Frac Manifold Systems

Increase operational efficiencies of simultaneous completion operations

Modular, flexible designs save time and money

The equipment and technicians required to hydraulically fracture (frac) a well are expensive — estimates range up to as much as 30% of the total cost of the well.

When completing a single well, a significant amount of idle time is imposed on these costly resources. Time spent waiting for an isolation plug to be set, to position and fire perforator guns in the next zone, to retract the wireline and the perforator gun carriers, and to isolate the lubricator from the well — all of these operations contribute to a costly underutilization of the frac crew and equipment.

A frac manifold is an arrangement of flow fittings and valves installed downstream of the frac pump output header (often called the "missile") and upstream of each frac tree being served by it. From the main supply line of the frac manifold, a dedicated frac supply line is installed to the goat head atop each well. Utilizing this arrangement, the manifold is used to quickly isolate wells that have completed a frac cycle and for which intervention (plug and perforate) is now required, and to redirect the flow of frac fluid to a well that is prepared for the next frac cycle. The use of actuated valves improves transition speed and eliminates the need for manual adjustment, reducing safety risk.

The use of a frac manifold in this manner is called "zipper" or "zip" fracturing, and it can provide for almost continuous utilization of the frac crew and equipment, from the first treatment at the toe of the first well to the last treatment at the heel of the last well. This represents a substantial improvement to the effective use of the fracturing resources and, thus, to the overall economics of the well.

Frac Manifold Designs

Frac manifolds can be constructed and installed to accommodate as many wells as required, in essentially any configuration. The primary variables are frac pump service capacity, nominal size of the frac lines, nominal bore size of the frac tree, and wellbore characteristics.

Typical components of a frac manifold include spools, tees, crosses, gate valves, and goat heads. These are assembled into various configurations to suit the number and spacing of wells being simultaneously serviced, the planned arrangement of the frac lines, the extent to which actuation is desired, etc. Our frac manifolds may also be equipped with a safety ladder and platform to provide safe access to the valves.

Our frac manifold design is modular, flexible, and can result in a vast array of possible configurations. Each leg of the manifold may be aligned vertically, horizontally, or at any angle, and will typically have one or two gate valves—two is common. One of the gate valves in each run may be actuated to allow for remote and fast control of the manifold with a central control panel, while a second, typically manual valve, may be used as a backup if required.

Design features and benefits

Enhances safety of operations

- Streamlined manifold design reduces clutter at well pad. Hydraulic actuated gate valves allow remote operation, removing the opportunity for personnel exposure to potentially pressurized vessels.

Increases number of fracs performed per day

- Allows for continuous operation of multiple wells, improving utilization of pumping services

Provides ease of operation

- Hydraulic valves allow remote control of manifold valves to direct flow as desired

Decreases number of rig up/rig down cycles

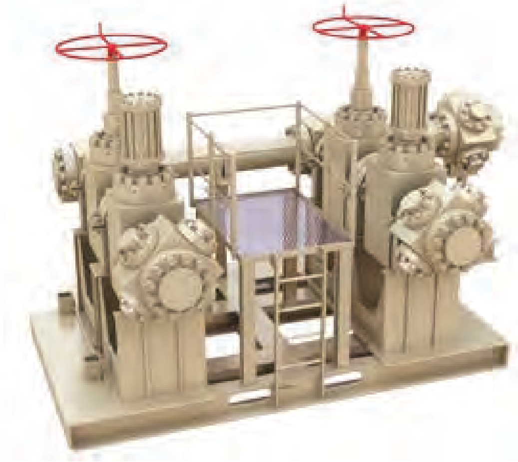
- Manifold design allows for control of fluid flow to multiple wells; eliminating the need for rigup and rigdown between frac stages

