MPR Profile
Issue 7, Spring 2001
An Exchange of Engineering Challenges

Advanced Control Technology for Ruptures and Leaks Using Smart Valves

Industrial fluid systems typically are not designed for rapid recovery following events which damage piping such as natural disasters, human error or deliberate destructive attacks. Under such adverse conditions, isolation of piping which contains hazardous chemicals (or high-cost chemicals) is needed and recovery of safety systems such as fire protection is desired. In addition, leak detection systems are required for an increasing number of piping systems to comply with environmental regulations. As manning of facilities is reduced, the need for automated technologies to detect and recover from ruptures and leaks is increasing.

MPR Associates has been developing technologies for smart valve control systems to respond to ruptures and leaks under sponsorship by the U.S. Navy. A smart valve control system is a network of valves and their associated controls which communicate with each other and with a central supervisory control station. Each smart valve consists of an embedded microprocessor, network transceiver and pressure sensors in the valve inlet and outlet. For a survivable and fault tolerant design, MPR developed the Rupture Path Logic method (patent pending) for distributed control in the smart valves. This innovative, embedded device-level algorithm detects and isolates a rupture (without isolating intact piping) even with multiple valve failures, loss of the supervisory control station, and/or loss of communication between smart

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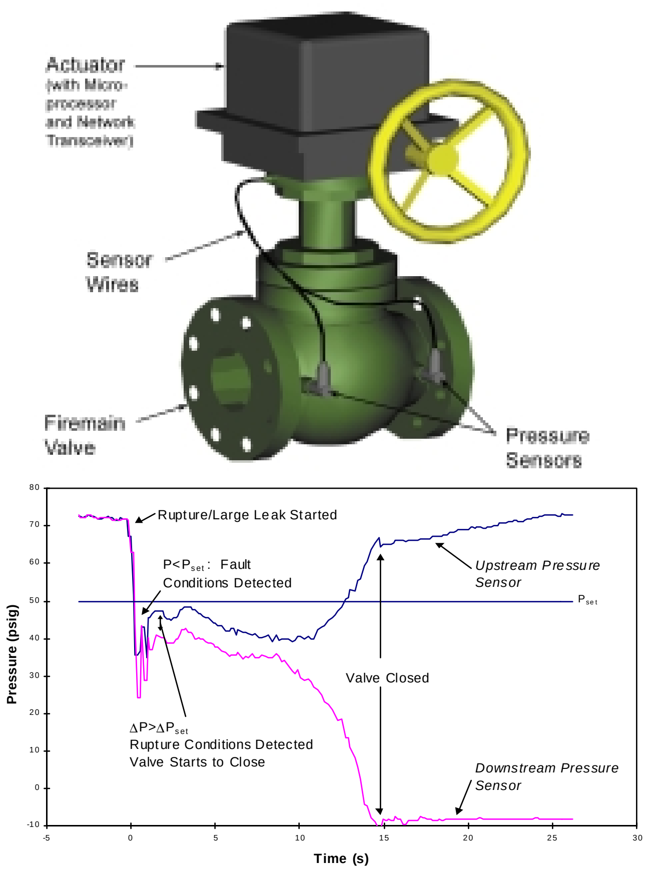


Rupture Path Logic (developed by MPR, patent pending) distinguishes between rupture conditions and other conditions by measuring the quasi-static hydraulic resistance of the piping system and isolates the rupture using a sequence of time delays where valves furthest from the fluid sources close first.

In This Issue

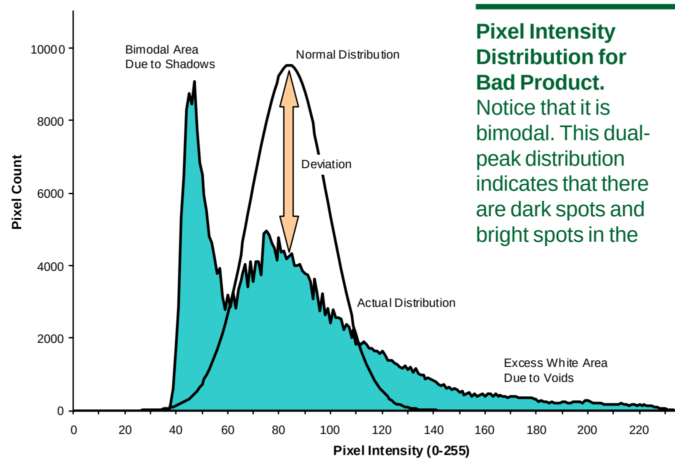
Ted Rockwell Elected to National Academy of Engineering

Theodore Rockwell, principal officer (retired) and co-founder of MPR Associates, Inc., has been elected to the National Academy of Engineering (NAE) for contributions to the development of reactor shielding technology and nuclear-power reactor safety.

