A PUBLICATION OF THE DRESSER-RAND COMPANY

insights

THIRD QUARTER 1999

Featured in this issue of *insights:*

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insights

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Client Requirements Drive New Marketing Organization

With Dresser-Rand's reorganization – the move to providing total energy conversion solutions and the crafting of global regions – marketing now plays an ever-expanding role in the success of the company and the clients it serves.

Until recent years, Dresser-Rand's marketing was much like others in our industry. We took the "If we build it, they will come" approach. We built what we knew how to build, made improvements dictated by our best instincts, and then hoped for a good response from our clients. Or, we based our efforts on the last order that we lost, devoting our efforts to react to that problem.

There was nothing wrong with this method; it worked for us. Dresser-Rand was formed over a dozen years ago by joining several manufacturing units into one entity that is now a partnership of Ingersoll-Rand and the Halliburton Company. Some of these manufacturing components have a century of success under their belts.

Before we began our recent shift to a more global solutions strategy, we saw that there was more to marketing than had been our traditional approach. This became evident with the DATUM™ line of centrifugal compressors that Dresser-Rand introduced a few years ago. For the first time, we produced market research through extensive client interviews and involvement.

We didn't rely on gut instinct, but on an essential principle of the marketing discipline – research.

One of the main functions of our new marketing organization is to break the pattern of applying today's technology to yesterday's problems. Another is to focus on longer-range, strategic planning. In the past, we had spent 95 percent of our efforts responding to requests for proposals, and only five percent on strategic, long-term marketing. We'll be readjusting that ratio as we deploy our strategies as a supplier of total energy conversion solutions.

Our focus now is to be driven by the market. For example, should we invest a million dollars to develop a new single-stage turbine if our research tells us that the market is only good for 1,000 units? What if, instead, we invested $30,000 to develop a retrofit kit that answers the clients' needs and the kit could be applied to 50,000 units already in the field?

Market Research, now, is one of the four components of Dresser-Rand's new Marketing Organization. Our Market Research will work through our regions to establish on-gong dialogue with all of our clients. Our clients are, indeed, the front line of product and service development.

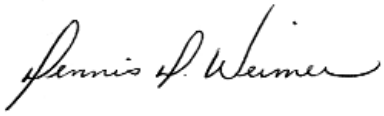
The other three components of the Marketing Organization are Market Segment Managers, Product Managers and Solutions Development.

Market Segment Managers are regionally based industry experts. Each is charged with monitoring a specific market, such as ammonia plants, gas lift and power generation.

Product Managers are our product line "champions" and based in our manufacturing facilities. Each has the full-time responsibility for leading the development and promotion of a particular product line, such as expanders, reciprocating compressors, large steam turbines, and so forth. It is the responsibility of Product Managers to maintain the competitive leadership of their products.

Solutions Development is a new concept to Dresser-Rand, but is a proven process at many businesses such as Honeywell, Intel and Codex that have been successful in routinely bringing innovative ideas to the market place. This process is at the heart of Dresser-Rand's shift from a product-focused company to a solutions business. It will focus on integrated packages of products and services with a strong emphasis on business development, including strategic acquisitions and joint ventures. This group is Dresser-Rand's key to providing seamless solutions to our clients' needs.

The new Marketing Organization is aligned to enhance Dresser-Rand's position in the marketplace and its profitability. But the catch is that this is only possible through helping our clients in their production and profitability goals. Mutuality has its rewards. ■



Denny Weimer
Executive Vice President,
Marketing

Cycle Time Reduction Program Exceeds Expectations

Editor's Note: In the last several years, Dresser-Rand has successfully reduced cycle times for engineering, manufacturing, and after-market parts and services. The following article is one in a series, and describes the positive results at the company's Olean operation.

Dresser-Rand's Cycle Time Reduction Program has proven to clients that time is, indeed, money and often much more.

The program, initiated two years ago, has resulted in dramatically reduced delivery cycle times, from order to shipment of equipment – cutting industry delivery standards by 50 percent. In addition, the program has improved the company's manufacturing efficiency, lowered error rates, and led to better manufacturing and testing methods. Dresser-Rand now delivers a single motor and compressor skid in six months as standard practice, where once 12 months was required.

"What began as a broad objective, has developed into the most far-reaching initiative ever implemented at Dresser-Rand," said Vince Volpe, Dresser-Rand chief operating officer. "In 1997, we asked ourselves, 'How can we bring more value to our clients?' We challenged ourselves to focus on a two-step process of on-time delivery and improving production and process technologies. The results have exceeded our expectations."

DATUM™ Program Serves As Genesis

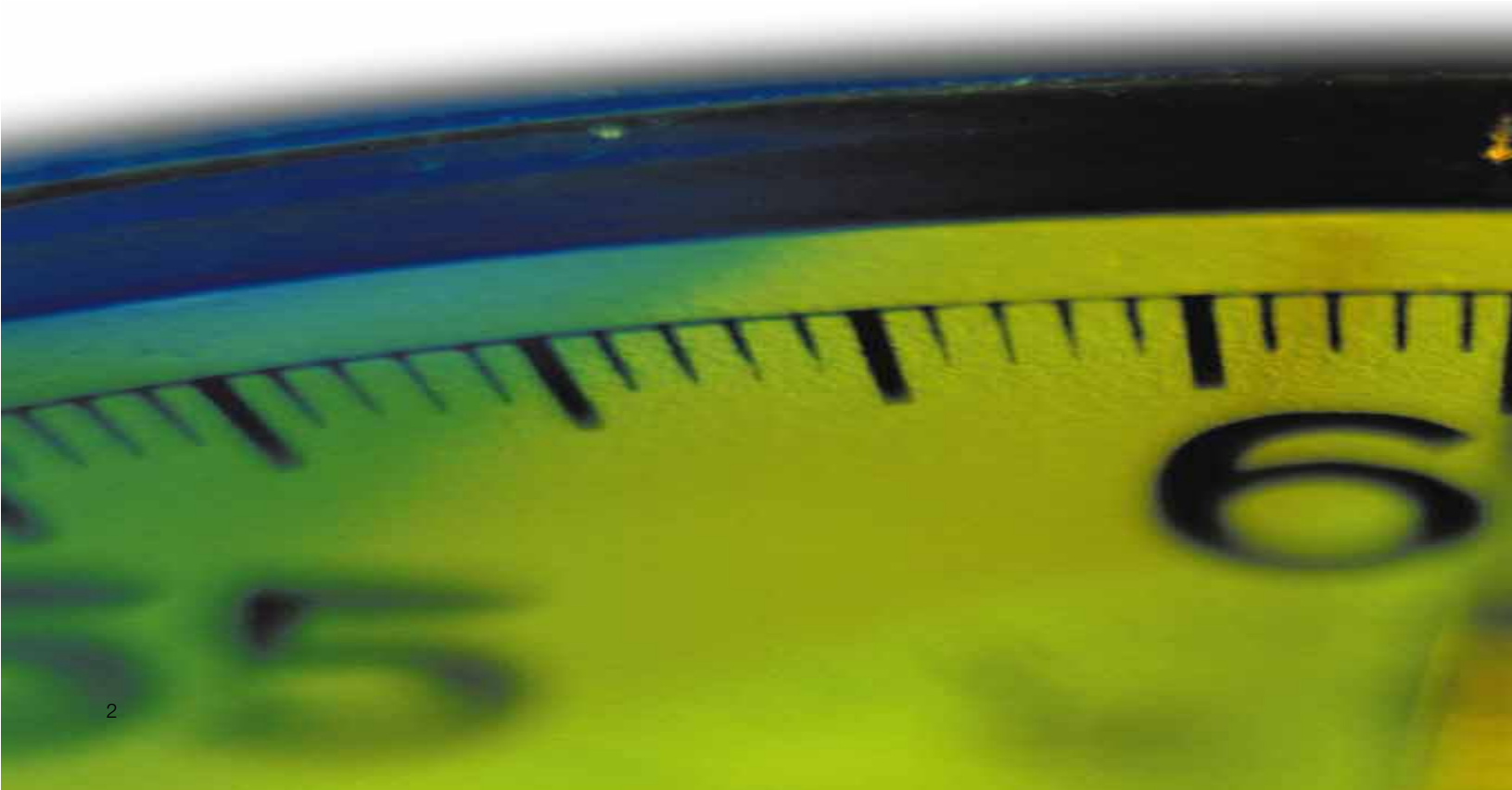
Early in the process, Dresser-Rand recognized that no one single thing would lead to on-time delivery. Instead, a total program involving literally every area of the company and every person within the company, as well as key suppliers, would be required.

"The foundation for the success of the Cycle Time Reduction initiative actually had its birth several years before with the development of the DATUM line of centrifugal compressors at the Olean, New York manufacturing facility," said Art Titus, senior vice president of operations at the Olean operation. "In 1992, when we kicked off the DATUM project, one of our goals was to reduce engineering time by up to 75 percent. As an example, where a specific application design might have taken us 26 weeks to complete, we wanted to reduce the time required to approximately 6 weeks."

At the same time, the reduction in time was not to be achieved by simply dedicating more effort. "We knew that what we really hoped to achieve was a true reduction in the "man-hours" required," Titus said.

According to Miles Bintz, vice president development engineering at Dresser-Rand's Olean operation, the design process had to be re-thought. Previously, all design was done using 2-dimension CAD software. "It was then that we realized our legacy drafting process would not allow a significant reduction in the time required," Bintz said. "So we selected an entirely new computer design system – one that better suited the modular design concept of the DATUM compressor line. When you consider the business of making a compressor – from drafting to engineering to manufacturing – this dramatically reduced our time requirements."

