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**Dresser-Rand + 3**

**Team Rebuilds Turbine After Refinery Fire**

**Dresser-Rand Providing Equipment for Industry's First  
Floating LNG Project**

# insights

A PUBLICATION OF DRESSER-RAND



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# Dresser-Rand + 3

**DRESSER-RAND RECENTLY** completed three acquisitions. Each is consistent with the company's commitment to a "bolt-on" acquisition strategy to expand services to its clients and acquire products, services, and technologies that enhance market positions. (For insights into managing D-R's growth strategy, see Rossi's article on next page.)

**PETER BROTHERHOOD LTD.**  
(JULY 2, 2008)

Dresser-Rand's UK subsidiary, Dresser-Rand Company Ltd., completed the acquisition of certain assets of Peter Brotherhood, Ltd., a company that specializes in the design and manufacture of steam turbines, reciprocating gas compressors, gas packaged combined heat and power systems (CHP), and gearboxes. The Peter Brotherhood business had sales of approximately \$100 million in fiscal year 2007.

Stephen Fitzpatrick, managing director of Peter Brotherhood, commented, "Dresser-Rand recognized the success we have forged by a clear set of values focusing on customer care and satisfaction and the delivery of great products by a highly motivated and successful workforce."

**ENGINUITY LLC**  
(AUGUST 8, 2008)

Dresser-Rand acquired the assets of Enginuity LLC, a private, U.S.-based provider of combustion and catalytic emissions technology solutions, controls and automation, and after-market services for reciprocating gas engines used in the gas transmission market. In 2007, Enginuity reported sales of approximately \$16 million. In connection with this acquisition, Dresser-Rand established its Gas Engine Technology Center in Fort Collins, Colorado, headquarters to Enginuity since 1999.

Chad Fletcher, founder and CEO of Enginuity, observed, "The well-established Dresser-Rand brand provides the platform whereby Enginuity can realize its vision of 'bringing energy and the environment into harmony.'"

**ARROW INDUSTRIES, INC.**  
(AUGUST 29, 2008)

Dresser-Rand Services, LLC, acquired all of the stock of Arrow Industries, Inc., a premier provider of foundation and mechanical services for reciprocating engines and compressors used in the North American pipeline industry. In 2007, Arrow reported sales of approximately \$30 million.

Arrow's diverse servicing expertise supports Dresser-Rand's Applied Technology strategy and will enable it to develop markets that are expected to increase earnings. ■



# CANDID visions



## GROWTH BY ACQUISITIONS: AN INTERVIEW WITH CHRIS ROSSI

***Editor's Note:** The following article is based on an interview with Chris Rossi, executive vice president, Product Services Worldwide at Dresser-Rand. Rossi discusses Dresser-Rand's recent acquisitions (see article on previous page), and how their integration will improve Dresser-Rand's ability to meet client needs.*

***insights:** On what basis did Dresser-Rand select Peter Brotherhood, Arrow Industries, Inc., and Enginuity LLC for acquisition?*

**Rossi:** One of our business strategies is to focus on acquisitions that strengthen and enhance our core capabilities, that add new products, services, and technologies, or that give us access to new markets or enhance our position in current ones. Each acquisition was consistent with this strategy.

Peter Brotherhood specialized in the design and manufacture of steam turbines, reciprocating gas compressors, gas engine-packaged combined heat and power systems (CHP), and gearboxes. Their primary clients are in the worldwide oil and gas industry, specifically marine and floating production, storage, and offloading (FPSO) vessels, refining, petrochemical, combined cycle/co-generation, and renewable energy industries. This acquisition is obviously complementary to Dresser-Rand's steam turbine and reciprocating gas compressor products and services. It just made good business sense for D-R and Peter Brotherhood to combine their technical expertise, R&D

capabilities, and worldwide sales organizations. With a manufacturing facility and strong presence in Europe, Dresser-Rand Company Ltd. (the purchaser of certain assets of Peter Brotherhood) strengthens our position in the European Served Area for reciprocating compressors and steam turbines – and it increases the size of our industry-leading installed base.

Arrow Industries, which has been folded into Dresser-Rand Field Operations, was recognized as a premier provider of foundation and mechanical services for reciprocating engines and compressors used in the North American pipeline industry. Dresser-Rand and Arrow Industries had worked together in the past, and each company has decades of experience in the energy markets. The acquisition of Arrow Industries specifically enhances our ability to better serve the pipeline industry, but also improves our position in other markets. In turn, it affords Arrow the opportunity to expand its current capabilities with support from the resources and solutions of a technology-leading OEM such as Dresser-Rand.

Enginuity has long been known as the technology solutions leader for reducing gas-fired engine emissions, and for engine and compressor controls and monitoring for gas transmission in North America. Enginuity strengthens our engine technology position and value proposition in the gas transmission market, and enhances our Applied Technology capabilities (applying Dresser-Rand technology to other OEM equipment). Perhaps most importantly, it will enhance Dresser-Rand's role in reducing CO<sub>2</sub> emissions from compressor systems. Dresser-Rand's highly engineered

products and global sales and service support capabilities provide a platform to expand on Enginuity's vision of 'bringing energy and the environment into harmony.'

In connection with the acquisition of Enginuity, we've established a Gas Engine Technology Center in Fort Collins, Colorado, which has served as Enginuity's headquarters since 1999.

***insights:** In your view, what are the most critical integration issues facing D-R and their effect on providing seamless service to clients, both from the perspective of Dresser-Rand's clients and the client bases of Peter Brotherhood, Arrow, and Enginuity?*

**Rossi:** Among our greatest challenges for the three acquisitions are integrating sales channels and organizing to capture the "synergies," or value we expect to create by combining businesses. These acquisitions were targeted because we saw opportunities to better serve our clients by adding talent, complementary services, and market-leading products to fuel additional growth for Dresser-Rand. Some sales personnel from the acquired companies manage the same client relationships, and may have overlapping territories or serve slightly different roles than their D-R counterparts. Moreover, the client-facing personnel of each company need to be versed in the full breadth of products and services of the others to successfully bring them to market. So, to seamlessly serve our clients and capture growth opportunities made possible by the acquisitions, we have to move quickly while being smart about integrating the client-facing personnel into Dresser-Rand's existing

aftermarket and new unit sales organizations.

**insights:** *Was there any consolidation or merging of offices, service centers, or manufacturing space following the acquisitions?*

**Rossi:** No. The acquired companies' footprints complemented D-R's existing footprint well. Moreover, the capacity represented by the talent and facilities of the combined companies will satisfy clients and support our growth objectives.

**insights:** *We're hearing more and more about emissions control and "green" initiatives in the energy industry, and emissions control is one of Enginuity's strengths. How is Dresser-Rand adapting its products and solutions to be more environmentally friendly and meet tighter emissions standards?*

**Rossi:** There's no doubt that global demand for energy continues to grow. And when people think about the oil and gas industry, they don't necessarily associate that with "clean and green." However, Dresser-Rand has exciting prospects for providing environmentally friendly solutions for oil and gas production and processing, and for supplying equipment for coal-related processing such as coal-to-liquids, coal-to-gas, and CO<sub>2</sub> sequestration.

Dresser-Rand is committed to responsibly addressing climate change and greenhouse gas emissions. Emission control is at the heart of Enginuity's core competency and, as such, the incorporation of Enginuity's products and expertise helps us in a major way.

Enginuity's solutions reduce many pollutants, including NOX, CO, hydrocarbons, hazardous air pollutants, and greenhouse gasses which include both hydrocarbons (primarily methane) and CO<sub>2</sub>. In fact, Enginuity's solutions reduce NOX emissions by about 120,000 tons a year and greenhouse gas emissions by more than 100,000 tons a year.