Election to the NAE is among the highest professional distinctions accorded an engineer. Academy membership honors those who have made "important contributions to engineering theory and practice, including significant contributions to the literature of engineering theory and practice," and those who have demonstrated "unusual accomplishment in the pioneering of new and developing fields of technology."

Automated Visual Inspection Systems

In an ongoing effort to reduce production costs, many manufacturers have introduced automated machine vision systems to replicate inspection steps previously done using manual methods. While automated machine vision is a well established technology for many routine visual and dimensional inspections, innovative image analysis techniques can expand the technology to many other applications. In particular, traditionally manual inspections for non-uniformity or flaws are subject to inspector perception and can be done more reliably by an automated system if those flaws can be quantified.



Pixel Intensity Distribution for Bad Product. Notice that it is bimodal. This dual-peak distribution indicates that there are dark spots and bright spots in the image that complement each other. Light passing through a flaw is reflected near fracture surfaces giving a dark shadow that outlines the flaw. Typical good product results in normal, bell-curve distribution. The deviation from the normal distribution provides a quantitative indication of missing mass.

MPR recently developed an automated machine vision system for a pharmaceutical manufacturing process in which the amount of non-uniformity in drug product was strictly defined. Using a manual process resulted in product with acceptable flaws being rejected too often.

The task was particularly challenging because an important attribute was the mass of drug product inside a translucent delivery device. Voids or bubbles in the drug product reduce its mass and dosage, but whether the product is acceptable depends on the size and number of voids. Analysis of a large database of images and known

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Developing a Performance Monitoring System

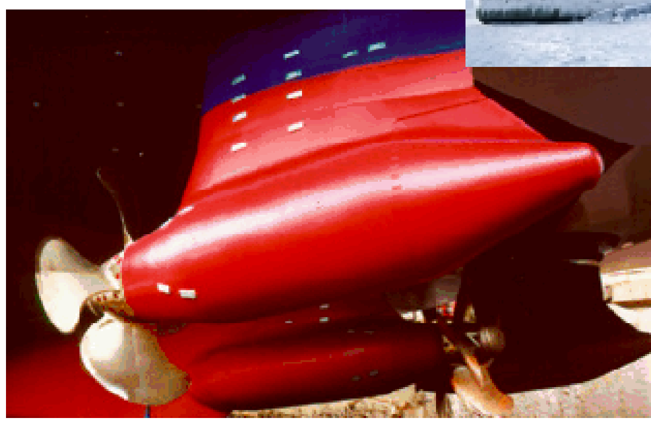
On board U.S. Navy submarines, monitoring the performance of vital equipment was labor-intensive, time consuming, and inefficient. Navy Performance Monitoring Team members gathered data at individual equipment stations using non-graphical, non-interactive data recording equipment, which required all data analysis to be done later at shore-based offices. This made it virtually impossible for the team to assess system performance, diagnose problems, and perform on-the-spot maintenance while on board. To increase the efficiency of periodic performance monitoring, the Navy contracted MPR to design and help implement a newer technology-based system.

The first phase focused on development of a custom-fabricated, semi-portable, PC-based device that automatically records, displays, and stores basic performance data of a ship's major equipment. The new device provides graphical display of real-time data as it is recorded, online procedure forms to speed required manual data recording, online analysis of some data, the ability to collect vibration information, and a C-language programming interface for adding new software capabilities. To minimize cost and avoid project delays, MPR used commercially available hardware but developed custom software. This device is now widely used by the Navy, resulting in enhanced operational efficiency and manpower savings.

With that design complete and the approach proven over time, the Navy issued the next challenge: development of an updated, state-of-the-art version — a small, modular unit capable of assessing, reporting, and storing the widest possible range of

performance data, including information from hydraulic rams, governor valve actuators, and magnetic bearing amplifiers. The new system will be optimized for portability and designed for hardware and software modularity, expandibility, and maintainability. MPR is currently working on this project, again developing software and using available hardware, but also creating specialized hardware when necessary.

Great Lakes Ice Breaker Will Cruise with Electric Drive



Above: The USCGC MACKINAW breaking ice on the Great Lakes. Left: Podded propulsors on a cruise ship (courtesy of ABB Azipod).