Decreases pumping downtime

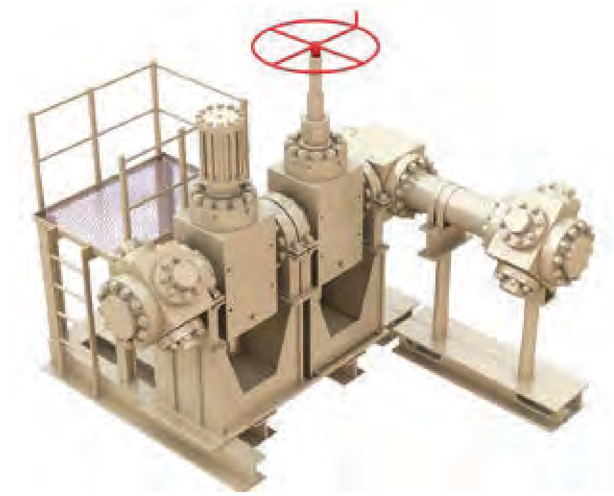
- Allows for frac to occur at one well while running wireline services at another well simultaneously

Reduces multiple frac lines

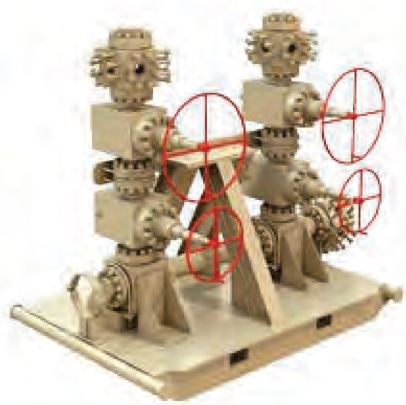
- Single inlet for pumping equipment drastically reduces number of flowlines required
  - Maximum working pressure: 15,000 psi
  - Maximum temperature rating (API): P+U
  - Product specification level: PSL-1, -2, -3
  - Nominal bore size: 7$\frac{1}{16}$ in, 5$\frac{1}{8}$ in, 4$\frac{1}{16}$ in
  - Well configurations: 2, 3
    Additional well configurations available



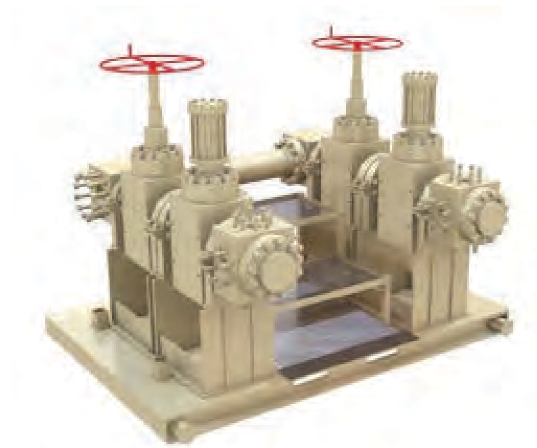
Two-leg manual valve and hydraulic valve isolation frac manifold with safety platform for safe access to valves



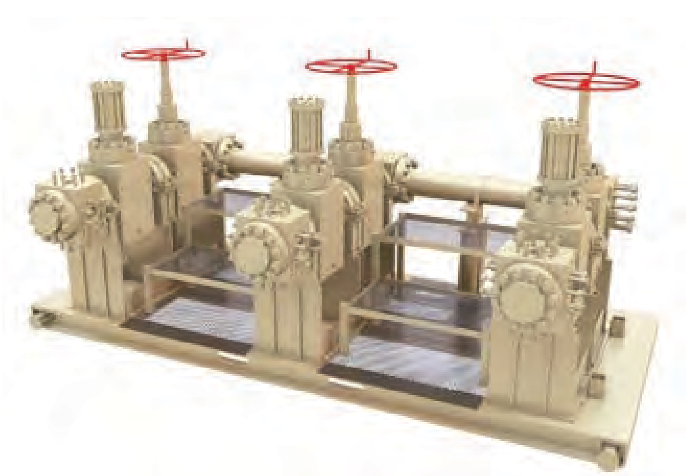
One-leg frac manifold with safety platform for safe access to valves



2-leg vertical frac manifold



Two-leg manual valve and hydraulic valve isolation frac manifold



Three-leg manual valve and hydraulic valve isolation frac manifold

Our frac manifold design is modular, flexible, and can result in a vast array of possible configurations, while allowing for continuous operation of multiple wells, improving utilization of pumping services.