We recognized early that Enginuity had a great deal to offer in meeting emissions standards—and in getting business. Joining Dresser-Rand gives Enginuity the global stage it needs to grow in a larger market, especially considering Dresser-Rand's large installed base of integral gas engines. With the impact that these solutions already have on clients, Enginuity has the experience and the necessary relationships to guide D-R's move into this important market.

Dresser-Rand Company Ltd. has an installed base of proven and efficient combined heat and power (CHP) packages configured to provide secure power, heating, and cooling services tailored to the needs of each installation. Some of the CHP installations also enable the use of biofuels such as digester gas, bio-diesel, and landfill gas. Dresser-Rand Company Ltd. also has developed, tested, and patented the design of a power take-off module that captures energy from ocean waves for offshore and onshore applications using oscillating water column (OWC) technologies.

Dresser-Rand also recently invested in Ramgen Power Systems, LLC, a development-stage company with highly efficient compressor technology designed to compress, capture, and sequester carbon dioxide. We're actively pursuing

the emerging CO<sub>2</sub> compression market as it applies to carbon capture and sequestration, or CC&S. And the Ramgen compressor technology is projected to reduce the capital costs of CO<sub>2</sub> compression, one of the most expensive aspects of this process, by as much as 65 percent and produce a minimum of 25 percent operating cost savings. We believe this emerging market and the growing market for enhanced oil recovery will together represent a multi-billion dollar per year market potential for Ramgen's CO<sub>2</sub> compressor.

So all in all, we're pleased with the environmental solutions promise of our acquisitions.

**insights:** *When you look at the energy industry today, what other opportunities are there for mergers and acquisitions, either to grow the business in terms of new markets and technology or to expand Dresser-Rand's current products and services? Can we expect to see more acquisitions from Dresser-Rand as a part of your growth strategy going into 2009?*

**Rossi:** We believe acquisition opportunities remain, both in the areas where we compete today, as well as in adjacent products and services. As we develop and more clearly define our environmental solutions strategy, for example, we expect to identify several attractive companies and technologies that make sense for Dresser-Rand. We're excited about the opportunities to acquire additional aftermarket businesses that excel in markets that have not been a focus for Dresser-Rand in the past, and to acquire service capability on equipment contiguous to our compressors and turbines. ■

# PROFILE

## Jim Sorokes



### DRESSER-RAND'S "RENAISSANCE MAN" PROMOTES LIFELONG LEARNING

*Editor's Note: Jim Sorokes is a principal development engineer at Dresser-Rand in Olean, New York, USA. During his 30 years with the company, he has designed high-performance, radial turbomachinery and held various supervisory and management positions.*

Whether working on his next technical article, testing new aerodynamic designs, pulling weeds in his garden, or shooting hoops, Jim Sorokes seems perfectly at home. A well-rounded individual who brings real life interests and experiences to the job, Jim enjoys working with others and lends new meaning to the concept of "lifelong learning."

When describing his most vivid memories of experiences at Dresser-Rand, the adage, "Give a man a fish and he'll eat for a day; teach a man to fish and he'll eat for a lifetime," is apropos. Jim has actively engaged in educating both clients and younger engineers at Dresser-Rand. He's taught several popular seminars and advanced courses on compressor aerodynamics, compressor aero-performance and compressor rotating stall. He's also published several practical papers that are invaluable

to helping end users understand complex design compromises that affect aerodynamics, rotordynamics and stress, and manufacturing.

"My best moments are spent mentoring others and seeing them get promoted to positions of increasing responsibility," Jim said.

During his long and distinguished career at Dresser-Rand, Jim's been responsible for the aerodynamic development, design, and analysis of centrifugal compressors. He's held supervisory and management positions in development engineering, aerothermodynamic design, and aero-performance engineering.

This year, Jim was elected to the level of Fellow in the American Society of Mechanical Engineers (ASME). As described on the ASME Web site, it is "the highest elected grade of membership within ASME, the attainment of which recognizes exceptional engineering achievements and contributions to the engineering profession."

Jim earned this honor because of his diligence, dedication, and work that includes all aspects of centrifugal compressor aerodynamic design, stage rig testing, practical application of computational fluid dynamics, and the use of new design philosophies and techniques. He also provides training both within and outside Dresser-Rand, and authors technical papers on subjects such as low solidity diffusers, rib

diffusers, high Mach number impellers, and aero-mechanical excitation. Engineers from several energy-related companies wrote letters sponsoring Jim's election to the Fellow grade – evidence that his accomplishments are recognized and respected throughout the turbomachinery community.

As supervisor of aerodynamic engineering, Jim was the technical leader in the aerodynamic design of Dresser-Rand's DATUM® compressor line, and served as a principal aerodynamic consultant for the complete Dresser-Rand product line. He has also taught centrifugal compressor design and analysis in seminars, short courses, and tutorials.

Jim graduated from St. Bonaventure University with a B.S. in physics. He's a member of the ASME, the ASME IGTI Turbomachinery Committee, the American Institute of Aeronautics and Astronautics, and the National Management Association. He's written more than 35 technical papers, holds two United States patents: Variable Vane Height Diffuser, U.S. Patent 4,932,835 (June 12, 1990); Position Validator Device, U.S. Patent 5,152,070 (October 6, 1992), and has two patents pending.

Jim lives in Olean, New York with his wife, Penny, and they have three children. He enjoys golf, basketball, fishing, photography, carpentry, gardening, playing his acoustic guitars, and writing. ■

SURVIVING A

# Crash Landing

*Editor's Note: In August, Dresser-Rand's UK subsidiary, Dresser-Rand Company Ltd., completed the acquisition of certain assets of Peter Brotherhood Ltd., a company that specializes in the design and manufacture of steam turbines, reciprocating gas compressors, gas packaged combined heat and power systems (CHP), and gearboxes. This article describes events that occurred earlier this year, before the acquisition. (Investigation into these events is ongoing in an effort to determine the exact cause of the reduction in thrust on both engines that resulted in reduced fuel flow and power loss.)*

British Airways flight 038 from China to the UK had been routine.

Peter Brotherhood's Managing Director Stephen Fitzpatrick, and Sales and Marketing Director Stephen Wellburn, were returning from Beijing last January aboard the flight, no doubt discussing a contract they secured with a client in China – the single largest contract in Peter Brotherhood's history. As the jetliner approached Heathrow under control of the autopilot and automatic throttle system, senior first officer John Coward prepared to take manual control as the plane descended below 1,000 feet.

Suddenly, the 150-ton Boeing 777 lost power. "There was nothing from any of the engines, and the plane started to glide," is how Coward recounted the moment in an interview with BBC News.

"At first, I didn't think we'd clear the fence," he said. "As we landed, I braced myself for an enormous thud. But instead of one thud, there was a series of thuds as the plane bounced along the grass. Eventually, it shuddered to a halt. I was trying to stop the plane. I struggled to try and keep it in a straight line."

Fitzpatrick recalls feeling "a mighty bang, which I now know was the undercarriage being ripped away. There was no warning. The captain didn't shout 'Brace!' at all. Obviously, he was concentrating on doing what he had to do."

Fitzpatrick adds, "It went dark, and as we skidded along the ground I watched the portside engine slowly breakup."

All 136 passengers and 16 crewmembers survived. One person suffered a broken leg and others received minor injuries during the emergency evacuation.

The initial assessment from the investigating team was that the jetliner failed to respond to demands for extra thrust during its final descent. This lack of thrust meant that the speed of the aircraft decreased, and it came down on the grass short of the runway.