On December 20, 1944, United States Coast Guard Cutter (USCGC) MACKINAW was commissioned into service. Since commissioning, she has provided heavy icebreaking services to assist in keeping channels and harbors open to navigation, provided flood relief, and provided search and rescue services on the Great Lakes. Because of her age, and because the ship is manpower intensive to operate and maintain, the USCG plans to replace the MACKINAW with the multi-mission Great Lakes Icebreaker (GLIB).

The GLIB project incorporates technology advances into the ship design. One such advance is integrated electric propulsion, which means that the same diesel generators provide power for both ship's service electrical power and for propulsion. The GLIB design includes podded propulsors that are installed outside of the ship hull. Podded propulsors contain the propulsion motors and the pods can be rotated, providing both propulsion thrust and superior directional control.

The benefits of integrated electric ship propulsion are accompanied by new challenges to the design of the electric power and distribution system. With traditional geared drive propulsion systems, the ship's electrical systems are isolated from ship propulsion transients. With integrated electric ship propulsion, both propulsion and ship service electrical systems are powered from a common electric bus. Therefore, the electrical generation and distribution systems must be designed to handle the propulsion transients associated with ship maneuvering while providing acceptable power quality for ship's service.

MPR has developed validated transient models of diesel generators and distribution systems for power plant applications. MPR also has developed transient models of ship propulsion performance. Because of this experience, the USCG hired MPR to evaluate the transient performance of the GLIB integrated electric system and determine if it could satisfy the requirements in the GLIB performance specification.

MPR developed a transient analysis model of the GLIB that consisted of 1) the central power plant which includes three diesel generator sets; 2) the electric propulsion system which includes motor drives and motors for two podded propulsors and a bow thruster; 3) the hull; and 4) the electric plant distribution systems which include a non-sensitive bus, a sensitive bus, associated power conditioning, and their connected electrical loads.

Six dynamic events were simulated using the model. These events included a free water crash-back (reversing the ship's direction), loss of one diesel engine during icebreaking, and ice-jamming of one propeller. Details of dynamic event initial conditions and

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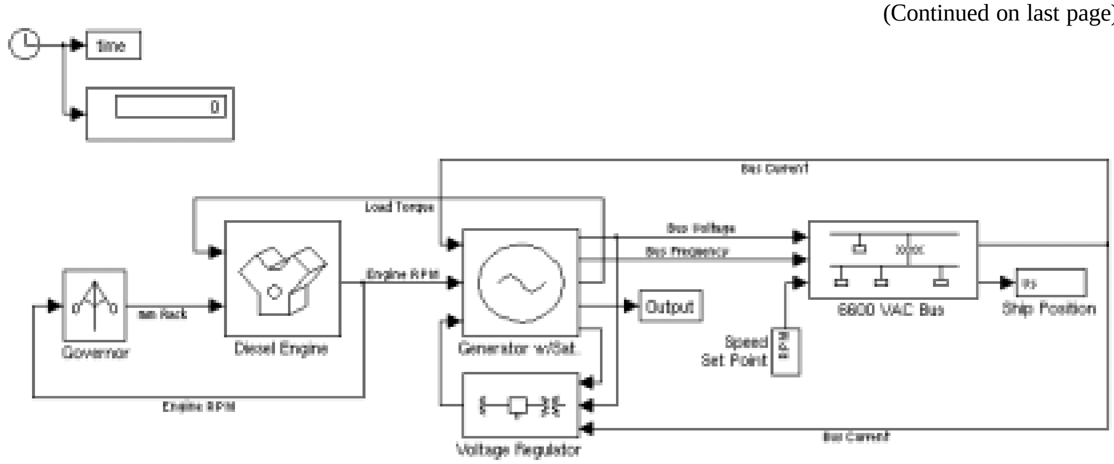


Model of GLIB integrated electric propulsion system (implemented using Matlab/Simulink software, distributed by The Mathworks Company, and MPR's Transient Performance Advisor model libraries).

Energy Demands....
400 MW in 19 Months

The Gregory Power Facility in February 2000 as construction neared completion.