Monoline Technology

Cameron delivers another cost and time saving innovation to the frac industry—our Monoline* flanged-connection fracturing fluid delivery technology.

Once a pad of frac wells is completed through the production casing stage, the drilling crew is dismissed and the frac crew arrives. A frac tree is installed over the well and a frac manifold is placed in close proximity to the wells that it will service. High-pressure frac fluid is routed from the frac trucks through the missile to the frac manifold.

The next, and final, link required is from the outlet of the frac manifold to the inlet of the frac tree. This link is made awkward by the inherent misalignment between the manifold and the tree in the vertical and horizontal planes. These misalignments have traditionally been accommodated by the use of several (typically from four to eight) 3-in or 4-in pipe segments joined by hammer union swivel joints. This assemblage is known as frac iron.

The frac iron solution generally works well enough once the installation of it is completed; however, this approach has some notable shortcomings—it is costly, it is time-consuming to install (which adds to expense), it creates a cluttered work environment (safety issue), and making up swivel unions is done with a sledge hammer—a less-than-precise tool with the inherent risk of impact damage to the connectors and to the pipe (another safety issue).

Our latest innovation—the Monoline technology—presents a safer, faster, cleaner solution.

The Monoline technology concept is fairly simple. A series of 5-in high-pressure pipe segments are joined together with 90 degree elbows and swivel flanges. This configuration allows for the full 3-degrees of freedom of movement needed to accommodate vertical and horizontal misalignment between the frac tree and the frac manifold.

The Monoline technology is moved into position in two stages. The first stage is made up with an API flange to the horizontal inlet of the frac tree. The second stage of the Monoline technology is made up with an API flange to the outlet of the frac manifold. The two stages are then joined together, with the swivel flanges rotating as necessary to align the connection perfectly. Once the connections are all in face-to-face alignment, they are torqued to API recommended pre-tension values.

The Monoline technology delivers a number of significant improvements:

- It is cost effective compared to the alternative traditional use of frac iron
- It is assembled quickly, reducing OPEX and NPT
- It significantly de-clutters the work environment
- It uses industry standard flanges with conventional tools and known recommended torque values—no sledge hammers involved. No potential for impact damage.

The Monoline technology is available in nominal sizes 5 in thru 7 in (OEC connectors).

Our latest innovation, the Monoline technology, presents a safer, faster, cleaner solution than the "frac iron" method.

The Monoline technology uses a series of 5-in high-pressure pipe segments joined together with 90-degree elbows and swivel flanges. Shown is a nine-well pad with a single modular manifold connecting to each well, eliminating leak paths and reducing safety hazards.

Field service technicians assemble the Monoline technology.