"It could have been a completely different outcome, not just for us but for the people on the ground," said Fitzpatrick. "There are houses right up to the perimeter, so it could have been a real disaster."

Mr. Coward was credited by his captain, Peter Burkill, for averting a major crash.

"I was only doing my job," Coward told BBC News. "The crew, the passengers, and everybody else acted heroically."

"Flying is all about teamwork and that is what we all displayed."



# Team Rebuilds Turbine

After Refinery Fire



*URC produces petroleum products for cars, trucks, airplanes, and farm and construction equipment, as well as homes and industries in Pennsylvania and portions of New York and Ohio.*

**IN MARCH 2008**, United Refining Company (URC) had a pump fire in its vacuum tower. The fire severely damaged a Dresser-Rand (formerly COPPUS) single-stage RLVA model steam turbine that drives an Ingersoll Dresser light vacuum gas oil pump. The turbine had been in service since 1998.

The refinery, based in Warren, Pennsylvania, USA, operates 24 hours a day, seven days a week, and averages throughput of 70,000 barrels of oil a day.

Part of URC's mission is to provide clients with a stable supply of petroleum products, and the steam turbine was the only turbine that fit into the restricted space in the vacuum tower, so it was critical to get the damaged unit back up and running as quickly as possible.

The turbine was shipped to Dresser-Rand's Horsham, Pennsylvania, service center and work began as soon as it arrived. The damage to the turbine was extensive, so new components had to be located and installed. Dresser-Rand employees in Worcester, Massachusetts, and in Olean and Wellsville, New York and Horsham worked together to locate new and used components for the turbine through D-R's Restored Classics program.

The Restored Classics is essentially an engineered recycling program for D-R steam turbines. Its objective is to match clients with fully refurbished units, specifically engineered

to clients' needs. A Restored Classics turbine can be delivered in a fraction of the time of a newly manufactured turbine, and for lower overall cost.

Parts from three older turbines were used in rebuilding the damaged turbine. A major challenge the team faced was the unit's vertical orientation, because the three older turbines were all horizontally configured. This required extensive alterations and specialized engineering skills to reconfigure the turbine components. Nonetheless, in just two weeks the employees at the Horsham service center, with engineering support from technical specialists at the Steam Turbine Technology Center in Worcester, built a new turbine from these components.

The rebuilt turbine underwent a full mechanical steam test, and with its functionality fully restored, the rebuilt unit was shipped mid-April 2008 and installed by URC. URC was pleased with the easy "drop-in" installation and unit start-up, particularly as the refurbished turbine perfectly matched the previous turbine's footprint.

Although the project offered plenty of challenges, through it all, team members closely coordinated their efforts and pooled their resources and talent to provide the client with a fast, effective solution to get the turbine back up and running. The strength of Dresser-Rand's service was put to the test and proved as individuals from different locations quickly and efficiently formed a non-traditional team to help URC in its hour of need. ■

# DRESSER-RAND OPENS New Valve Facility



**IT WAS AN UNUSUALLY CHILLY** afternoon in Houston last January, but that didn't discourage employees from attending the ribbon-cutting ceremony to officially open Dresser-Rand's new Gimpel valve-manufacturing facility.

The facility was created by overhauling existing office and warehouse space located at 1210 West Sam Houston Parkway. Two floors of office space were removed, and the remainder of the building was given major renovation to turn it into a state-of-the-art valve-manufacturing facility.

Dresser-Rand acquired the Gimpel product line from Tyco International last year because it is a perfect fit for its steam turbine business, complements D-R's current repair operations, and enables Dresser-Rand to produce trip-and-throttle valves for its complete line of steam turbines.

Renovation took fewer than six months, a spectacular feat considering the effort involved. Jeff Wood, general manager of the Gimpel Strategic Business Unit who presided over the ribbon cutting ceremony, credits Jim Methven, director, Worldwide Facilities and Manufacturing Strategy, and Wayne Gassmann, Supply Chain manager, Product Services, as integral to the design, layout, and implementation of the facility conversion.

Gimpel products are engineered-to-order, and the new facility is serving the Gimpel product line well. Because the facility was designed specifically for Gimpel products, it has helped reduce cycle-time and increase product quality. Orders are being filled more efficiently, resulting in more on-time deliveries.

*Gimpel products are engineered to order.*

Wood said the team has worked very hard this year to "gain the confidence of OEM turbine manufacturers in our ability to provide competitive pricing, consistently meet design and delivery commitments, and provide timely responses to inquiries and requests."

The Gimpel brand is recognized as one of the highest quality and most dependable trip-and-throttle valves on the market because of its advanced technology for quick closing capability and extensive experience with industrial, API-611/612, coal-fired and nuclear-fueled power plants, and nuclear-powered US Navy aircraft carrier and submarines.

Dresser-Rand's Gimpel steam turbine valves for commercial applications include oil-operated trip and trip-throttle valves, top and inverted mechanism mechanical latch-type trip throttle valves, and swing disc non-return valves for extraction, induction, and extraction/induction service. The commercial product line covers mechanical drive steam turbines from 1,000 horsepower (hp) to more than 100,000 hp, utility boiler feed water and nuclear reactor main feed pump drive steam turbines up to 50,000 hp, and geothermal, industrial, and non-reheat steam turbine-generators up to 150 MW.

Before Dresser-Rand purchased Gimpel Valve, the trip-and-throttle valve was quite often the pacing item for the delivery of the turbine. Wood noted, "We've worked hard to improve the delivery performance of trip-and-throttle valves and we haven't missed any critical valve deliveries for new steam turbines to date."

Dresser-Rand steam turbine engineers in Wellsville, New York, Worcester, Massachusetts, and Burlington, Iowa, work closely with the valve design team in Houston to meet client design requirements and select the correct components for each specific application.

According to Wood, "Building a facility dedicated to the manufacture of these valves was necessary to show our clients and other steam turbine manufacturers that we will give long-term support to the Gimpel line – and fulfill their orders efficiently with a high-quality product." ■

# ENGINEER'S notebook



Norman A. Samurin



George C. Talabisco

## SYSTEM DESIGN STUDY USING DYNAMIC SIMULATION OF A PROPYLENE REFRIGERATION PROCESS COMPRESSION TRAIN

**Norman A. Samurin, PE,**  
Principal Engineer  
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Principal Engineer  
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### INTRODUCTION

The procurement of the compressor and driver included a dynamic simulation study of the system. The compressor vendor was the prime contractor to supply the rotating equipment and perform the dynamic simulation study. The simulation established the requirements for the prevention of surge during normal operation and emergency shutdown. The study also evaluated the parameters to start the compressor train based on the client's specified operational constraints.

This paper describes the process and equipment along with the initial simulation study results. The study indicated that modifications to the process and equipment were beneficial.

### THE PROCESS

The process uses a two-section refrigeration cycle using propylene as the heat transfer medium. The process heats a low-temperature ethylene stream. The process is shown on the Pressure-Enthalpy diagram (Figure 1). Starting from the compressor final discharge the hot high-pressure gas flows to the main condenser where it is cooled and condensed to a liquid. The liquid then flows to the second-stage ethylene heat exchanger where the propylene is further cooled. The propylene liquid pressure is dropped through a valve to the second-stage compressor inlet pressure. The two-phase mixture flows through a separator where the gas stream flows to the compressor sidestream (interstage) and the separated liquid flows to a liquid holding tank. From the holding tank the liquid flows to a first stage heat exchanger. The cooler exit stream flows through a valve that drops the stream pressure to the first-stage compressor inlet pressure. The two-phase fluid flows to a separator. The stream temperature is controlled by the addition of hot discharge gas from a recycle valve mixing with the cooled two-phase fluid. The gas flow out of the separator goes to the first section compressor inlet.