The Gregory Power Facility, a combined cycle cogeneration plant located in Gregory, Texas, began commercial operations in July of 2000, 19 months from the start of construction. The plant, developed by Columbia Electric Corporation and LG&E Power, Inc., produces 400 MW of electricity while supplying up to 1,500,000 lb/hr of steam to BPU Reynolds' Sherwin Alumina Company. The Sherwin Plant uses steam in the process of refining bauxite ore into aluminum oxide, the basis of Reynolds Metals' raw material for many aluminum products. The Gregory Facility, constructed by Bechtel Power, has two GE 7241FA combustion turbines, two Foster Wheeler HRSG's, a MHI steam turbine, and an extensive water treatment plant for reprocessing of the returned condensate. MPR played an important role in ensuring the success of the project by providing owner's engineering services and on-site owner's representation during the construction of the plant.

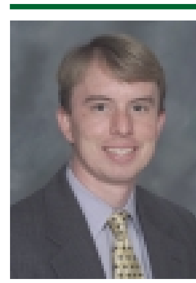
MPR's involvement with the Gregory Power Project began 4 months before construction, during the development of the plant. Acting as owner's engineers, MPR utilized its power plant engineering background to perform reviews during the design process. These reviews encompassed all aspects of the design of the plant, including piping and instrumentation diagrams, heat balances, and performance test procedures. MPR also provided engineering support for factory inspections and witnessing of factory acceptance tests. During construction of the plant, MPR engineers provided technical support as new issues arose.

In addition to providing owner's engineering services, MPR engineers joined a team of personnel on-site who represented the owner's interests during the construction of the plant. On-site representation was essential to keep the owner, Gregory Power Partners, L.P. in touch with emerging issues, getting quick resolution, and keeping the project on schedule. The on-site engineers provided technical expertise as these issues were resolved and, when necessary, were able to draw upon the resources of MPR's Alexandria office. On-site MPR engineers helped supervise the construction of the portions of the plant that the owner was responsible for delivering. A major component the owner was responsible for was the gas yard, where natural gas is metered and filtered before transmission to the turbines and boilers. Despite several late design changes, the gas yard was on-line in time to deliver gas and support the project schedule.

MPR engineers helped coordinate the activities of the various organizations involved with the Gregory Power Project. Daily meetings were held on-site between the owner's representatives, the operators, Bechtel representatives, and Sherwin Plant Alumina Company representatives to plan the construction and start-up activities. MPR engineers were instrumental in ensuring that all interfaces between the new plant and existing utilities, services, and the steam host were successfully made on time.

As construction of the plant neared completion, MPR engineers participated in the turn-over of the plant from the contractor to the operators. This involved inspection of the systems, notification to the contractor of deficiencies, and verification that the deficiencies were corrected. Working closely with plant operations personnel and Bechtel representatives, MPR engineers helped resolve a majority of outstanding issues before the plant became commercially operational.

The owner of the Gregory Power Facility considers the project a success. The plant was ready in time to meet its power sales commitment for the summer and has been in operation since that time. MPR played an important role in making the project a success and is currently working on several similar projects.



Since joining MPR in 1998, Eric ten Siethoff has worked as an Owner's Engineer for new combustion turbine plants, performed thermal and structural evaluations of nuclear components, and worked on mechanical designs for nuclear and medical applications.

Automated Visual Inspection Systems

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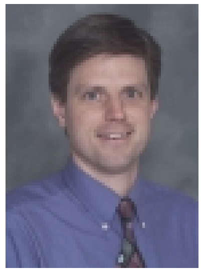
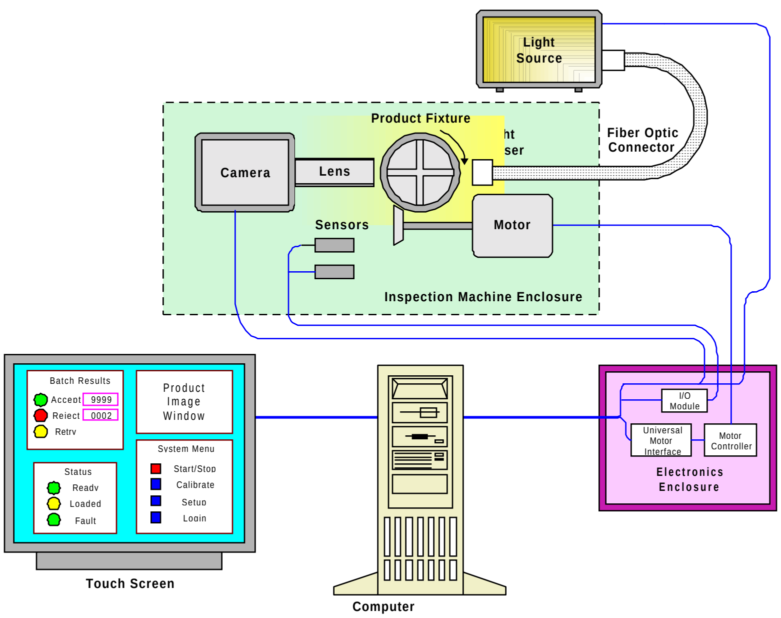
product weight measurements allowed us to develop an algorithm that would correlate statistical representations of the image brightness with the mass of the product. This allowed us to quantify the effect of voids and infer the product mass so that product would not be rejected just because a bubble is present.