Frac Valves

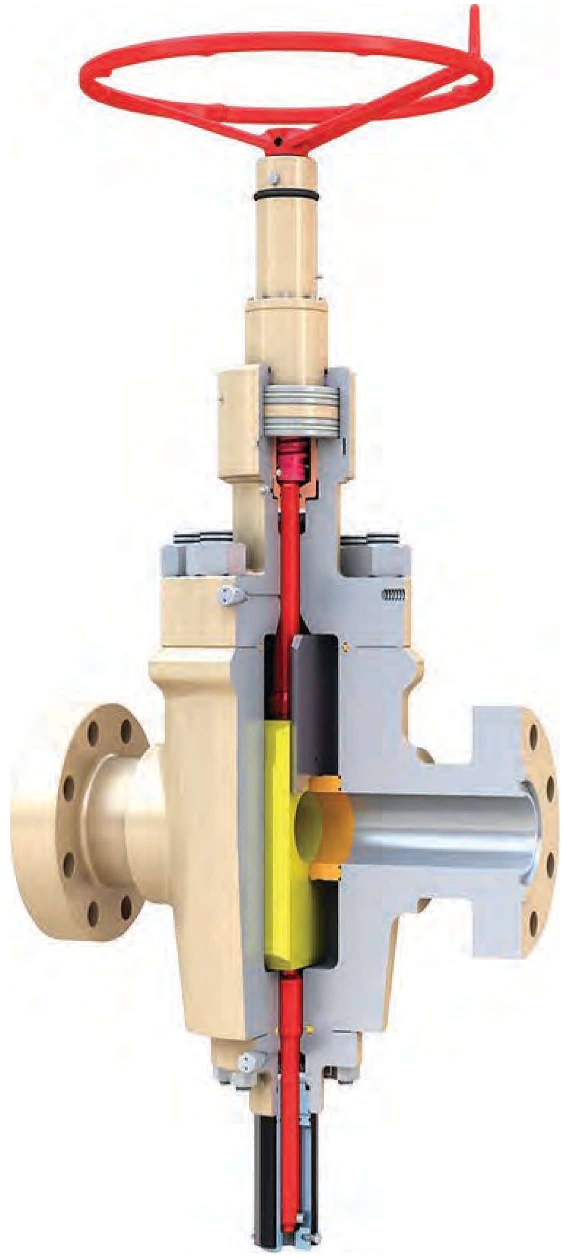
Frac service is just about as harsh as it gets. With the introduction of "zip" fracturing, gate valves assembled into frac manifolds are exposed to nearly continuous service, flowing and controlling high-pressure, high-volume, abrasive fracturing fluid for days, and even weeks, on end.

Given the erosive, corrosive, and sometimes sour nature of typical frac and flowback fluids, the FLS-Frac*, FLS-R-Frac* and FLS-DA2-Frac* API 6A gate valves are designed with these special features:

- Trimmed for maximum corrosion and erosion protection
- CRA inlay in seat pockets and ring grooves for added protection
- "Zero-chamfer" flowbores are another standard feature, utilized in order to mitigate turbulence that is known to exaggerate erosion
- Two grease fitting ports are utilized for flushing and greasing the valve body cavity

As a result of these special features designed into Cameron frac valves, and of the special care given to them when they return from the field for cleaning, disassembly, inspection, re-assembly and testing for the next project, they have grown an enviable and valuable reputation for enhanced reliability.

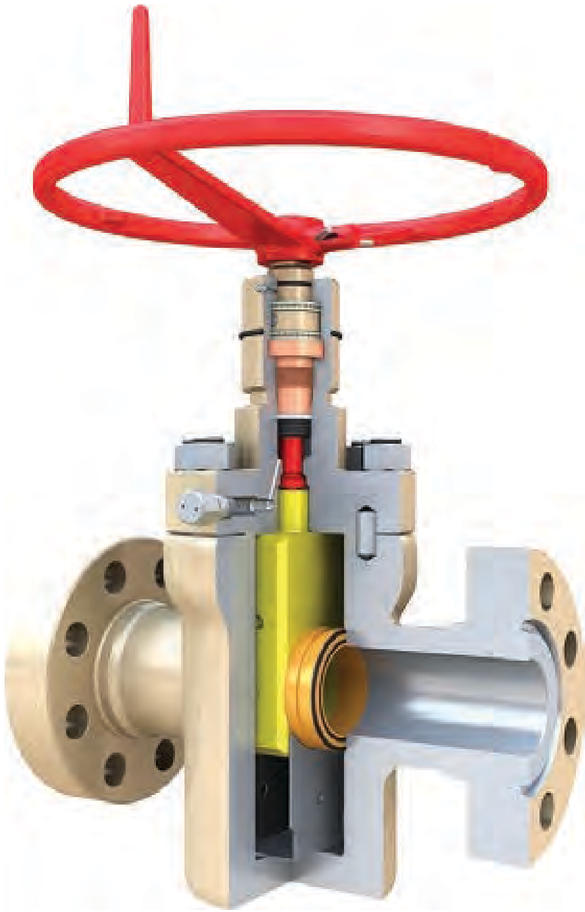
Three-leg manual and hydraulic valve isolation frac manifold