The effort was a huge undertaking involving representatives from throughout Dresser-



Rand, according to Titus. "The team consisted of design engineers, manufacturing engineers as well as machine operators," said Titus. The results in terms of moving designs forward to manufacturing have been dramatic. "A typical DATUM compressor diaphragm design alone now can be modeled in approximately five percent of the time we previously allotted," Bintz said. "We literally could be cutting chips in six hours."

New Methods For Success

Product design process improvements alone would not achieve the cycle time reductions that Dresser-Rand sought, however. New order entry software and alliances with key suppliers also played critical roles.

A new software program implemented at Dresser-Rand, incorporates all aspects of product delivery – from order entry, to engineering, drafting and manufacturing. "This essentially made it possible for all of the internal components in the process to work together in concert with one another," said Titus.

While Dresser-Rand's internal teams worked to make cycle time reduction a reality, the commitment of numerous key vendors was critical. "The success of our key supplier alliances has been the result of a mutual sharing of information," said Bintz. "We have established several major preferred supplier relationships allowing us work smarter together, and eliminating much of the back-and-forth that might have slowed us down in the past. We can now produce a design of a cast nozzle, for example, and have them in one-third of the time we were accustomed to."

New Benchmarks

The results of the Cycle Time Reduction Program have paid significant dividends for both Dresser-Rand and its clients. By receiving equipment sooner, Dresser-Rand clients are able to dramatically reduce plant development times or revamp schedules, allowing them to begin production sooner, or get back on-line quicker.

In 1997, the company established a baseline average for all equipment manufactured at the Olean facility – which included the most complex multistage compressor packages. "In 1998, that average was reduced by 33 percent, and actually included a record number of units produced," Titus said. "In 1999, we expect to cut that figure by another 10 to 15 percent, and we expect to reduce that even further in the year 2000. A single motor and compressor skid is now quoted at one-half of the time required previously."

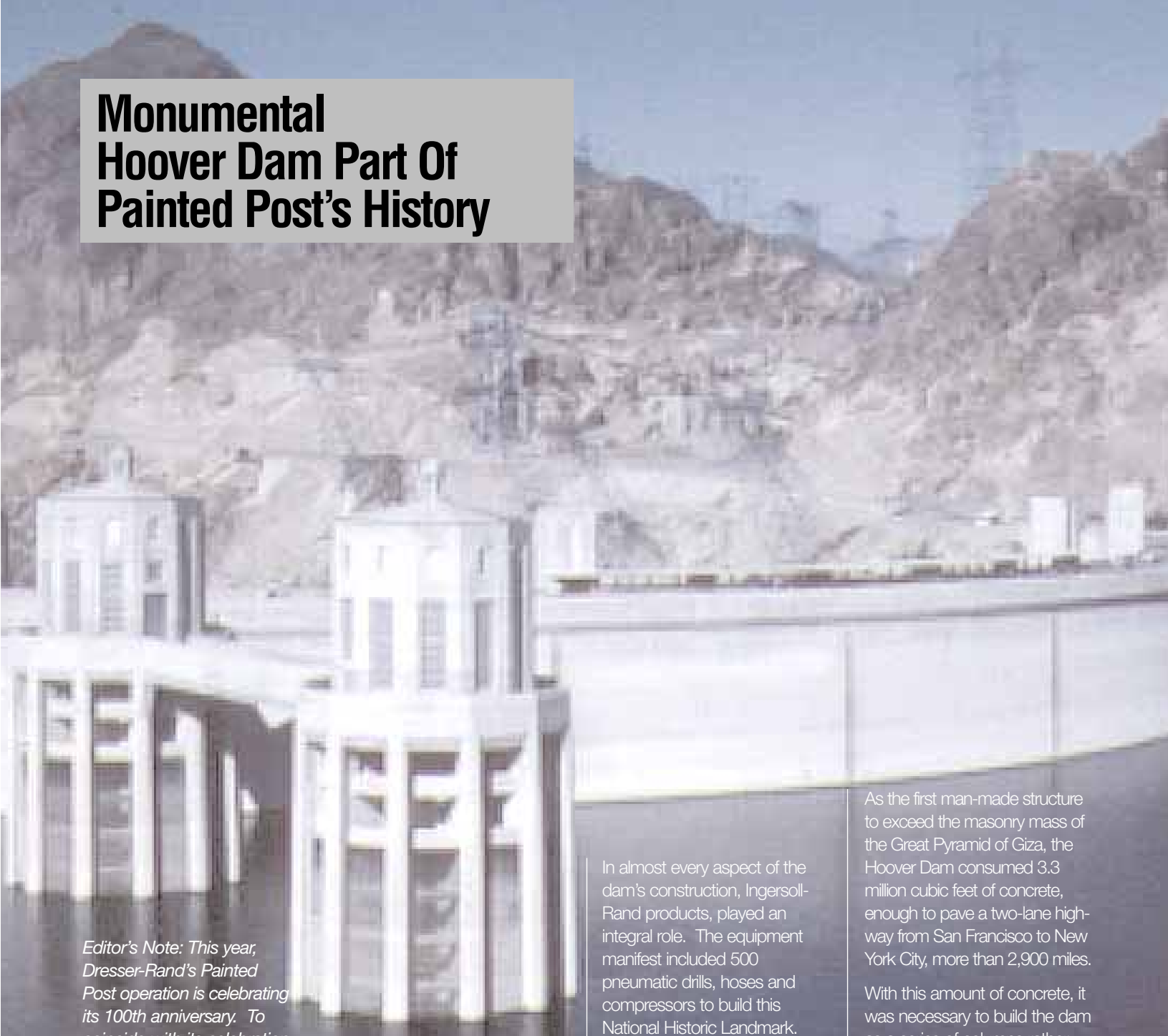
These successes have not escaped the notice of Dresser-Rand clients. In May 1998, Dresser-Rand received a booked order for a 50PDI-HS pipeline booster compressor. The unit, which would be driven by a gas turbine, was required for a Texas refinery in six months. As the ship date neared, Dresser-Rand notified the customer of the ability to ship early. The unit was shipped five months and two days after receipt of the order.

An ethylene package, which formerly required 18 months, is now quoted at 8 to 9 months. The decrease in the plant development time alone more than pays for the equipment, according to Titus.

"Clients are working with us now," Titus said. "We have demonstrated credibility. They know we can do it. We have done it. At the same time, we've been able to improve our own manufacturing efficiency, lower error rates, and simply do better at executing the job of manufacturing highly engineered equipment."

"We understand that we've raised the bar in the industry," added Volpe. "But this is what our clients expected, and we knew we had to deliver. We also understand that this industry will not stand still – there is still room for improvements in all areas of our business processes – and plans are in process at this time for the next generation f change." ■

Monumental Hoover Dam Part Of Painted Post's History



Editor's Note: This year, Dresser-Rand's Painted Post operation is celebrating its 100th anniversary. To coincide with its celebration, the first quarter 1999 issue of insights highlighted some of the historical projects the Painted Post operation has been involved in during the past 100 years.

For the past 100 years, Dresser-Rand's Painted Post facility in New York State's southern tier, has supplied equipment needed to construct many of the world's great man-made designs, including one of the Seven Engineering Wonders of the World, the Hoover Dam.

As the tallest dam in the United States–727 feet high and 1,244 feet long – the Hoover Dam, located on the Nevada-Arizona border, was built to separate Lake Mead from the Colorado River in an effort to control flooding and droughts that affected the area.

Construction of the dam began during the Great Depression in 1932 and was planned to be completed seven years later. The 5.5 million-ton dam, however, was remarkably completed in just four years.

In almost every aspect of the dam's construction, Ingersoll-Rand products, played an integral role. The equipment manifest included 500 pneumatic drills, hoses and compressors to build this National Historic Landmark.

Ingersoll-Rand jackhammers were most often used by "high-scalers," men – many of whom were circus acrobats and former sailors – who were lowered down the canyon walls on ropes to strip away loose rock and drill for explosives.

Weighing approximately 44 pounds, the jackhammer drills were lowered to the high-scalers who then maneuvered the drills into position by hand. Once the holes had been drilled into the canyon rock, they were loaded with dynamite.

As the first man-made structure to exceed the masonry mass of the Great Pyramid of Giza, the Hoover Dam consumed 3.3 million cubic feet of concrete, enough to pave a two-lane highway from San Francisco to New York City, more than 2,900 miles.

With this amount of concrete, it was necessary to build the dam as a series of columns rather than as a single block of concrete. According to the U.S. Bureau of Reclamation, engineers calculated that if the dam were built using a single continuous pour, the concrete would have become so hot that it would have taken 125 years to cool to ambient temperatures.

The columns, trapezoidal in shape, contained cooling coils of one inch thin-walled steel pipe, and rose in five-foot lifts. When the concrete was first poured, river water was circulated through the coils.

After the initial cooling, chilled water from a refrigeration plant–operated by Ingersoll-Rand compressors and pumps–was circulated through the pipes to complete the cooling process. Once each concrete block was cooled, the cooling coils were sealed off and injected with grout at 300 psi by pneumatic grout guns.

Costing $49 million to build, President Franklin D. Roosevelt dedicated the Hoover Dam on September 30, 1935.

Over the past 100 years, Dresser-Rand's Painted Post operation has had a significant role is some of the world's most historic man-made designs. And as the Painted Post operation celebrates its 100th anniversary of taking on the surname Rand this year, one can not help but wonder what amazing engineering feats will occur during the next 100 years. ■

New Dresser-Rand Web Site Expands Information Available Online

Dresser-Rand Company recently completed a full redesign of its internet web site, www.dresser-rand.com, reflecting the company's recent organization shift to providing clients energy conversion solutions worldwide.

"In addition to being easier to navigate, the new Dresser-Rand web site makes a great deal of information readily accessible that our clients as well as others in the industry will find beneficial," said Diana Maguire, e:communications coordinator for Dresser-Rand.

The site has been divided into seven primary sections for quick, easy and logical navigation.