To improve the accuracy of this inspection algorithm and obtain the best mass measurement, MPR performed several statistical analyses, each using multiple images of each sample. We conservatively tuned this procedure to reject the border-line product in order to increase process reliability, minimize the probability of accepting bad product, and maintain high product quality.



Eric Claude has over 15 years experience in design and development of electro-mechanical systems, and is currently focusing on engineered solutions for pharmaceutical manufacturing and medical devices.



Major components of a computer-based vision system include a computer for hardware control, image processing, and operator interface; data acquisition hardware; a camera and lens; lighting; and a positioning system. The configuration and selection of components is based on the particular requirements of the application.

MPR's system integrated all commercial off-the-shelf components to keep the cost low. The computer provided all motion control, lighting control, image acquisition and analysis, and user interface functions.

The process starts when the operator places the product in the fixture. Photoelectric sensors verify that the product is positioned properly and the operator's hand is out of the way, then a stepper motor spins the fixture. The rotation is timed such that we obtain sequential images of the product every 45 degrees of rotation. A total of eight images are acquired and analyzed in 1/4 second. The computer evaluates the data, displays an accept/reject indication to the operator, and maintains a count of accepted and rejected product for each batch.

Advanced Control Technology

(Continued from page 1)

valves. If communication is available, the performance of the system is enhanced with system-level algorithms installed at the supervisory station. In addition, flow balance logic was implemented at the supervisory control station to monitor for leaks in firemain segments. With this hardware and software architecture, ruptures can be isolated within 30 seconds for most piping systems and leaks as low as 2% of the pipe capacity can be detected.

The first demonstration of a smart valve system for rupture isolation has been performed in a Navy firemain aboard a ship dedicated to research and development. The results of this initial demonstration are promising and indicate that different detection technologies may be developed to reduce the isolation times to less than 1 second and to reduce the threshold leak size to less than 2% of pipe capacity. These valves were manufactured by Tyco Valves and Control using a commercial line of valves and actuators.

Several smart valve control technologies are emerging which provide cost effective performance enhancements for existing systems or are a basis for new designs of industrial fluid systems.

The MPR Smart Valve Development Team: (l-r) Tom Lestina, Ryan Downs and Eric Runnerstrom.

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(Continued from page 3)

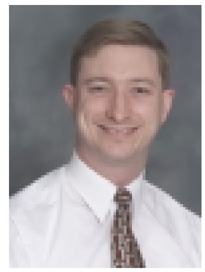
sequences of events were developed by MPR and reviewed and approved by the USCG prior to accomplishing the simulations.

Model results were compared to performance criteria. Primary concerns were the icebreaking performance of the ship, the maintenance of acceptable ship's service power quality and avoiding overloading the diesel engines during severe propulsion transients. The model predicted that the GLIB design would satisfy most of the specified performance criteria, particularly criteria for the ship's primary mission of icebreaking. For the less critical criteria that the model indicated might not be met, MPR performed parametric studies of design changes that would be needed to meet the original criteria. With this information, the USCG was able to decide whether to change the criteria or change the design.

MPR also provided recommended performance specifications for an innovative control system design that protects the main engines from being overloaded by the propulsion system while maintaining acceptable ship's service power quality and maximizing the maneuvering performance of the ship.

The GLIB transient analysis model is a good example of how simulation can answer important "what if?" questions early in the design process, helping to optimize the design and avoiding potential costly problems later in the acquisition.

For more information on the GLIB, see http://www.uscg.mil/hq/g-a/glib.



Since joining MPR in 1992, Ralph Paul has acquired significant experience with the development of transient analysis models for mechanical, electrical, and thermal-hydraulic systems for electric power, industrial, and naval applications.

Contact us for more information on our experience with the topics that appear in this issue of *MPR Profile*

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