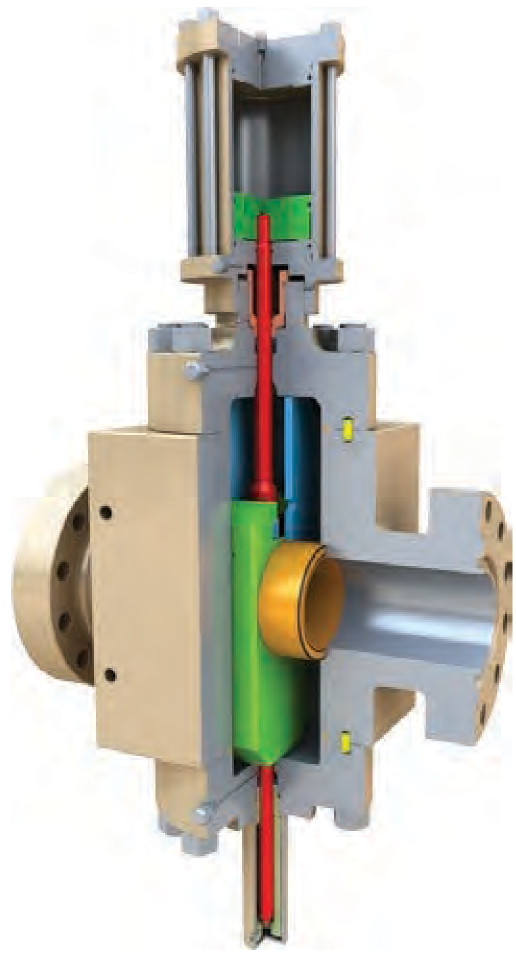


FLS-R-Frac gate valve

At the forefront of our frac valve offering is our premium FLS-R-Frac API 6A slab-style gate valve, based on the widely recognized, field-proven FLS-R gate valve. Designed as a manual valve for high-pressure applications, in all the nominal sizes and pressure classes required in the frac industry and with reliable metal-to-metal seals throughout, the FLS-R-Frac gate valve has established a global reputation as the ultimate heavy-duty, reliable gate valve for hydro-frac applications. The FLS-R-Frac gate valve's design features a ball screw for the upper stem and a lower balancing stem, which combine to substantially reduce break-open and running torques. Another benefit of this premium design is that the gate quickly cycles from the fully-closed to the fully-open position, dramatically reducing exposure to potential erosion and contamination associated with the mid-range position.

With the introduction of zip fracing, gate valves assembled into frac manifolds are exposed to nearly continuous service. Our FLS-Frac, FLS-R-Frac and FLS-DA2-Frac gate valves are designed with special features.





FLS-Frac gate valve

Depending on the size and pressure requirements, our FLS-style API 6A gate valves may be a better fit in some frac service environments. In these cases, Cameron offers the FLS-Frac gate valve, based on the field-proven model FLS gate valve but modified for frac service in the same manner as the FLS-R-Frac gate valve.

FLS-DA2 gate valve

For actuated frac gate valve requirements, Cameron offers the FLS-DA2-Frac gate valve, a gate valve that offers all the same metal sealing features of the FLS-R-Frac gate valve with the addition of a double-acting model DA2 hydraulic actuator. The FLS-DA2-Frac gate valve features fast, positive remote actuation—opening and closing—with a simple design that provides for quick and easy field maintenance.

FracServ Enhanced Valve-Reliability Program

Given the severity of the hydraulic fracturing environment, and the impact to equipment, our design and quality engineers have compiled recommended procedures for maintenance of our frac equipment. The FracServ* program establishes a sequence of activities and inspections designed to ensure that any degradation of frac equipment is identified and corrected before the equipment is reassigned to another frac project. Adherence to these service procedures yields Cameron frac valves in “as new” condition for each frac project.