Products and Services leads site visitors to a section containing information on the various products and services the company offers, including new products, replacement parts and a broad variety of support services.

Contact D-R contains relevant contact information for the company's various manufacturing operations, service centers worldwide and the company's regional headquarters offices. The section also has a trade show schedule for Dresser-Rand as well as an e-mail contact form.

The Newsroom contains various information about the company, specifically tailored for the media and other information gathering organizations. News releases, fact sheets, a detailed company history, and photos suitable for downloading are all incorporated into this section.

Solutions is a section containing case histories of how Dresser-Rand has helped to solve its clients problems or how it meets its customers requirements in unique and innovative ways.

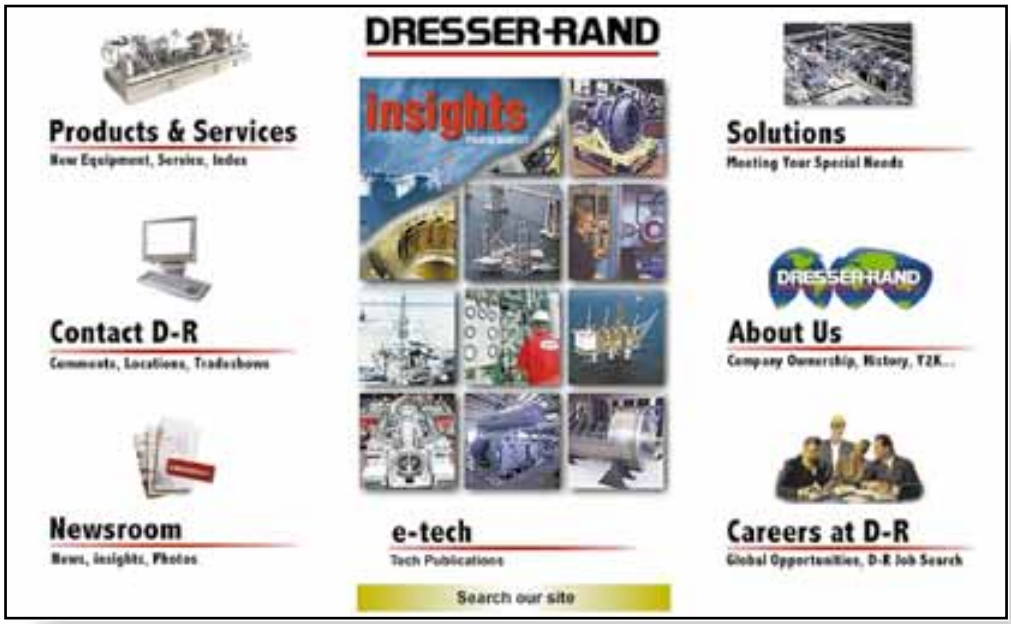
About Us highlights a variety of facts about the company and helps the site guest gather a better understanding of Dresser-Rand Company. Details on company ownership, facilities, key personnel and quick, did-you-know facts are kept here.

Careers At D-R is the recruitment part of the site. Information about current job opportunities and compensation are detailed here.

Insights magazine is the center graphic on the Dresser-Rand front page. The online *insights*, which is available in HTML format or as a portable document format file, also includes a technical paper not included in the printed magazine called "engineer's extra."

e-Tech is a new area of the site that contains a growing list of technical articles authored by Dresser-Rand engineers.

A new navigation bar makes moving from one section to another simpler and faster. A powerful search function can be activated from the front page of the site and from the navigation bar to search based on keywords. Links have also been established on the front page to the Dresser-Rand parent companies, Halliburton and Ingersoll-Rand. ■



Total Solution Project Makes Kimberly-Clark Mill Self-Sufficient

To be a total solutions company sometimes means looking for spare parts in a clients warehouse while engineering a turbine system to cut downtime and make the client self-reliant for energy needs.

Such was the case with Kimberly-Clark Corporation based in Irving, Texas. The company needed a complete rerate on a turbine at its Abercrombie Point pulp mill in Nova Scotia, Canada.

The company also wanted to have the capability to operate without electrical energy from the local utility. An additional challenge was to limit outage to 30 days.

"We currently produce 90 percent of our own electric power," said Jerry Mason, project manager at Kimberly-Clark's Abercrombie Point pulp mill. "However, with a 5 megawatt increase in capacity to the turbine, we would be able to produce 100 percent of our own power, meaning that we will have the capability to produce all power for the mill."

Following the rerate of the turbine, Kimberly-Clark will be generating 24.5 megawatts of electric power to operate the mill.

As a leading manufacturer of tissue, personal care and health care products, Kimberly-Clark has manufacturing operations in 39 countries and sells its products in more than 150 countries. The company's global brands include Huggies, Pull-Ups, Kotex, Depend, Kleenex, Scott, Kimberly-Clark, Tecnol, Kimwipes and WypAll. Other brands well known outside the United States include Andrex, Scottex, Page, Popee and Kimbies. Kimberly-Clark also is a major producer of premium business, correspondence and technical papers.

The desire to have the mill become self-sufficient resulted from years of rapid load swings, which caused the turbine generator to trip, resulting in lost production and increased cost.

For several years, Dresser-Rand had proposed that Kimberly-Clark convert its existing governor arrangement at the Abercrombie Point mill to a more responsive electronic control system. This, in addition to Kimberly-Clark's

desire to become self-sufficient, led to a series of engineering evaluations of the turbine generator's capabilities. While Dresser-Rand was able to alter the turbine to suit Kimberly-Clark's range of operating conditions, which included range of throttle, extraction flow, and power requirements, the generator's capacity was limited. The generator did not have the flexibility to increase its output from 22059 kVA to the desired 25600 kVA.

"The availability of a "mothballed" generator at a Kimberly-Clark plant in Winslow, Maine, and Dresser-Rand's ability to repair and relocate the generator made the realization of a revamp possible for Kimberly-Clark," said Jeffrey Miller, product specialist for Dresser-Rand.

In addition to the steam turbine rerate, Dresser-Rand is responsible for the installation of a new control system, the reapplication of a General Electric generator, a 10-year overhaul, and all associated field work.

The Abercrombie Point pulp mill is located approximately 100 miles northeast of Nova Scotia's capital, Halifax. The bleach kraft mill has been running for more than 30 years.

Current production is approximately 720 air-dried metric tons of bleach kraft pulp per day and 245,000 air-dried metric tons of bleach kraft pulp per year.

Dresser-Rand's operation in Wellsville, New York, is manufacturing the turbine components for Kimberly-Clark. Shutdown at the mill is scheduled for mid-September 1999, ten months after the contract was signed. Start-up is scheduled for October 1999.

"This type of project would normally take about one year to complete, from concept to start-up," Miller said. "The turnaround time for this project, however, is only 40 weeks."

During the last several years, Dresser-Rand has completed various projects for Kimberly-Clark and has remained a steady parts supplier for the company.

"Dresser-Rand was selected for this project for several reasons, but mainly for technical reasons," Mason said. "One of the main reasons is that Dresser-Rand is the original manufacturer of the equipment. In addition, it was determined that the turbine modifications best suited Dresser-Rand."

By adopting the total solutions philosophy, the Dresser-Rand Company has established a track record in addressing unique requirements of clients, from pulp mills to oil fields. ■

Effective Total Solutions Strategy Leads To Increased Productivity In Nigeria

The total solutions concept at Dresser-Rand is already proving to be working smoothly with positive results. This practice is clearly demonstrated by Dresser-Rand's ongoing relationship with the Shell Petroleum Development Company in Nigeria.

As a challenge many companies are now facing, the Shell Petroleum Development Company of Nigeria Ltd. (SPDC), was looking to use a single source supplier of integrated energy conversion solutions, who would be responsible for supplying products and technical solutions, as well as the maintenance of equipment at seven of their gas lift compressor stations throughout Nigeria.

The gas lift compressor stations for SPDC extract oil and gas from a reservoir and separates it into crude oil and gas. The gas is then sent to the gas compression station where it is compressed and the gas is then reinjected into the reservoir to lift further crude oil. The surplus gas is flared.

With a presence in Nigeria, for over 20 years, Dresser-Rand was selected by SPDC to fulfill their contract needs. "Dresser-Rand has been progressively installing SPDC stations in Nigeria since 1967", said Terry Mitchell, manager, regional operations for Dresser-Rand Compression Services.

"The most recent station completed prior to this contract was the extension to the Olomoro facility, which finished commissioning in 1996."

The two year contract, with a possible one year extension, requires Dresser-Rand to have total responsibility for the complete refurbishment and maintenance of equipment in seven SPDC gas lift compressor stations, which are located throughout Nigeria. This includes eleven high-speed separable compressors with Waukesha and Caterpillar drivers, five low speed separable Thomassen compressors with Waukesha (through gear) drivers, four Dresser-Rand and Cooper Ajax integral compressors, sixteen generator sets with Caterpillar drivers inclusive of all associated station process equipment and instrumentation.

As part of the contract, Dresser-Rand provides support for technical and maintenance problems, while SPDC handles the operation of the equipment at the stations.

"The site as a whole from 'Gas In' to 'Gas Out' is the responsibility of Dresser-Rand," Mitchell said. "To maintain this involves local power generation, plant air supply compressors, gas compressor drivers, gas compressors and all associated instruments and control systems, as well as safety and shut down systems."

As a way for Dresser-Rand to be more efficient in assisting the needs of their clients throughout Nigeria, a service

centre was built in Warri, a town in the Niger Delta, that serves as one of the two centers of oil production in Nigeria, the other being Port Harcourt, Nigeria.

The Dresser-Rand support centre in Warri consists of a workshop, warehouse, and office complex. In addition, housing for Dresser-Rand employees is in a compound that is situated approximately one mile from the facility.