Any liquid in the separator is pumped back to the final discharge holding tank (accumulator).

### SITE CONDITIONS

The plant is located in the southwest United States.

- Ambient temperature ranges from  $-20$  to  $100^{\circ}\text{F}$
- Normal barometric pressure is 12.8 psia
- Site elevation of 3600 ft.

### CLIENT PROCESS CONSTRAINTS

The client specified initial system constraints for the refrigeration compression system.

1. There was no onsite storage of propylene refrigerant. This encourages a constraint to minimize the loss of process fluid. On a unit shutdown, the system should not be blown

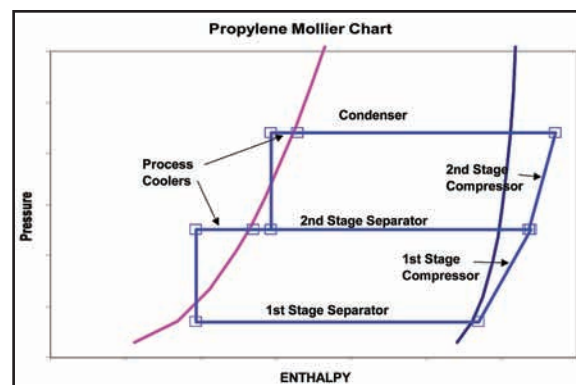


Figure 1. Propylene refrigeration cycle pressure-enthalpy chart.

## ABSTRACT

This paper discusses knowledge gained during the installation design of a propylene refrigeration process compression train using a dynamic simulation model. The discussion will follow the steps taken from initial conceptual design through modifications based on dynamic simulation of the selected equipment and process. The original process control system and requirements for start up and shut down are discussed. The dynamic simulation results of the original design and the subsequent redesign of the system are presented.

The propylene refrigeration system has a centrifugal compressor driven by an electric motor with a VFD control and a speed-increasing gearbox. The system was evaluated using a dynamic process simulation model to size valves and determine the suitability of system components. Through a collaboration of efforts of several people, revisions to the original system were implemented. The final result was a successful plant start up of this equipment without motor overload or compressor surge in July 2007.

down. Refrigerant replacement would have to be done by tanker truck. The nearest supply source was located 300 miles from the site.

2. The process does not have an inlet throttle valve before the first compressor stage.

3. The compressor had to start with a settle-out temperature of 100 °F in the fluid system. [Note: Since there was no isolation of the liquid and gas sections, at 100 °F some of the liquid will vaporize (boil off) and the equilibrium system pressure will be 227 psia. This pressure exceeds the normal compressor discharge pressure of 215 psia. See the Pressure-Enthalpy diagram (Figure 2) and the P-T diagram (Figure 3, Ref. 4).]

4. The system design needs to prevent or minimize compressor surge on an emergency trip.

5. The system design needs to prevent compressor surge during start up.

## COMPRESSOR TRAIN EQUIPMENT

The compressor train consists of an induction motor, speed increasing gear, and a two-section centrifugal compressor.

The driver is an 1800 rpm, ~10000 hp induction motor with a variable frequency drive (VFD) system. The motor was cooled by internal shaft-mounted fans.

The gear is a speed increasing gear with a speed ratio of 3.127.

The compressor was a two-section centrifugal with a single sidestream inlet with operating speed at 5778 rpm. The first section of compression has a suction pressure of ~40 psia; the second section has a suction pressure of ~70 psia and a discharge pressure of ~215 psia.

## SIMULATION PROCESS MODEL

The client supplied the following information from which the simulation model was created.

- Process and instrumentation diagrams
- Process flow diagrams and supporting data
- System volumes of piping, vessels, and coolers
- System process control philosophy and methodology

The process was modeled using the QMC Dyflo dynamic simulation program (Ref. 1.) in creating the dynamic simulation model. The initial model is shown on Figure 4. The main inlet, sidestream

inlet, and discharge volumes for piping and vessels were lumped as a single volume at each section. The pressure drops were accounted for by using valves. Not all of the components were modeled on the liquid side of the process.

Continued on page 10

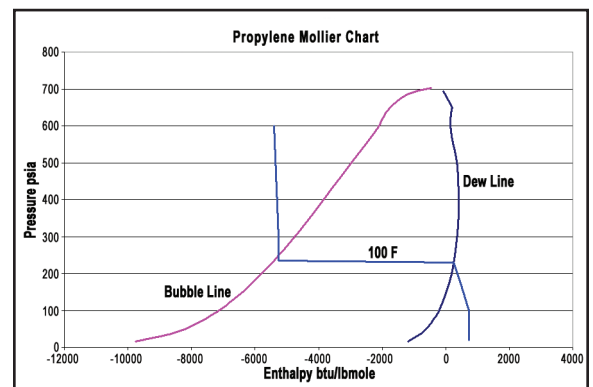


Figure 2. Propylene pressure-enthalpy chart.

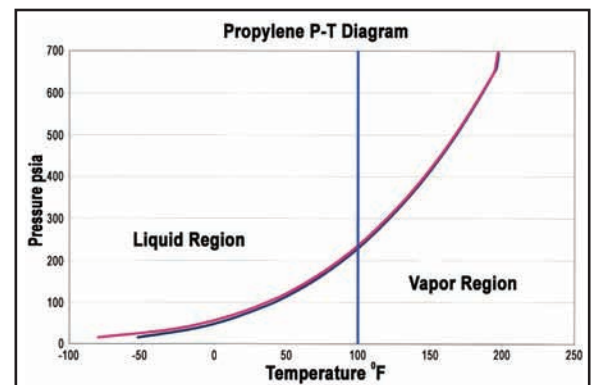


Figure 3. Propylene pressure temperature chart depicting liquid - gas phase regions.

# ENGINEER'S notebook

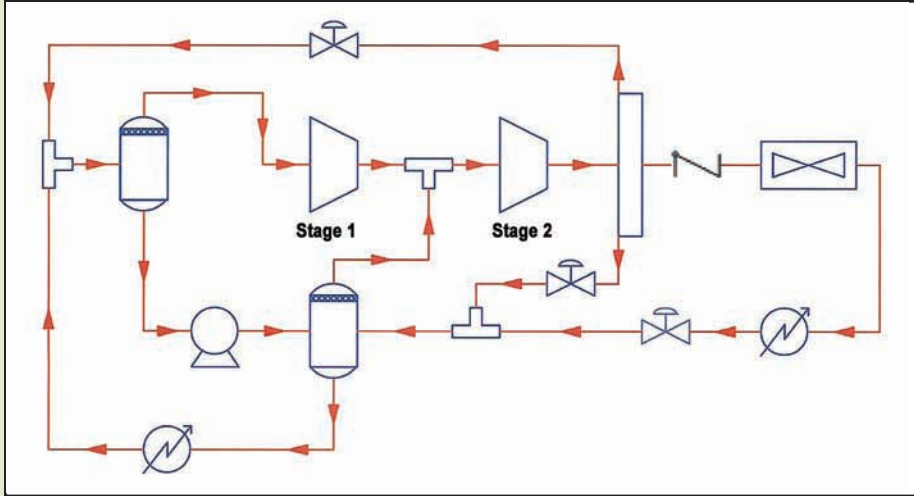


Figure 4. Propylene process schematic initial design.