The result of our stringent procedures is reliability that minimizes downtime and extra expense from your bottom line. Our valve success rate is 99.95%. Estimates available to us indicate that the failure rate of non-Cameron frac valves ranges from a minimum of 10% to more than 30%.

In the absence of the FracServ program, the potential exists of having to cease frac operations through a frac manifold in order to service or replace a component, which can be expensive. As an example, the time lost to have a new valve brought to the well site, set a plug and replace the faulty valve is about the time it takes to complete a frac stage. In essence, then, the cost to replace a frac valve is about the same as the substantial cost of a frac stage.

Equipment is offloaded and checked for NORM. The customer and well name are documented and part number and serial number are verified.

Dedicated cells are set up to follow defined QA for frac valves. The technician begins disassembly.

Trained inspectors qualify or disqualify components per the FracServ program.

The valve is reassembled with qualified parts.

The valve is tested.

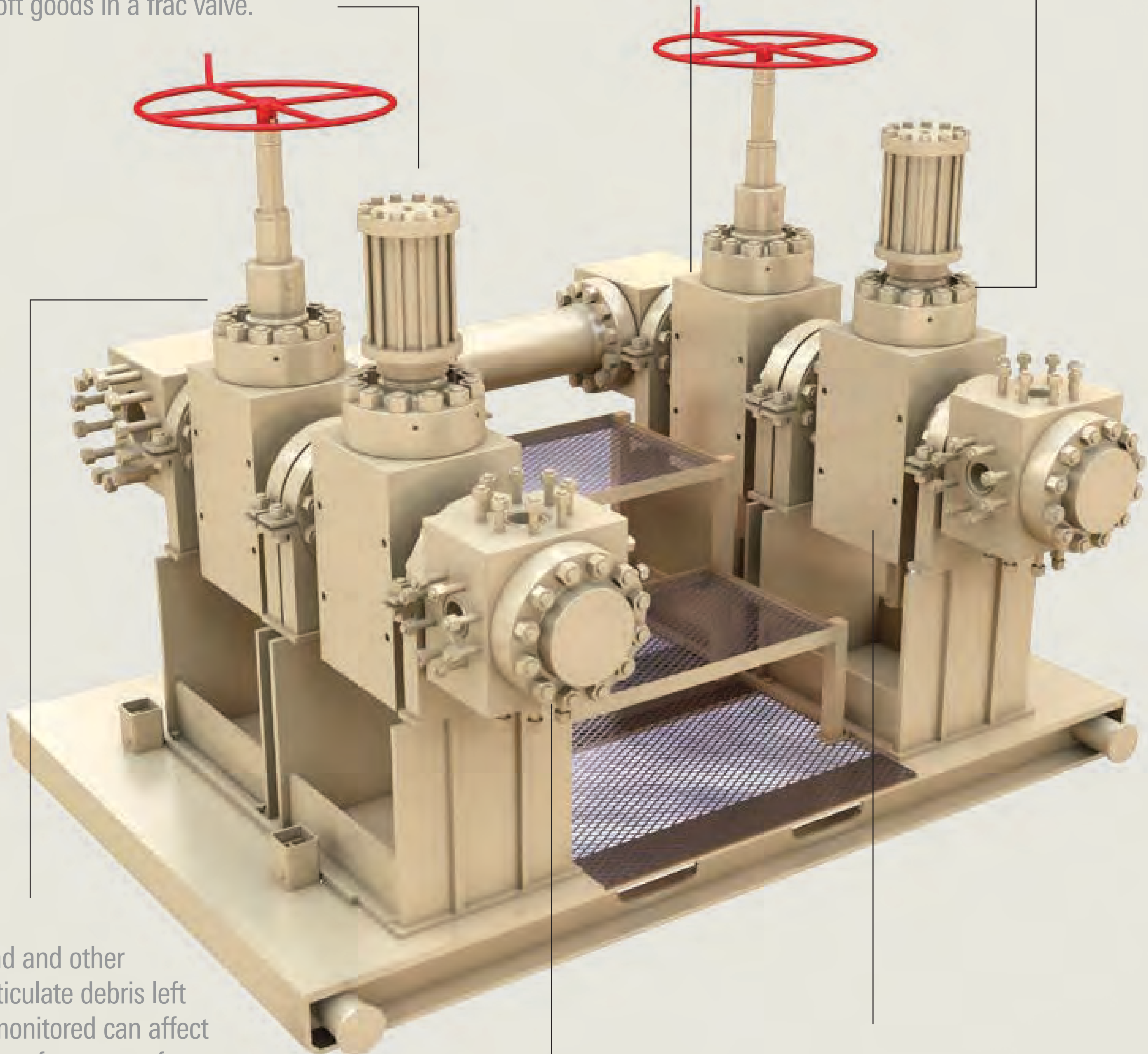
Painted valves are tagged with a test tag verifying repair is complete.