The workshop was custom designed and built to support gas compression equipment maintenance in the Niger Delta and it is equipped with machining capabilities to support the repairs and refurbishment of the gas compression and associated equipment. In addition, a comprehensive warehouse stocked with parts for Dresser-Rand and other OEM equipment is part of the support facility. The facility also provides technical information, problem solving, predictive maintenance and condition monitoring.

"The Warri facility ensures prompt support and an easily accessible supply of parts and materials that are needed by engineers working in the field on gas compression equipment," Mitchell said. "As a result, the scheduled servicing can be carried out in an efficient and cost effective manner to ensure that downtime of the compressor and loss of production are reduced to a planned level."

To completely refurbish and maintain the equipment in all seven of the SPDC stations, 22 expert Dresser-Rand engineers and technicians provide their services in addition to approximately 70 local technicians and tradesmen.

The result has been a four-fold increase in oil out put from the SPDC West land area fields. An increase in reliability and an increase in the availability of the gas compression equipment were also achieved. The installed capacity is 104.8 mmscfd.

"This project is the first of its type within Dresser-Rand, where we buy spare parts required from the client, thus reducing the clients inventory," Mitchell said. "Where no stock is available, Dresser-Rand takes ownership of the purchasing chain to supply the required item."

This contract is also unique because of a parts purchasing system incorporated into the contract designed to reduce downtime.

The same Dresser-Rand team is currently working on bidding a new project for the Nigerian Gas Company. There are nine gas treatment and compression stations which require complete refurbishment and this will be followed by a three year O&M contract which will be managed by SPDC. Also similar to the existing contract, new machinery will be supplied by Dresser-Rand. "We feel confident, that based on our previous experience, we will be able to execute this contract to the satisfaction of our customer and prove the benefits of the Dresser-Rand total solutions concept," Mitchell said.

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– Terry Mitchell, manager, regional operations for Dresser-Rand Compression Services

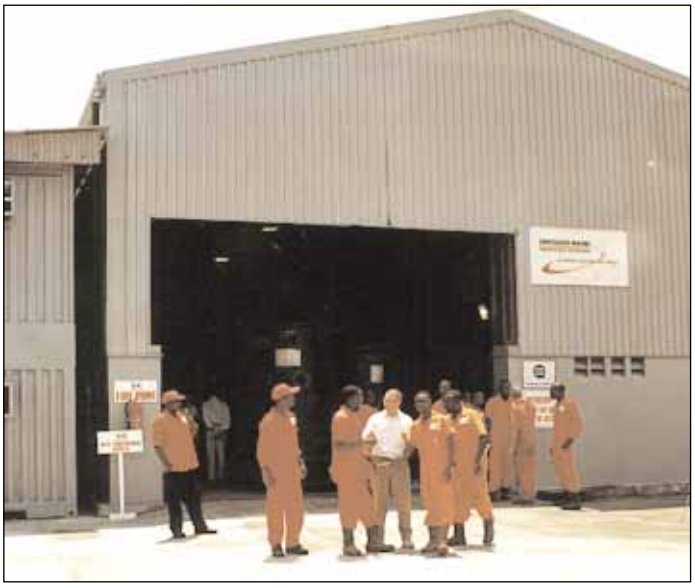
The Dresser-Rand parts purchasing system takes effect at the end of the project when wearing parts are requested and supplied. The parts that are worn or damaged out of the normal range of wear and tear are identified at the time of strip down, and purchased by Dresser-Rand. The costs of these parts are covered in the contract price.

In addition to this contract, Dresser-Rand currently has two other contracts within Nigeria. The OGUTA contract is a similar project, however, Dresser-Rand only has total site responsibility maintenance for one station. The contract is for three years, with the option to extend the contract for an additional year.

A second contract, the OBIGBO, is a 17-month operation and maintenance contract for a single Dresser-Rand rental compressor package.

"Working in Nigeria has been very unique and complex with each site or station being situated within a community where there may be tribal, religious, environmental, and economic concerns. This can involve lengthy discussions and negotiations with local Chiefs and officials."

A commitment to delivering product and more comprehensive services to the clients' operation, no matter how remote the location may be, with speed and personal service is the total integrated energy solutions strategy being practiced by the Dresser-Rand team worldwide. ■



Employees at the Dresser-Rand workshop in Warri, Nigeria.

Oil Company Mega Mergers Present Opportunities In The Field

Recent mergers of several of the world's largest oil companies eventually will have considerable impact on investors and employees, but step down to the vast tier of suppliers to the industry and the impact is already being felt.

In the marginal Boqueron Field near Maturin in northeastern Venezuela, for example, the Dresser-Rand Company of Houston began the engineering process last year for high-pressure natural gas reinjection equipment.

The first of two phases was scheduled to go on line later this year for Union Texas Petroleum, which wanted to reinvigorate oil production by reinjecting natural gas at 10,000 psig.

But in early 1999 ARCO acquired Union Texas Petroleum, changing the complexion of the project. Dresser-Rand began working with ARCO engineers. Then in April 1999, British Petroleum announced it was acquiring ARCO. A week later, Dresser-Rand engineers were meeting with BP officials in Venezuela on the project. "You just go with the flow," one Dresser-Rand engineer said with equanimity. The project is on target for a November start-up.

The recent flow of mega mergers began in 1998 with Exxon acquiring Mobil, and BP taking over Amoco. Then in April, BP-Amoco announced the acquisition of Arco. The Exxon-Mobil configuration makes it the largest oil company in the world with a little less than 10 percent of the crude oil market.

While government regulators haven't approved the mergers yet, the companies have already begun making their arrangements felt, according to Dave Norton, president and chief executive officer of Dresser-Rand. He cited BP-Amoco-Arco as an example, "They are definitely pursuing a strategy of reducing the number of suppliers."

This is going to be the case with most oil companies as they strive to lower their production costs, Norton says. As a result there will be a scramble among some suppliers to maintain levels of business. "If you don't succeed in becoming one of those key partners, your opportunities for new business are going to be dramatically reduced," Norton predicts.

The mergers also delay capital investments. "Every one of these mergers seems to freeze decision making at all levels of the companies," Norton says. "On capital investments, decision making gets shut down all the way to the people in the field ordering spare parts." But, he points out, the delays are just that, temporary.

For companies like Dresser-Rand, though, the mergers present tremendous "opportunities for growth," he says.

Opportunity lies within the reasons for the mergers in the first place, Norton explains. All of the world's oil companies have been laboring under a long period of low oil prices. Historically, the price of oil has fluctuated. The large oil companies, however, figured that the best way to profit when the price is low is through mergers, consolidating operations and cutting the cost of administration. "It's the economy of scale," Norton says.

Both the large and the smaller oil companies are going to narrow their focus as they gear down to their core technologies – production, refining, distribution and sales. And even those will be honed further.

And there lie the opportunities. For example, oil fields need rotating equipment – compressors, turbines and related products and components. "Operation and maintenance of rotating equipment is a specialty, our specialty," Norton points out.

"Several years ago we began to see companies start to use us more for our expertise rather than just our products." Contract compression, in which Dresser-Rand owns operates and maintains a compression site and contracts to provide compression to the oil company, is a key example. "Oil companies want compression – oil production – not compressors," Norton says.

Dresser-Rand began to realign its strategic thinking several years ago in anticipation of changing needs in the marketplace. "Dresser-Rand began to see this and perceived what our clients wanted, responding to factors in the marketplace before the mergers happened," said Sammy Antoun, executive vice president of Dresser-Rand Compression Services.

Over the past year, Dresser-Rand shifted its emphasis from a manufacturer of product to a supplier of "total energy conversion solutions." This is a quantum leap prompted by the marketplace. "It shows that Dresser-Rand is paying attention to the marketplace and our clients' needs," Antoun says.

Dresser-Rand began making its changes before the spate of oil company mergers. Norton does not foresee continuing mergers of the largest oil companies. The mergers underway now still need approval of government regulators – the Justice Department in the United States. "If the Justice Department is lenient, the current batch of mergers will force others to consider," Norton says. He cited Chevron, Texaco, and Conoco as likely candidates.

"Additional mergers may not be among the big boys," Antoun says. "We may see it at other levels, as well."

But there is a level of companies that is limited in expansion because of territorial restrictions. If the mergers among large oil companies result from a need to cut costs, then those companies that cannot merge are captive. These essentially are state-owned oil companies.

"This will place more pressure on them to find private partners," Norton says. "They're going to have a very difficult time competing. They have their own set of circumstances, such as accepting a major part of their countries' social burdens."

"Several years ago, we began to see companies begin to use us more for our expertise rather than just our products."

- Dave Norton
Dresser-Rand president and chief executive officer

The creation of giant oil companies might lead the "state-owned companies to become more receptive to strategic partnering," Norton says. Strategic alliances with companies such as Dresser-Rand may be the solution to competing with the biggest oil companies.

In any case, those companies that want to survive and thrive amidst the current atmosphere in the world oil industry need to maneuver with the shifting marketplace, and do it with alacrity. ■

For Dresser-Rand, The Name Of The Game Is "Service"

Maintenance and Repair Service Is Offered For All Makes of Equipment

For evidence of Dresser-Rand's commitment to total energy conversion solutions, one needs to look no further than the company's Product Services operation. Dresser-Rand frequently provides full maintenance and repair services for all steam, turbo and reciprocating products manufactured by its competitors, as well as its own nameplate equipment.

"With all of their equipment, what our clients really want is 100 percent availability and reliability without the maintenance headaches," said Peter T. Salvatore, vice president of product services at Dresser-Rand's operations in New York's southern tier.

At the same time, an increasingly competitive business environment has forced many companies to streamline their equipment service programs. "There is a change in the industries we serve in that they are looking for fewer suppliers as they try to structure partnerships with the companies that provide services and equipment to them," Salvatore said. "And Dresser-Rand is uniquely positioned to supply total maintenance and repair services to all steam, turbo and reciprocating equipment on a worldwide basis. Other original equipment manufacturers can't offer such broad scope. Our non-OEM competitors that provide maintenance and repair service are mainly niche competitors."