The sidestream connection was modeled such that the pressure changes inside the compressor did not instantaneously affect the external

and efficiency map was digitally characterized from predicted performance data. A proprietary calculation code was used to define compressor performance. This code uses the real gas properties for pressure, temperature, volume, and enthalpy to establish the head, flow, and efficiency parameters during the transient calculations.

## SURGE EVALUATION AND RELATED INITIATIVES

Once the model was completed, the simulation was run for steady state to validate the model code. The anti-surge valves were sized using standard design rules (Ref. 5). The model was then exercised to simulate an

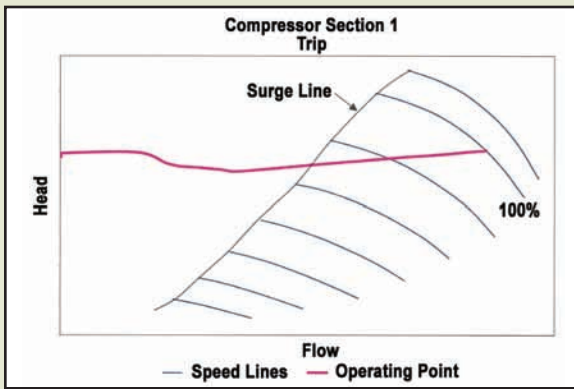


Figure 5. Compressor section 1 head vs. flow response to ESD event with initial system design.

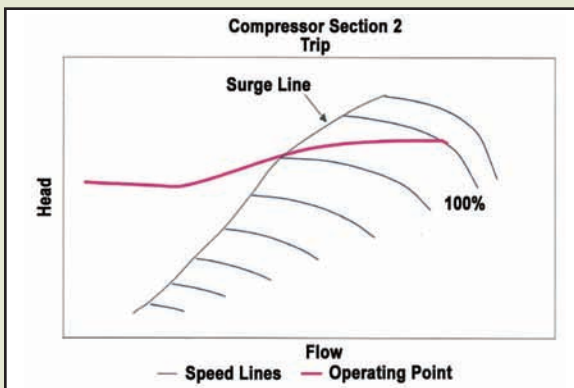


Figure 6. Compressor section 2 head vs. flow response to ESD event with initial system design.

stream pressure. The compressor internal flow is at high velocity and the mixing of flow streams is based on static pressure, not total pressure. More information on the sidestream mixing is described in the ASME PTC-10 Compressor Test Code Ref. 3.

The DyFlo modified Lee-Kessler equation of state was used for the fluid properties (Ref. 2 patent #7,228,241).

Each compressor section flow, head, speed,

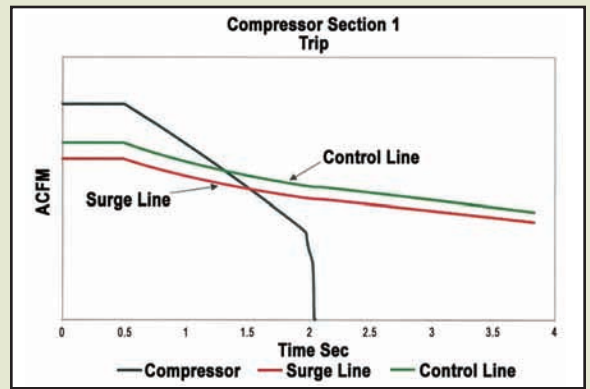


Figure 7. Compressor section 1 flow vs. time response to ESD event with initial system design.

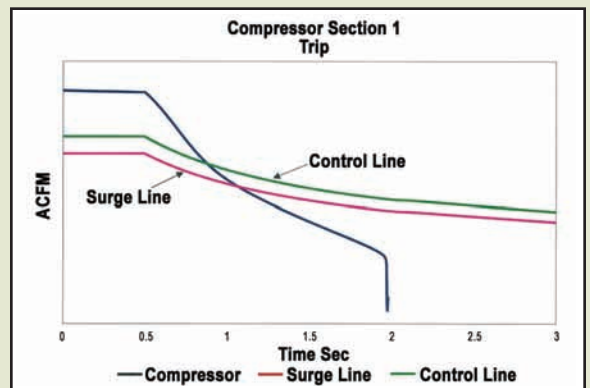


Figure 8. Compressor section 2 flow vs. time response to ESD event with initial system design.

emergency shutdown event from the specified design operating point. This was used to confirm the anti-surge valve sizing and system response to the transient event.

Initial runs indicated the unit could not avoid surge with the client-supplied process arrangement. Figures 5 and 6 show a result of the initial run on the head flow map for each section. Figures 7 and 8 show the event as flow versus time. The sidestream pressure was essentially constant due to the large connected volume. The main inlet volume was also very large, therefore, the inlet pressure also remained constant. This resulted in section 1 external pressure ratio and head to remain essentially constant as the compressor decelerated. Thus,

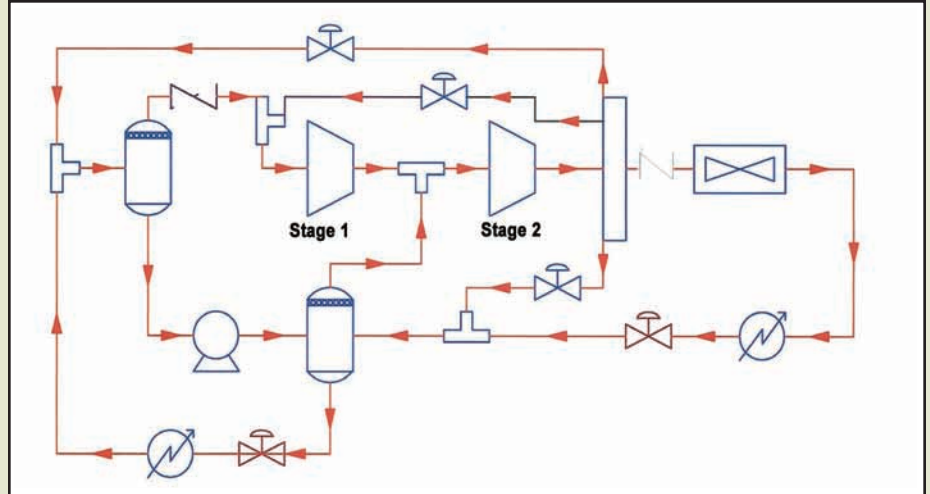


Figure 9. Propylene process schematic revised design for trip case.

the first section compressor could not generate the required head during deceleration so back-flow occurred, resulting in compressor section surge. The second compressor section also went into surge. This is typical of many centrifugal compressors with sidestream feeds.

To resolve the compressor surge-on-trip dilemma, modifications to the process piping were proposed. An additional recycle line from final discharge to compressor inlet was modeled. A check valve was added between the separator and the compressor inlet flange. The new recycle line was tied into the inlet piping between the compressor inlet flange and the check valve. This effectively reduced the system suction volume for the trip condition.

Numerous simulation runs were made to identify an acceptable inlet volume and emergency

shutdown valve (ESD) capacity, characteristic, and stroking speed. The concept of reducing the inlet volume was to allow the inlet pressure to rise during a trip event. Also, the inlet temperature would rise since it would not be cooled by the large inventory of fluid on the inlet. Consequently, the suction pressure rise reduced the first section external head requirement and the temperature increase allowed an additional increase in volume flow.

The resulting model is shown in Figure 9. Upon trip, the discharge check valve prevented back-flow from the condenser section. As flow develops across the ESD valve, the isolated first-section inlet pressure will rise. The discharge recycle valve also will open upon an emergency trip to dump the discharge section mass inventory and lower the discharge pressure.