Frac Facts

Lacking proper attention, the high-pressure variations and chemical make up of fluids used during a frac job can reduce the lifespan of elastomers and other soft goods in a frac valve.

Sand, acid, and many other erosive and corrosive elements of a frac job reduce the life of a valve's gate and seat, if left untreated.

Without intervention, the extreme nature of frac service can cause pitting and other frac valve seal surface damage over time.



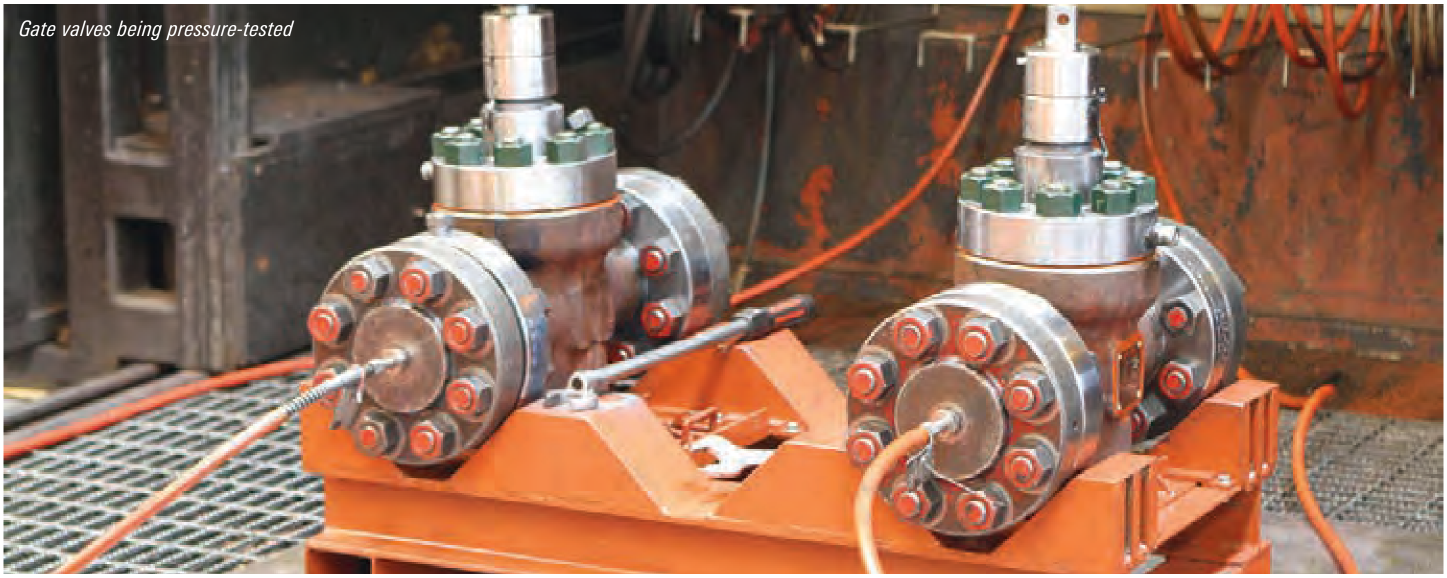
Sand and other particulate debris left unmonitored can affect the performance of grease fittings over time.