"With all of their equipment, what our clients really want is 100 percent availability and reliability without the maintenance headaches."

– Peter Salvatore, vice president, Dresser-Rand Product Services

Clients such as British Petroleum Toledo Refinery have relied on Dresser-Rand's expertise to service a variety of non-Dresser-Rand nameplate equipment for many years. The 155,000 barrels-per-day plant, located in Toledo, Ohio, has used Dresser-Rand's service center in Cincinnati for maintenance and repairs on steam turbines, compressors and pumps at the facility.

"Dresser-Rand is a primary source of equipment service at the plant for both planned shutdowns and emergency-basis work," said Jim Hughes, rotating equipment engineer at BP Toledo. "They have always done exceptional work at a reasonable cost."

Dresser-Rand recently completed an overhaul of a General Electric DRV-225 steam turbine, including disassembly, refurbishing of the shaft, grinding the case split line, boring the case, and re-assembly. The turbine, which produces 1,250 hp at 9,000 rpm, is used as a compressor driver at the refinery.

"They also provide services we can't get anywhere else such as their rotor storage capabilities," added Hughes. "They rebuild our rotors, and we will run them for four to five years. Then we put in the spare, and Dresser-Rand will take the old one, rebuild it, and put it in storage in a controlled environment. It frees up our own warehouse, and it's available at a phone call. We use this service for rotors for many of our machines."

Hughes, who has been at the refinery for more than 20 years, says Dresser-Rand has been providing service to the plant longer than he has been there.

"We apply the same standards of quality to all of the equipment we repair," said Mel Harris, operations manager at the Dresser-Rand service center in Cincinnati. "And, as an OEM ourselves, we understand all of the equipment and have the resources available to service them."

Harris also coordinates Dresser-Rand's repair services for a major chemical processing company in Cincinnati, where Ernie Eve is maintenance supervisor. "In addition to providing repair services for their own compressors and turbines, Dresser-Rand provides routine as well as crisis repairs on Elliott turbines, and blowers for the boiler house," Eve said.

The plant, which produces fatty acid feedstock, operates three processes at more than 45,000 pounds per hour. "We're a 24-hour-a-day, seven days per week operation," said Eve. "Dresser-Rand is quick to respond if we have a problem. They will jump through hoops to get a particular part for us."

For years, OEMs provided maintenance and repairs only for the equipment it manufactured. "That was the logical formula," Salvatore said. "Several years ago Amoco came to us and asked us to take care of all equipment, regardless of nameplate," he recalled.

"The client wanted one company to take care of all its compression equipment. By not providing that service we would be at a competitive disadvantage." Dresser-Rand began to examine its services operation. "If a client has a need, we have tremendous skills and talent to develop a solution."

As Dresser-Rand began to shift its company-wide commitment to a broader, more comprehensive provider of total energy conversion solutions, the decision to expand its maintenance and repair operations beyond its own equipment was a natural one. "We will provide a total solution to a client's needs, not a partial solution," Salvatore said. "We will offer them the energy solutions that they need without having the hassle of maintenance and operation. As long as they have equipment, we'll take care of it."

Dresser-Rand brings a full complement of resources for the expanded service program. With more than 20 major service centers strategically located throughout world with special focus on the oil- and gas-producing regions, Dresser-Rand is well situated. "We can certainly apply our proven technologies and manufacturing capabilities to other OEM equipment," Salvatore explained. "And the company has arranged cooperative agreements for parts with its OEM competitors."

In addition, the Dresser-Rand worldwide field service organization has worked for many years on compressor trains that have had other nameplate units coupled with Dresser-Rand equipment. The company also has established agreements with engineering firms that have worked with competitors' equipment to compliment its own engineering expertise.

"The key here is that we use the technology, engineering and expertise that Dresser-Rand has employed over the years. We take the best the competition has to offer and add our experience, knowledge and capabilities providing a total energy conversion solution." ■

Two New Single-Purpose Cylinders Provide State-Of-The-Art Unloading Capabilities

Maximum Flexibility and Flow Capabilities are Hallmarks of New Designs

By Russ Burget

Editor's Note:
The following article has been reprinted by permission of ***Compressor Tech Two*** *magazine.*

With the recent introduction of two specific application compressor cylinders, one for gas storage and the other for low ratio gas pipeline operations, Dresser-Rand Gas Field Compressor Operations has again demonstrated a commitment to the advancement of its gas compressor equipment technology. In the case of the gas storage cylinder, GFC appears to have broken new ground. The design features that set the gas storage cylinder apart include a MAWP (maximum allowable working pressure) of 2425 psig (167 bar), and an array of innovative unloading options which provide advanced flow/pressure regulation on the fly. These options are unavailable with conventional cylinders.

The new cylinders are performance matched with the field proven D-R HOS frames, which are available in two-, four- and six-cylinder configurations with power ratings of 2000 bhp (1491 kW), 4000 bhp (2982 kW) and 6000 bhp (4474 kW), respectively. Bore sizes on the pipeline cylinders are 11.5, 12, l2.5 and 13 in. (292, 294, 305 and 330 mm). The gas storage cylinders have bore sizes of 7, 7.5 and 8 in. (178, 191 and 203 mm). Both operate with a 6 in. (152.4 mm) stroke at speeds ranging from 600 to 1200 rpm, and provide double acting compression (standard on all D-R compressors). Both are single stage but can be made multistage when operated in combination with conventional HOS cylinders.

A cutaway view of Dresser-Rand's Storage Cylinder.

The pipeline cylinder's valves, port unloaders and FVCP (fixed volume clearance pockets) are designed and strategically placed to assure optimum pressure and power control, thereby providing maximum flow efficiency. There are two D-R high performance valves at each corner. Triple-function ports, located between the inlet valves at both the inboard and outboard ends, can serve either as clearance pockets, port unloaders or additional suction valves. Also available is a FVCP that can be installed in the outboard head. All of the clearance pockets and unloaders are pneumatically operated by interfacing regulator controls.

The D-R HOS gas storage cylinders are specifically designed for the dual role of injecting and withdrawing gas at the highest possible rate over a wide range of operating conditions. The cylinders, when combined with HOS frames, are provided in two-, four- and six-throw configurations. The MAWP of 2425 psig (167 bar) exceeds that of most comparable cylinders in the bore sizes available with the D-R gas storage cylinders.

Two of the D-R HOS gas storage compressor packages, each equipped with six,7.5 in. cylinders, have completed one year of operation at a gas storage facility located near Edmonton, Alberta, Canada. The compressors are driven by 3335 bhp (2487 kW) Caterpillar G36l2TA gas engines running at 1000 rpm. An Allen Bradley model 250 PLC interfaces directly with the compressors and drivers. Overall station controls were provided by Moore Products and Quadlog. A keyboard manual override is also a part of the engine and compressor control system.

The gas storage facility is being operated by Energy Spectrum Canada, Inc., on behalf of the Alberta Hub Joint Venture. The other joint venture participants include Sabine Hub Services, a division of Texaco Canada Petroleum, Inc., and Niton Hub Services, a subsidiary of Dominion Energy, Inc. Energy Spectrum Canada is a wholly-owned subsidiary of Energy Spectrum Partners LP, a private equity investment company with investments in pipeline and transmission assets; energy services companies; gas gathering, processing and compression; and of course, gas storage and terminal assets.

A 25 year old gas reservoir has been converted to gas storage after it became obvious gas production was no longer economical. The cycling capacity of the reservoir is approximately 25 Bcf (708 x106 m3), and at the time it was converted to gas storage the reservoir pressure was 300 psia (20.7 bar), which has since been raised to as high as 2000 psia (138 bar).

Four wells with 8 in. I.D. casings serve as the conduits for gas injection and withdrawal. The two D-R HOS compressor packages operate in parallel through a common header and have thus far succeeded at injecting and withdrawing gas at peak rates of nearly 500 MMcfd (14 x 106 m^3/d) Energy Spectrum operating personnel charac-

terize the compressors performance as “versatile,” referring to the interaction between the PLC and compressors to react to compression ratio changes caused by fluctuating pipeline pressures or customer nominations. Semi-automatic loading and unloading features make the necessary corrections by calling upon the cylinders to maintain normal operating conditions. This in turn creates and maintains a consistent level of cylinder performance, allowing the drivers to operate at their most fuel efficient levels.