The final simulation demonstrates the unit decelerated without either section going into surge in the normal operating speed range. A point near surge was used as the system design worst case. Figures 10 and 11 show the head flow map for each compressor section. Section 1 heads towards surge at low speed and hence low energy. A further discussion on this issue

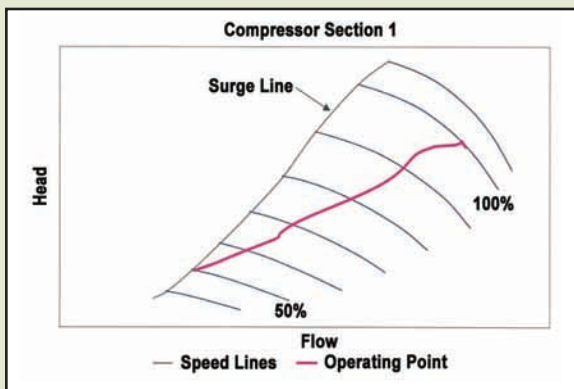


Figure 10. Compressor section 1 head vs. flow response to ESD event with revised system design.

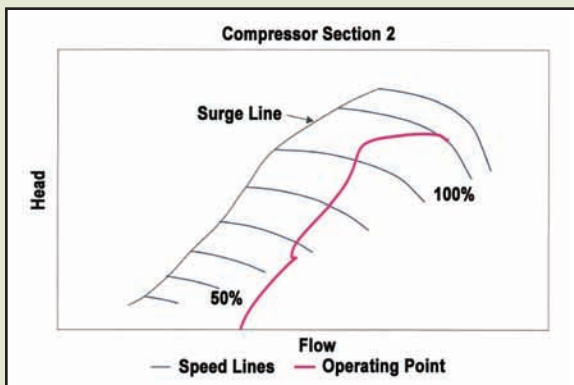


Figure 11. Compressor section 2 head vs. flow response to ESD event with revised system design.

Continued on page 12

# ENGINEER'S notebook

is available in Ref. 5. The flow vs. time plot with the predicted surge limit line and surge control line are in Figures 12 and 13. The unit deceleration is shown in Figure 14.

## START UP

The start up at a settle-out temperature of 100 °F would occur on a long-term shutdown because the refrigeration loop components are all insulated. As referenced earlier, Figure 3

is a plot of the propylene P-T diagram showing the bubble and dew point temperatures. Based on these ambient conditions, the system will have an equilibrium pressure of 227 psia. This is above the compressor discharge pressure at system design of ~215 psia.

The simulation quickly revealed that a start up from this settle-out pressure would require a much larger motor and would also exceed the discharge system components maximum working pressures. The initial start-up runs indicated problems with the motor/VFD system and the overall process piping arrangement.

After initial evaluation the following three improvements were proposed and investigated

- Revise the motor design to utilize full capacity of the VFD system
- Investigate blow-down (even though

blow-down is undesirable)

- Investigate piping changes to start up without blow-down of the refrigerant

## MOTOR INVESTIGATION

The induction motor as proposed had integral shaft cooling fans. This cooling scheme inhibited the motor's use of the full capacity of the VFD control system. The VFD can supply power to the motor that would allow it to produce full torque from 25 percent speed to 100 percent speed with the application of full-load current to the stator windings (Figure 15).

At this stage of the design and procurement, the motor could be modified. The motor design was changed to use external air cooling to allow for full motor torque during start up. The

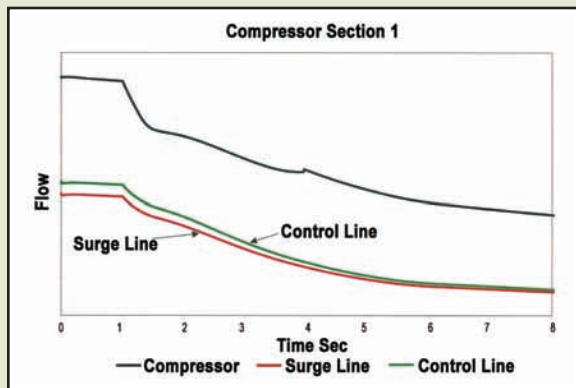


Figure 12. Compressor section 1 flow vs. time response to ESD event with revised system design.

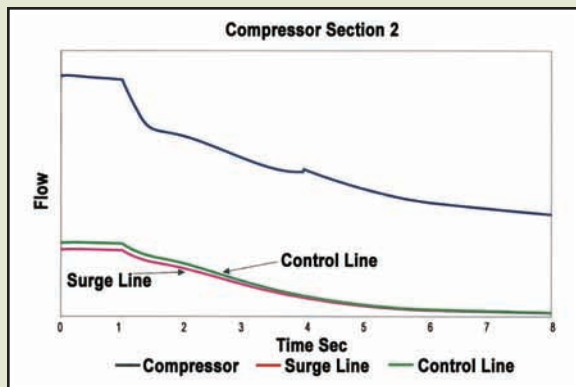


Figure 13. Compressor section 2 flow vs. time response to ESD event with revised system design.

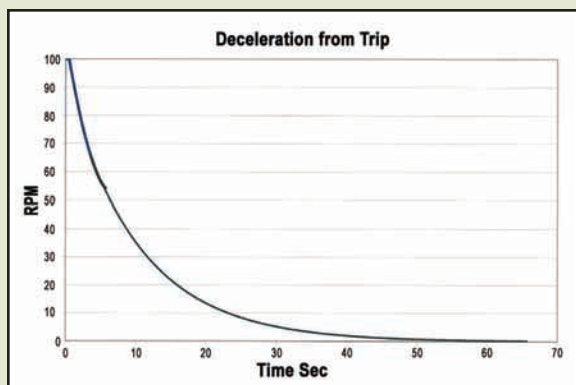


Figure 14. Train deceleration RPM vs time for ESD event.

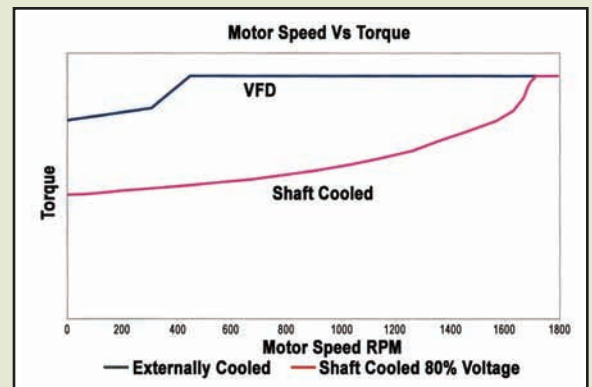


Figure 15. Motor speed vs. torque capability with integral fan and external ventilation design.

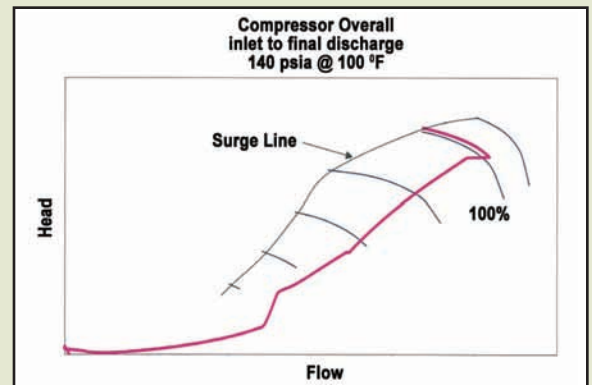


Figure 16. Compressor overall head vs. flow response to startup event at 140 PSIA and 100 degrees day.

external air cooling system requires an inlet filter, motor-driven fans, and associated ducting and controls. Because the proposed changes were defined early enough in the design phase, modifications to the components, as well as the facility layout, could be accommodated.

