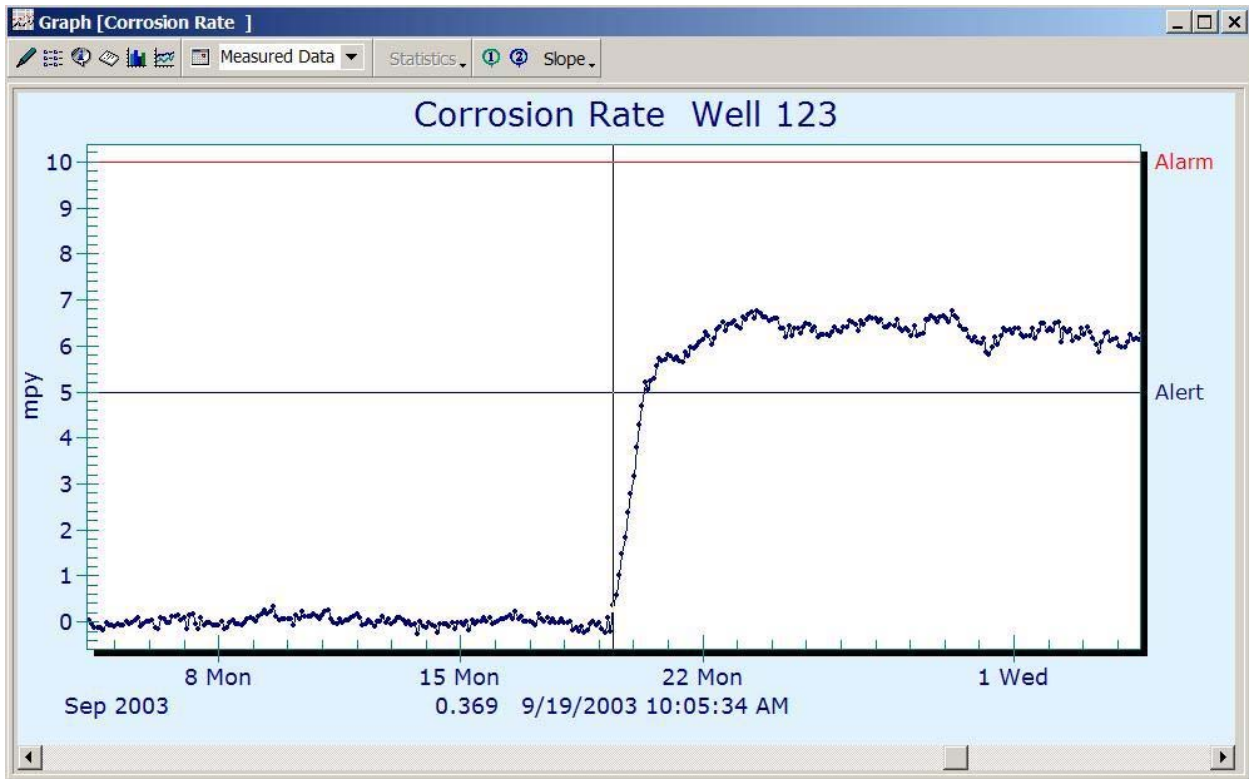


Figure 13 Computed Corrosion Rate from Metal Loss Signal

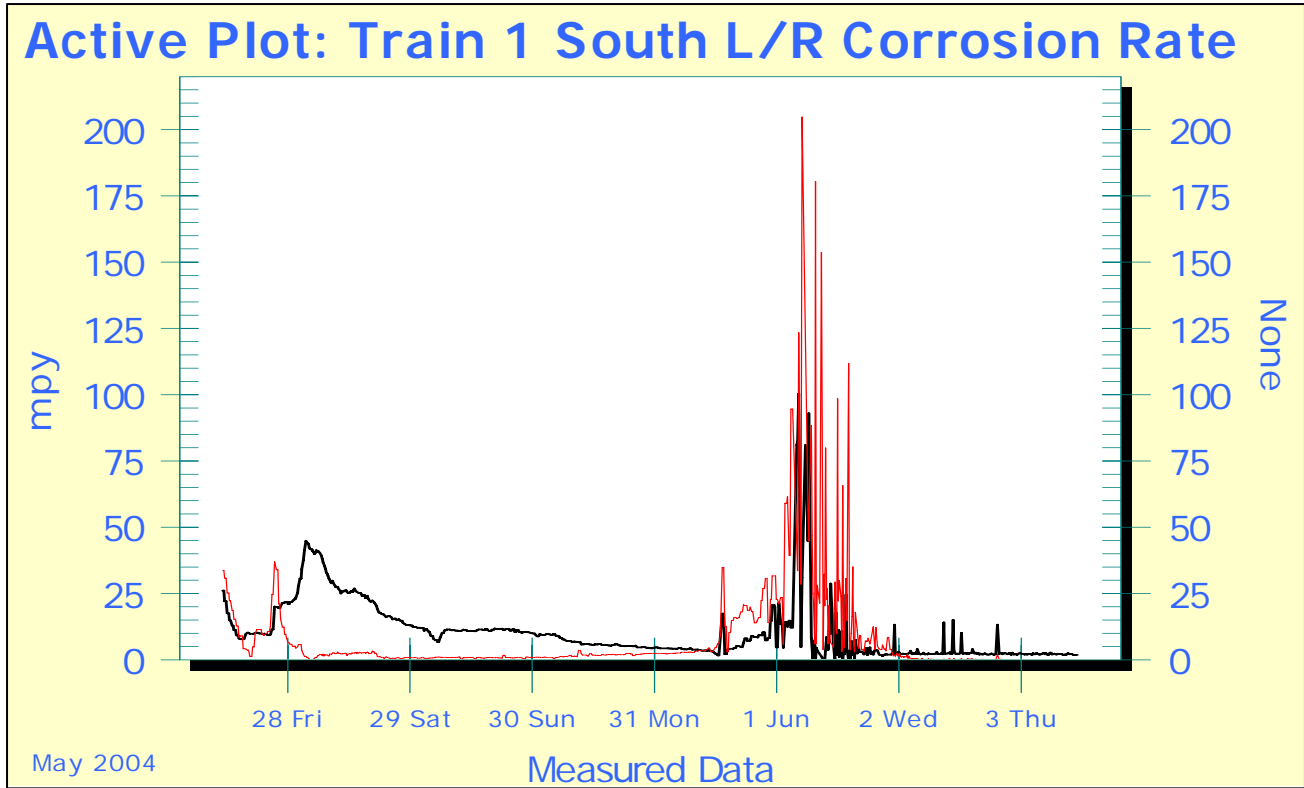


Figure 14 Corrosion Rate and Pitting Upset in an Amine Plant