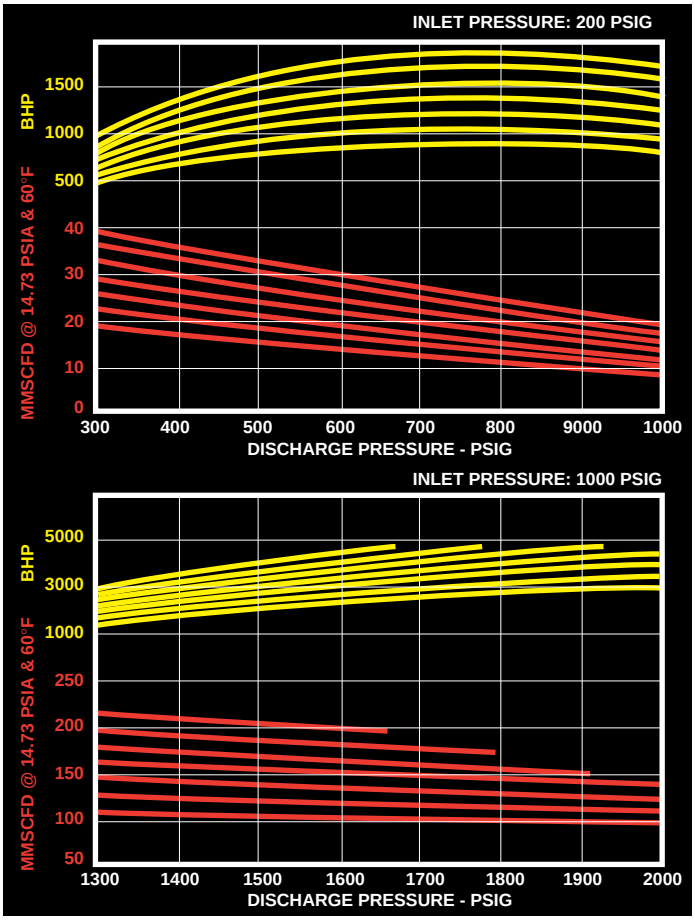
The key to this operating performance lies with a first-of-its-kind cylinder design that provides several innovative unloading features. There are two versatile unloader connections, one each at the head end and at the crank end. Each can be configured as an end unloader or as an automatic FVCP. An access hole to the inlet gas passage is located above each unloader connection. When operating as a port unloader, this hole is opened to allow gas to pass from the bore through the unloader into the inlet passage. The hole remains closed when the connection is used as an FVCP. Both of the Alberta Hub's gas storage compressors are equipped with pneumatically operated head end FVCP and head end port unloader on each cylinder. The large port area reduces power losses and heat build-up often experienced with some other types of unloaders. The port unloaders are completely separate from the compressor valves, so valve flow area and cylinder efficiency are not compromised.

According to Energy Spectrum operating personnel, they have high expectations for their D-R HOS gas storage compressors. They also pointed out they are pleased with the way D-R has carefully monitored the performance of the gas storage cylinders, as well as providing exceptional service support after the sale. ■

A view of a Dresser-Rand pipeline cylinder mounted on an HOS frame.

Energy Spectrum Canada reports peak injection and extraction rates of nearly 500 MMcfd (14 x 10^6 m^3/d).

TYPICAL PERFORMANCE OF SIX, 8" CYLINDERS WITH SEVEN ULOADING STEPS @1000 RPM



profile: Robert Poling

Poling, Pipeline Campaigner Brings Solutions To Mid-Atlantic States

Robert Poling, Dresser-Rand Gas Compression Specialist

Like a rural political campaigner, Robert Poling hits the hilly hustings in his mid-Atlantic territory, drumming up new business for Dresser-Rand along the thousands of miles of natural gas pipelines.

It's a new venture for both Poling and Dresser-Rand, which has dubbed it the "Pipeline Initiative." The name sounds like political intrigue, but it's a new component of the company's restructuring as a supplier of total energy conversion solutions.

Poling had been an account manager for Dresser-Rand's aftermarket sales for gas transmission. Except for a three-year intermission with General Electric, he has been with Dresser-Rand or one of its predecessor companies since 1973. Poling became the company's gas compression specialist when the Pipeline Initiative began January 1, 1999.

"For the last few years it's been a neglected segment," Poling says. The company has sold equipment for pipeline transmission ever since natural gas was shipped via pipeline. Some of the reciprocating compressors date back 50 years. While the aftermarket was supplied, there was no distinct initiative for reciprocating compressors for the gas compression industry – storage, compression, injection and distribution (pipelines).

With the new direction, directives and technological advancements in equipment components, Dresser-Rand is now focusing on the market, one that could produce $250 million in sales over the next five years.

Two factors are playing a role – new regulations of the U.S. Environmental Protection Agency and industry needs to cut operating costs. By May of 2003, pipeline companies in 22 states east of the Mississippi River will have to reduce their emissions of nitrous oxides to cut smog in the populous area along the eastern seaboard of the United States.

Poling, who logs 40,000 miles a year in his Ford Taurus, says he's witnessing first hand the reasons behind the EPA's call for reductions in nitrous oxides. "This summer is proving it out," he says. "Air quality is pretty poor."

The environmental issues are going to result in "very heavy upgrades and re-vamps," Poling says. "The potential is enormous." He figures Dresser-Rand has several hundred engines installed for the gas compression industry in those 22 states and the District of Columbia affected by the EPA regulations.

While the new technology that's available will cut emissions, it also means a reduction in maintenance costs, Poling says. "One of the big projects with CNG Transmission in Pittsburgh was justified by reduced maintenance costs," he says. "We estimated a savings of $32,000 per engine annually over the next three years. A station with ten engines makes a very significant cost saving."

Low gas prices are making the compression industry look more closely at operating costs, too, he says. Dresser-Rand's new technology for reciprocating products also means a reduction in fuel consumption from 7 to 10 percent. "This is a whole new venture for Dresser-Rand in that we've spent more money on R&D to meet the future requirements of the gas transmission industry."

Poling works out of his home in Columbus, Ohio, but reports to Frank Mount, who is Dresser-Rand's regional sales manager for product services at the Cincinnati Service Center. "We expect to see a lot happen because of his direct focus," Mount says.

Mount says it is a team effort with Reciprocating Product Services in Painted Post, New York. Poling interfaces with both George Zitka, pipeline business project manager and Chuck Wilke, senior project manager. The three have made a number of presentations, to client top management and station personnel alike, to discuss Dresser-Rand's product and service offerings. The clients have greatly appreciated the attention. "The gas compression industry certainly deserves the focus," Mount adds. "And now we have a team dedicated to the task."

Poling says that while the Pipeline Initiative is "concentrating mainly on Painted Post products, we'll expand into turbo products later."

In the meantime, he hits the road in search of sales leads and new business, advancing the operating needs of the gas compression industry. ■

engineer's notebook

PROBABILISTIC ESTIMATION OF THE EFFECT OF DIMENSIONAL TOLERANCE FOR TURBINE/COMPRESSOR BLADE ATTACHMENT

Murari P. Singh
Dresser-Rand Company

Editor's Note: This paper was presented at the ASME's International Mechanical Engineering Congress & Exposition, November, '98 in Annaheim, CA.

ABSTRACT

Root attachments of rotating blades of a turbine or a compressor often have multiple lobes. These lobes fit into a matching groove in a rotating disk. Dimension of these lobes, in general, will not be identical for each blade. However, these dimensions will be within manufacturing tolerance. The resulting dimensional fit becomes random in statistical sense within the specified tolerance. Thus precise dimension is unknown even if it is assured to be within the specified tolerance band.

This creates the possibility that for a given blade all the lobes might not be in contact i.e. there might be a gap in the joint. This also means that lobes will carry unequal load. The gap condition may be different for each blade. As the rotational speed increases, each gap will start closing and ideally will eventually close.

Description of a method to assess the influence of manufacturing tolerances on the reliability of such a joint for disk-blade assembly is presented. The resulting estimated stress as a function of rotating speed and tolerance stacking is also presented. The stress result is combined with probabilistic analysis that yields the probability for stress to be within a predetermined amount thus providing a measure of success.

INTRODUCTION

Design method of a mechanical structure is a decision making process. This constitutes formulation of a plan to fulfill stated design objectives. Execution of the process should result in a product with physical definition with expected utility. Traditionally, such methods rely on the assumption that the factors affecting the behavior can be quantified precisely. An indicator of margin for the design is used in the process. This is called "factor of safety." The desired magnitude of the factor of safety for a design is determined based on experience and test. The fact that the value of factor of safety is desired to be greater than unity demonstrates that everything is not precisely predictable.

Performance of a new design can be sensitive to small variations in input. Sensitivity analysis is desirable to quantify the influence of variations. One cannot argue that input parameters have variability, however small they might be. One can argue, however, about the sensitivity of performance due to the randomness of input and its implication on the design decision (Singh, 1991).

This paper describes a process that covers three design activities. First, without going into a complete detail of calculation, key element of stress estimation for a given set of dimensions and load is outlined. Secondly, from such calculation the effect of dimensional variation on resulting stress is quantified. Finally, a probabilistic method is applied to the stress estimation accounting for variation in the dimension.

The process also quantifies the chance for success of the design for a specified dimensional tolerance.

Many beam like structures loaded in tension are supported through a T-hook. An example of such a structure is a turbine blade or a compressor blade. More often the attachment is a multi-lobe construction. These blades are generally attached to a rotating disk.

A multiple T-hook construction similar to one used in steam turbines and in axial compressors is used as an example to demonstrate the applicability of the method. Furthermore, only the forces exerted on the blade due to rotational speed are considered.

STRESS SYSTEM IN ROOT ATTACHMENTS

Many studies into the stress estimate of blades' root attachment have been reported. The work of Ryan and Rettaliata (1940) utilized a two-dimensional photoelastic test to investigate stress distribution of turbine blade fastenings The fastening was a multiple T hook. They calculated load distribution between hooks by integrating radial stresses across each "neck." Hetenyi (1939) evaluated stress concentration factors for T heads in bolts again using 2D photoelasticity.

Heywood (1952) made a significant contribution by analyzing various thread forms as loaded projections and gave semi-emperical formula. He assumed the load on each hook to be acting at the midpoint of the contact surface. Macke (1951) made calculations for radial displacement of the contact surface of one hook with respect to the next. He equated this to the radial elongation of the fastening between these two surfaces. Together with the equilibrium condition this gives a set of simultaneous equations, which equals the number of pairs of hooks. The equation also contains the term for misalignment of hooks, thermal gradients and centrifugal body forces in the fastening. Bulasubramanian (1970) used finite element method to analyze fir-tree dovetail of composite materials. He assumed equal distribution of load among tangs and used a concentrated load at the center of tang. Lambert (1970) used a finite element program to develop equations of load sharing among the hooks.