### BLOW-DOWN INVESTIGATION

Blow-down of the system to a lower settle-out pressure was considered but was not preferred if another solution could be found. As noted earlier, there was no provision for on-site storage of refrigerant. This would require several tanker trucks to be available to recharge the system once the compressor system was restarted. There also was no inlet throttle valve, which could be used to lower inlet pressure to the first compression stage as the unit is starting up.

By successive simulation runs, it was found that a system pressure of 140 psia at 100 °F allowed the compressor train to reach minimum operating speed. The simulation model predicted the system restart (Figure 16), the head flow map for the overall compressor. The acceleration of the train is shown in Figure 17. The motor speed torque curve and compressor load are shown in Figure 18.

An alternate system was needed to meet the client's and site installation requirements.

### PIPING REVISIONS

After extensive review of the system process and instrumentation diagram it became apparent that, upon shutdown, the system had to separate the liquid and gas streams to minimize the settle-out pressure. The pressure in the original shut-in system rises because the liquid vaporizes into the gas phase. Modifications to the piping system required the addition of a new valve and the modification to the control of other valves. Figure 19 shows the new valve

added to the process, and the existing valves that will automatically close when the unit is shut down. This effectively separates the gas from the liquid sections of the system. The resulting trapped gas volume will then settle out at 88 psia at 100 °F.

### START UP 88 PSIA 100 °F

The simulation of this case with the revised motor and system piping was effective for the desired outcome. Figure 20 shows the compressor map for the overall compressor. Figure 21 shows the acceleration of the compressor train. Figure 22 shows the torque available from the motor and the required compressor load torque.

The system modifications to the motor and piping were implemented.

### FIELD START UP

The compressor train was started

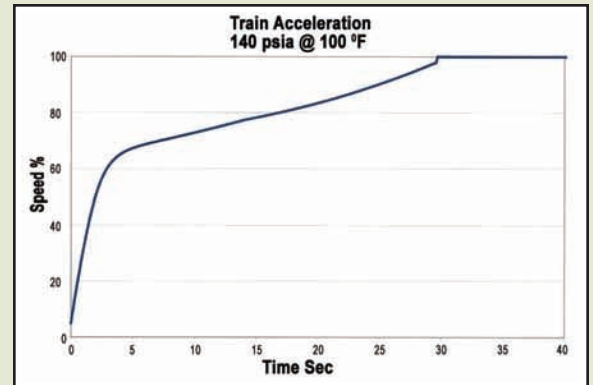


Figure 17. Train acceleration RPM vs time for startup event at 140 PSIA and 100 degrees day.

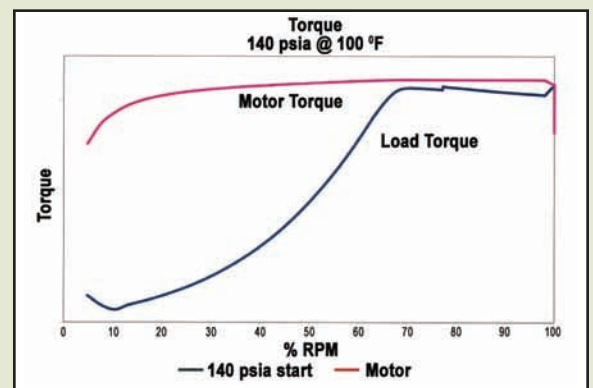


Figure 18. Torque vs. percent speed for startup at 140 PSIA and 100 degrees day motor and load.

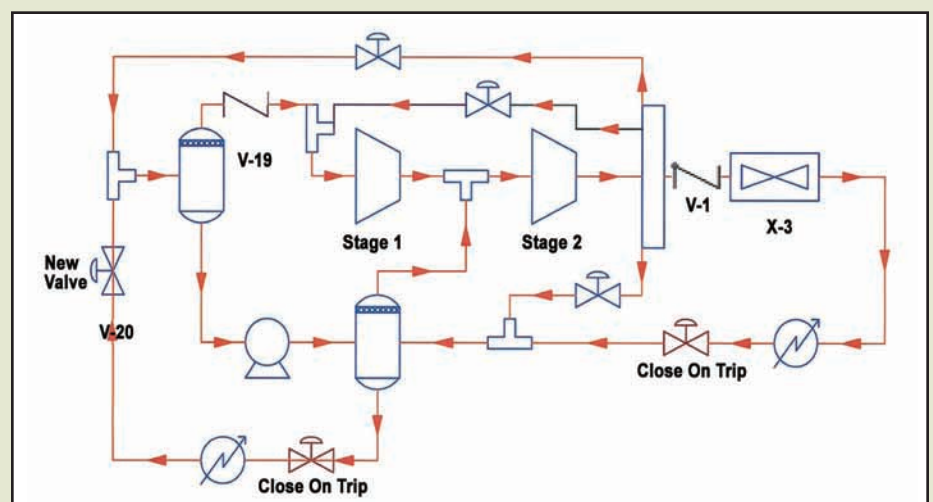


Figure 19. Propylene process schematic revised design for startup with reduced loop volume.

Continued on page 14

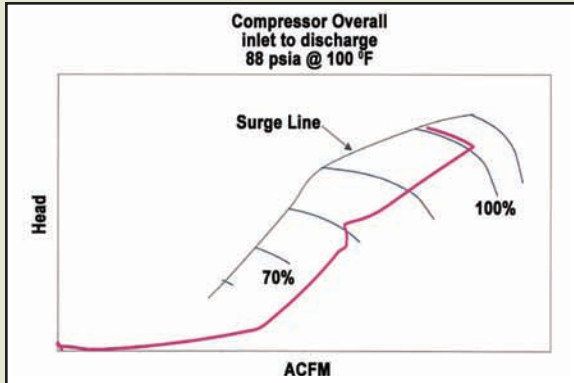


Figure 20. Compressor overall head vs. flow response to startup event at 88 PSIA and 100 degrees day.

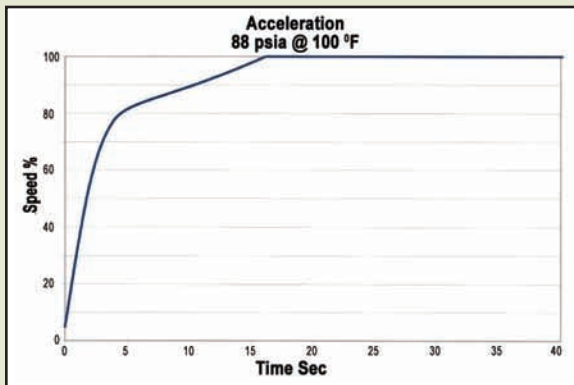


Figure 21. Train acceleration RPM vs time for startup event at 88 PSIA and 100 degrees day.

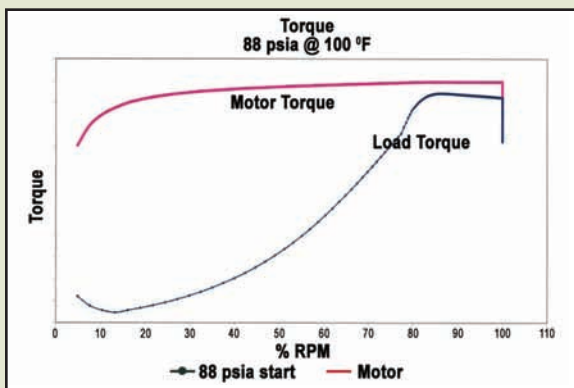


Figure 22. Torque vs. percent speed motor and load for startup at 88 PSIA and 100 degrees day.

for the first time in July 2007. The unit did not surge during acceleration up to speed as designed. Since starting, they have had some system shutdowns – all without reported compressor surge.