Stress in the root attachment area is a function of geometry, material and tensile load. Tensile load is a function of the speed of rotation. Figure 1

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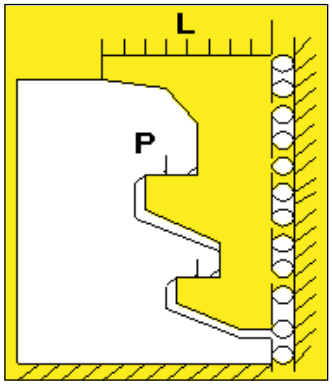

Figure 1. Blade root and groove area

STEAM TURBINE GOVERNING AND ELECTRONIC RETROFIT...

Continued from page 15

shows an idealized structure with load on the root and a reaction force on the upper hook. It is difficult if not impossible to write a closed form solution to estimate stress in root attachment.

The tensile load experienced by each hook depends on the resulting gap at other hooks of the blade root. The relationship between the total load (L) and the load experienced by the upper hook (P) can be expressed as follows:

$$P = \lambda L \qquad (1)$$

λ is a function of the starting gap, geometry and speed of rotation.

The tensile force (L) is a function of rotational speed

$$L = G(N) \qquad (2)$$

Where **L** is the total centrifugal force, **N** is the rotational speed

The resulting stress (σ) in the root attachment is function of load and geometry.

$$\sigma = \delta F(P) = F(\lambda G(N)) \qquad (3)$$

where σ is the stress of interest in the root.

The purpose of this paper is to demonstrate a concept of decision making and discuss the implication of results. Stress evaluation though important is secondary for this paper. Finite element technique has been employed to estimate stresses.

Figure 2 depicts the F.E. Model used. This consists of 350 nodes and 246 elements. Four nodal isoparametric elements have been used to represent the root and the support structure.

The finite element program, ANSYS®, was used for this example. Contact elements that work as compression spring have been used. These springs are incapable of taking any tensile load. A gap is considered closed when there is a compressive load in the spring. Linear static analysis under a constant load as shown was conducted. Many cases were run with varying load to represent the load due to rotation. Result of stress calculation is presented in Fig. 3.

This shows stress at the upper hook as a function of rotational speed. Curves are plotted for two cases. The bottom curve is for the case when all four hooks are in contact at assembly. The top curve is for the case when only top hooks are in contact.

EFFECT OF DIMENSIONAL TOLERANCE ON STRESS

Physical manifestation of dimensional tolerance is the resulting gap between root attachment and the supporting structure. For a given tolerance, a maximum and a minimum gap can be calculated. This provides two limits for the gap.

Results presented earlier are for the cases of a large gap and no gap. Two more cases were studied for the gaps between those two values. The gap values at the lower hooks for these cases are 0.001 inches and 0.002 inches.

Figure 4 shows the plot of maximum stress against speed for various starting gaps at the bottom hook.

The magnitude of maximum stress near the upper hook for any starting gap at the lower hook falls between the two curves plotted in Fig. 3. The stress for the cases with a gap at the lower hook follows the top curve (large gap). Eventually, stress curve bifurcates from the main curve. This indicates the gap has started to close at that speed and the bottom hook has started sharing load.

Figure 5 shows a plot of closing speed and the starting gap.

$$\text{Closing RPM} = f(\delta) \qquad (4)$$

where δ = initial gap in inches.

Results presented so far can be summarized as follows

1. Tolerances have an effect on the stress in the hook.

2. Closing speed for various initial gaps can be quantified.

3. A least square fit to the stress data will provide a predictive mathematical model for a given root-disk geometry.

PROBABILISTIC CALCULATION FOR RELIABILITY

Randomness in the value of the resulting gap in the joint can be quantified by a probability density function (pdf). The resulting cumulative distribution function (cdf) can also be generated. The ability of the joint to carry a desired load depends on the state of stress and the limiting material property. In the deterministic calculation, a design margin is established by ratio R/S (R is the material property and S is the magnitude of stress). However, R and S are random and are described by pdfs. The problem can be posed as follows:

$$P_f = P(R<S) \qquad (5)$$

Where P is the probability of failure when material property R is less than or equal to stress S.

Equation (5) can be expressed in the following form:

$$P_f = P(G(R,S)<0) \qquad (6)$$

Where G is "limit state function" and depends on R and S. For example, if the requirement of the design is that stress must not exceed 50% of yield strength (R) of the material, G can be expressed as

$$G(R,S) = 0.5*R-S \qquad (7)$$

Many methods like Monte Carlo, First Order Reliability Method (FORM) and Second Order Reliability Method (SORM) are available to tackle such a problem. Detailed explanation and discussion of these methods are beyond the scope of this paper. Melchers (1987) provides more thorough description of the theoretical basis. This section presents the result of calculation that utilizes The Monte Carlo method to

Figure 2. Finite Element Model

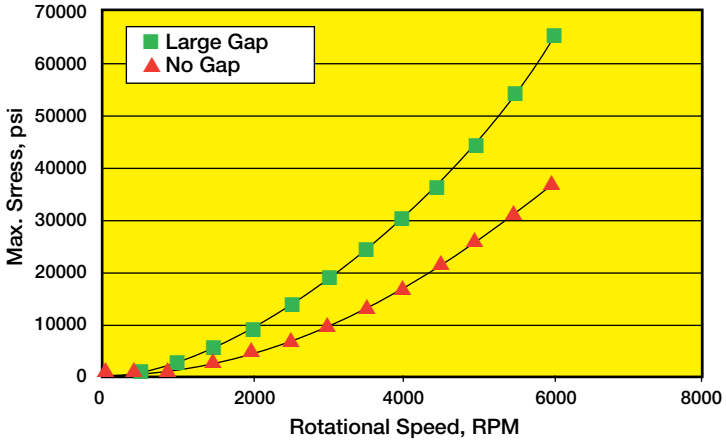

Figure 3. Rotational Speed vs. Max. Stress

estimate the reliability of the given design.

Results, based on deterministic approach, are presented in Fig. 4 and Fig. 5 that provide the required input for probabilistic type of calculation.

The distance between hooks of the root and the distance between hooks of the supportive groove will vary from their nominal values. The difference between these two distances determines the gap size.

Gap = δ = AL1 – AL2 (8)

Where AL1 is the distance between hooks of the root and AL2 is the distance between hooks of the groove.

Theoretically, a joint pdf for the gap can be derived when pdfs for the two distances (AL1 and AL2) are known. The aim of this exercise is to derive a cumulative distribution function which provides a measure of reliability as described in Eq. (5) and Eq. (6).

Result of such a calculation for gap sizes between 0.0 inches and 0.002 inches is plotted in Fig. 6. It is assumed that the distances are normally distributed. The horizontal axis defines the gap size and the vertical axis defines the percent probability of the gap to be above a defined value. This demonstrates that the chance for the gap to be larger than 0.001 inches (for this example) is zero but the chance of the gap to be larger than 0.0 inches is 100 %. It also confirms that the resulting gap size will be between 0.0 inches and 0.001 inches. This means that the stress in the root attachment of blades will be different from others even on the same disk. This finding might have reliability implications for such a structure.

Results plotted in Fig. 4 provide the values of stress for a given gap size. One can now be able to calculate the probability of stress to be larger than a threshold value after the probability of the gap size (Fig. 6) is calculated. Figure 7 presents the result for two rotating speeds (3600 RPM and 5000 RPM). Examination of this plot shows the percentage probability for stress to be less than for a given value. One also gets the range of stress from 0.0 % probability to 100 % probability.

SUMMARY

This paper presented a process to analyze a mechanical structure. The result is presented of an example that resembles root attachments utilized in turbines and compressors. A finite element analysis was performed to quantify stress. Results were also obtained for rotating speed at which a starting gap will close. Dependence of the resulting stress on the starting gap size is also presented. A probabilistic method is used to calculate a probability for gap and resulting stress to reach a limit value.

This shows the resulting stress is influenced by the resulting gap size. It is also shown that the gap size is a random quantity within manufacturing tolerances. Thus the resulting stress in the root attachment is a random quantity. This type of information should be valuable to designers in making decisions. ■

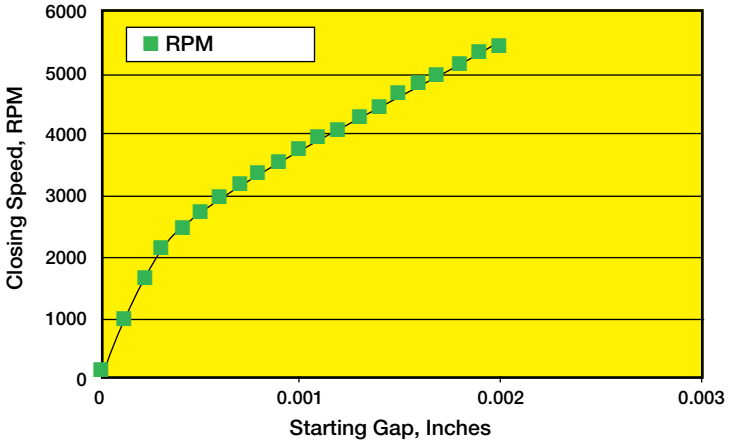

Figure 5. Starting Gap vs. Rotational Speed

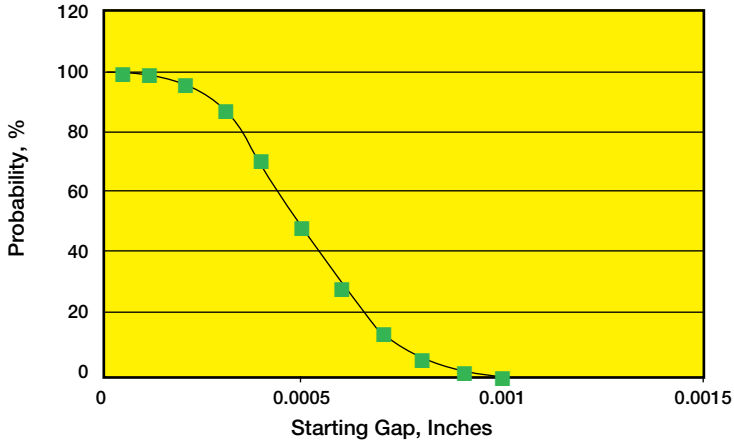

Figure 6. cdf for starting gap

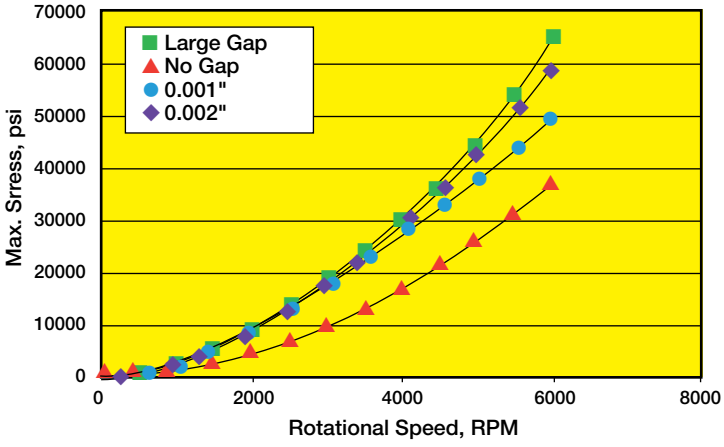

Figure 4. Rotational Speed vs. Max. Stress for different starting gaps.

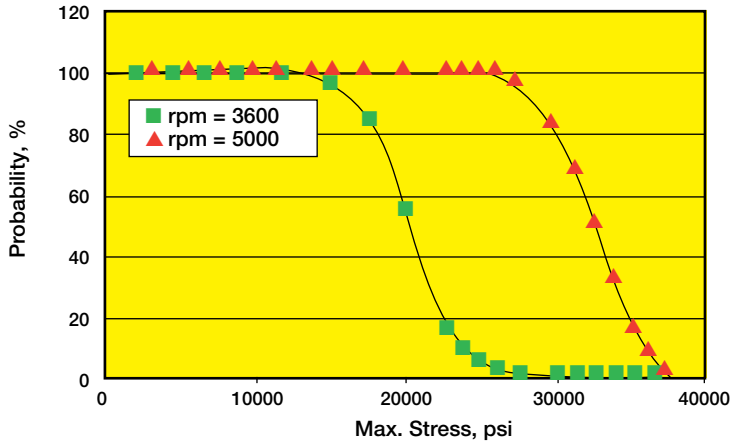

Fig. 7. cdf for Max. Stress

global visions

Dresser-Rand Offers Product Training Programs For 4th Quarter 1999

For the past 25 years, the Dresser-Rand Company has been conducting product training programs, designed for client operations and maintenance personnel with a wide variety of job disciplines. Programs integrate both interactive classroom learning with a hands-on laboratory experience.

Taught by full-time Dresser-Rand instructors, field service engineers and field service personnel, the product training programs are offered at Dresser-Rand factory schools in Olean, Wellsville, and Painted Post, New York, as well as in Houston, Texas, and Tulsa, Oklahoma. International clients can also take advantage of programs offered at Dresser-Rand's LeHavre, France, Wythenshawe, UK, or Kongsberg, Norway Training Centers.

The 1999 fourth quarter product training programs offered in the U.S., include courses on Centrifugal Compressors; Controls Systems; Gas Turbines; Reciprocating Compressors, including high speed separable and low speed process types; Integral Gas Engines; and Steam Turbines.

• Centrifugal Compressors - Dresser-Rand offers both five-day classroom and five-day hands-on labs in support of its centrifugal compressor products. The labs immediately follow the prerequisite classroom programs to allow attendees to reinforce class content.

• Control Systems - A 10-seat computer lab and a control panel simulator compliment the two-day DI-Tronics III and a DI-Tronics IV control system classes. These courses are designed for operations personnel, instrument/electronic technicians, and engineering personnel

• Gas Turbines - The Houston Training Center will host a three-day Gas Turbine Operation & Maintenance

Dresser-Rand 1999 Product Training Schedule

CONTROL SYSTEMS		September				October				November					December			
Product/Course Name	PRICE	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27
DCS-132 DI-Tronics 3 Controls System	$895										◆							
DCS-142 DI-Tronics 4 Controls System	$895										◆							
ENERGY SYSTEMS		**September**				**October**				**November**					**December**			
Product/Course Name	PRICE	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27
STC-103 Steam Turbine O & M	$895		◆						◆									
STL-212 Steam Turbine Hands-on-Lab*	$895		●						◆									
RECIPROCATING COMPRESSORS High Speed Separables		**September**				**October**				**November**					**December**			
Product/Course Name		6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27
HSS-105 Reciprocating Gas Compressor Course	$750						X											
HSS-215 Hands-on Gas Compressor Course*	$600							X										
RECIPROCATING COMPRESSORS Process/Integral Engine		**September**				**October**				**November**					**December**			
Product/Course Name	PRICE	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27
IES-105 Integral Engine School	$785		■															
IEL-215 Integral Engine Hands-on Lab*	$700			■			◆					■						
RCS-105 Reciprocating Compressor School	$785				■				■									
RCL-215 Reciprocating Compressor Hands-on Lab*	$700					■				■								
VRS-105 Valve Reconditioning School	$675																	
WAS-245 Certified Wire Alignment School	$875														■			
TURBO PRODUCTS		**September**				**October**				**November**					**December**			
Product/Course Name	PRICE	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27
CCS-105 Cent. Compressor O & M	$895							●		◆								
CCL-215 Cent. Compressor Hands-on Lab*	$895								●		◆							
GTS-103 Gas Turbine O & M	$895											◆						
PTL-212 Power Turbine Hands-on Lab*	$895																	

*These labs have prerequisite courses and limited seating

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class followed by a two-day, Hands-on Power Turbine Lab. The lab utilizes a portable DR-22 power turbine as a training vehicle.

• Reciprocating Compressors - Dresser-Rand has both five-day classroom and five-day hands-on lab courses covering its low speed process gas and high speed separable gas field compressors.

The Tulsa Training Center supports Dresser-Rand high speed separable gas compressors. The Painted Post Training Center supports low speed reciprocating process gas compressors. Each location has both types of programs scheduled in September and October. As with all Dresser-Rand labs, classroom training is a lab prerequisite.

• Integral Gas Engines - The Painted Post Training Center is also responsible for providing maintenance training on the slow speed integral gas engines formerly manufactured by Clark and Ingersoll-Rand. A five-day Integral Engine School followed by an innovative five-day Hands-on Engine Lab is being offered in September.

• Steam Turbines – A three-day Steam Turbine Operation and Maintenance (O&M) course and a two-day Hands-on Steam Turbine Lab are scheduled in Houston. Both programs are designed for operators, mechanics, supervisors, process engineers and mechanical engineers with emphasis on the practical aspects of steam turbine operation and maintenance.

• Custom Product Training - In addition to regularly scheduled product training classes, Dresser-Rand also offers customized training on a client's Dresser-Rand equipment. These very specific and detailed programs can be held at the client's site, at a regional location or at a Dresser-Rand facility.

For more information on any of these programs including scheduling and pricing, contact your Dresser-Rand sales representative; call Dresser-Rand Product Training direct at 800-275-3773 (Outside the U.S. 716-375-2791); or visit us at www.dresser-rand.com. and select Product Services. ■

Dresser-Rand Engineers To Present At 28th Annual Turbomachinery Symposium

Dresser-Rand Company has announced that engineers from its Wellsville and Painted Post, New York, operations will be technical presenters at the 28th annual Turbomachinery Symposium, September 12-16, at the George R. Brown Convention Center in Houston.

Lee Golder, manager, technical training for Dresser-Rand's Painted Post operation and Andrew W. Lake of Equistar Chemicals, LP of Deer Park, Texas, will be giving a presentation on *Maintenance Issues for Reciprocating Compressors*. The presentation will cover a variety of topics concerning reciprocating compressors, which includes maintenance issues for various components and systems and diagnostic methods/procedures for problem identification.

Stephen L. Edney, group leader, stress and vibration for Dresser-Rand's Wellsville operation and John C. Nicholas of Rotating Machinery Technology, Inc. of Wellsville, New York will be giving a presentation on *Retrofitting a Large Steam Turbine with a Mechanically Centered Squeeze Film Damper Bearing*. As part of the presentation, Edney and Nicholas will discuss the design and application of a squeeze film damper to a large flexible steam turbine rotor supported on tilting pad bearings.

Joe Lamberson, manager of engineering and technical support and Jack Reed, manager, commercial parts for Dresser-Rand's Wellsville operation will be conducting a presentation on *Steam Turbine Governing Systems and Electronic Governor Retrofit* at the annual turbomachinery symposium. The presentation will cover topics regarding control methods and equipment on older mechanical control systems that are being converted to modern electrical control systems. ■

Dresser-Rand Hse Reciprocating Process Compressors Brochure Available

Dresser-Rand Company has published a comprehensive product and services brochure for HSE Reciprocating Process Compressors. The brochure describes the rugged HSE balanced-opposed reciprocating compressor design that has performed successfully in over 1,000 process installations.

For the past 100 years, Dresser-Rand has designed and manufactured high reliability and low maintenance compressors for chemical, refinery and natural gas applications. The HSE compressors are designed to meet or exceed API 618 standards

To request the HSE Reciprocating Process Compressors brochure, call Ingersoll-Rand Marketing Services at 800-847-4041 or contact your Dresser-Rand Representative. ■

insights

Editorial Statement:

"insights" is a periodical publication of the Dresser-Rand Company. Its editorial mission is to inform our readership in the areas of energy industries, as well as business, and world affairs that have an impact upon our mutual concerns. Comments, inquiries and suggestions should be directed to:

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