### CONCLUSIONS

A compressor system with side-streams can be designed to shutdown without surging and start up without surging. However, changes to conventional piping systems are prescribed.

- Identify problems with system components.
- Match the driver and compressor to the system.
- Demonstrate control system strategy, so modifications can be implemented if required.
- Size control valves to meet the total system requirements.
- When using a VFD for motor control, the motor should be designed with external cooling to utilize the full capability of the motor/VFD system when required.
- Many other system components, such as relief valves, blow-down valves etc., can have their designs confirmed by simulation allowing a successful system design.

Dynamic simulation is a design tool that can now be used to better assure system integration by testing various transient scenarios before committing to hardware.

### NOMENCLATURE:

ESD – Emergency Shut Down

Head – Compressor Head

PF – Electrical Power Factor

Pressure – Pounds Per Square Inch Absolute (pressure) (psia)

RPM – Revolutions Per Minute (speed)

°F – Degrees Fahrenheit (temperature)

Lb.-Ft – Pound Foot (torque)

VFD – Variable Frequency Drive

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### ACKNOWLEDGEMENTS

The authors thank Dresser-Rand for the opportunity and support of this effort. ■



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# GLOBAL visions

## **FORBES RANKS DRESSER-RAND #25 IN TOP 100**

**DRESSER-RAND IS PLEASED** to announce its rank of #25 in *Forbes*' "100 Best Mid-Cap Stocks in America." Dresser-Rand was also among *Forbes*' "Top-Ten in the Mid-Cap: Best Earnings Growth."

## *"100 Best Mid-Cap Stocks in America."*

This is *Forbes*' fourth annual ranking of the "100 Best Mid-Cap Stocks in America." Every year, *Forbes* evaluates 1,000 publicly traded stocks with a market value between \$1.5 billion and \$5.5 billion and determines the top 100 companies with a unique combination of growth, financial stability, and promising forecasts. *Forbes*' "Top-Ten in the Mid-Cap: Best Earnings Growth" category predicts which mid-cap stocks will have the highest annualized earnings growth over the next three to five years.

"We are very pleased to be honored in this way," said Vincent R. Volpe Jr., president and chief executive officer of Dresser-Rand. "Our

rank among such prestigious and successful companies underscores the strength of our business model and reflects the company's commitment to growth and building shareholder value." ■

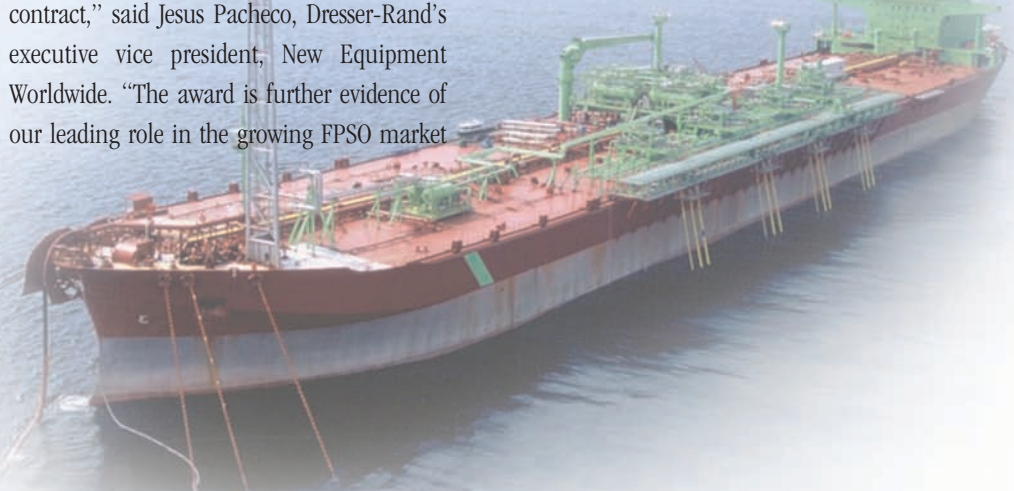
## **DRESSER-RAND WINS BP ANGOLA BLOCK 31 FPSO CONTRACT**

**DRESSER-RAND ANNOUNCED** recently that its Norwegian subsidiary will supply four power generation packages for a floating production, storage and offloading (FPSO) vessel. This will be the first of up to four identical contracts, as part of BP's Angola development program. The first contract's sales are estimated at approximately \$75 million.

"We are very pleased to have been awarded this contract," said Jesus Pacheco, Dresser-Rand's executive vice president, New Equipment Worldwide. "The award is further evidence of our leading role in the growing FPSO market

by also providing power generation solutions for offshore installations. This program further enhances our presence and commitment to supporting our equipment in Angola. The special significance of this order is that it will directly lead to add-on business for the following identical projects over the next few years."

The power generation packages, which feature Dresser-Rand's three-point mounted, torque tube design, will be full-load string tested at Dresser-Rand's facility in Drammen, Norway. Industry sources estimate that there are more than 100 FPSO projects planned during the next five years. Many of those projects are earmarked for Asia, West Africa, and Latin America, and Dresser-Rand continues to believe that this will remain a strong segment of the upstream market over the short- and mid-term future. ■



# GLOBAL visions

## **DRESSER-RAND PROVIDING EQUIPMENT FOR INDUSTRY'S FIRST FLOATING LNG PROJECT**

**DRESSER-RAND RECENTLY** received a Letter of Authorization to Proceed from Kanfa Aragon to supply the compression equipment for the world's first floating liquefaction plant (FLNG), the Flex LNG Ltd. LNGP1 destined for operation offshore Nigeria. The award is for approximately \$55 million.

The floating liquefied natural gas (LNG) unit will have a liquefaction capacity of approximately 1.7 MTPA. Samsung Heavy Industries Co., Ltd. ("SHI") is the EPCIC contractor for LNGP1, while Kanfa Aragon, a Sevan Marine subsidiary, is the Engineering & Procurement contractor for the topsides facilities of LNGP1 for SHI.

"Over the past three years we have identified LNG Liquefaction as a strategic growth opportunity for the coming 5 to 10 year period. While many of the land-based projects continue to experience delays in permitting and partner funding, it now appears that the offshore

floating projects present a real and present opportunity. We are very pleased to have been selected by Kanfa Aragon, SHI, and Flex LNG to supply the critical service equipment for this, the world's first floating liquefaction unit," said Vince Volpe, Dresser-Rand's president and CEO.

*"Dresser-Rand was chosen on the basis of their compressor technology and their gas turbine/compressor packaging concept, which are drivers for minimizing total project risk as well as maximizing the production of LNG."*

— Kristian Utkilen,  
technical director,  
Kanfa Aragon

According to Kristian Utkilen, technical director of the process designer and Engineering and Procurement contractor, Kanfa Aragon, "Dresser-Rand was chosen on the basis of their compressor technology and their gas turbine/compressor packaging concept, which are drivers for minimizing total project risk as well as maximizing the production of LNG."

Floating liquefaction units provide an economic means to develop stranded gas reserves to help meet the world's growing demand for natural gas. While the conventional, land-based LNG projects focus on an estimated 70-80 fields with gas reserves greater than 5 trillion cubic feet ("TCF"), there are more than 1400 small to medium sized fields with reserves between 0.25 and 5 TCF. This provides a target market of approximately 150 TCF, which can be developed using floating LNG technology. ■

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