If ignored, the dynamic nature of the frac environment can dramatically shorten the life of flange bolting due to fatigue damage.

Frequently fluctuating pressure coupled with corrosive and erosive service, left unchecked, can damage the structural integrity of a valve's body.

Commitment to Product Research, Development and Testing

The world of hydraulic fracturing is fraught with challenges—cyclic high pressures, varied and difficult chemistries, and erosive wellbore fluids. As a recognized leader in providing products and services for the frac and flowback industry, Cameron is actively committed to investing the resources necessary to realize cutting-edge technology and unrelenting product reliability.



Gate valves being pressure-tested

Foremost in this commitment is the ongoing simulation testing of Cameron products exposed to the harsh realities of frac service. This testing utilizes flow loops to expose real products to the rigors of real high-velocity frac fluid, as well as software simulations using 3D FEA, ABAQUS, Computational Flow Dynamics, and other analytical programs. These simulation exercises are directed at torque and fatigue life prediction, erosion analysis, and testing of other critical service features of flow containment and control equipment utilized in hydraulic fracturing and flowback operations.

This testing is a necessary component in the development of our in-depth knowledge and understanding of the harsh frac and flowback environment—hands-on knowledge that could not be attained by any other means. The results of these analyses are fed back into the design, manufacturing, and service functions of Cameron to achieve the absolute product reliability required by our demanding clientele.

Hydraulic actuated gate valves being gas-tested

Designed, Developed, Qualified, and Manufactured In-house

Over the last few decades the gate valve performance envelope demanded by the oil and gas industry has seen a significant expansion — not only in terms of temperature extremes, increased pressure, and ever more severe service environments, but also in terms of the quality and the attention to detail necessary to be instilled into every phase of product design, development, and production.

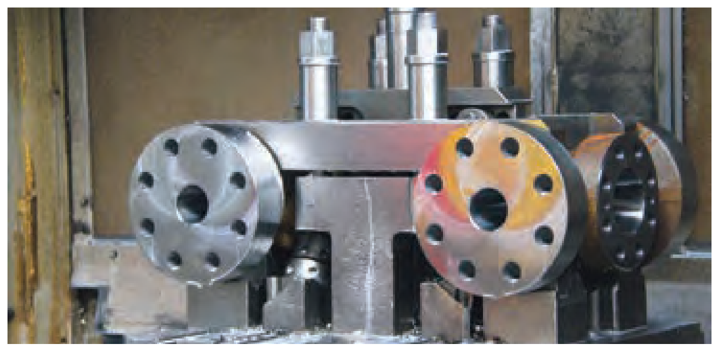
Against this backdrop, our heritage of industry leadership requires a focus on ever-increasing technology and on the application of decades of earned experience to the solution of the challenges of today and of the future. New and modified gate valve designs, once advanced from concept to prototype by a process of meticulous design reviews, are subjected to qualification testing designed to find and correct any material or design weakness. Once approved for production in a documented final design review, our gate valves are subjected to quality control measures in excess of those mandated by API.

Besides painstaking design and zealous qualification testing, another essential element in the production of reliable gate valves is proper material selection and careful procurement practices. Cameron has compiled a substantial body of knowledge to guide us in material selection, forming practices, heat treat, and welding processes, and inspection techniques to help assure safe and reliable products. The quality and integrity of the materials of construction for our critical gate valve components are controlled by material specifications written by Cameron design engineers and metallurgists to meet industry and customer requirements.

Having assured the selection and sourcing of proper raw materials, Cameron places equal importance and insistence on in-house manufacturing of critical components (body, bonnet, gate, seats, stem), and assembly and test of critical service gate valves. This policy assures that the manufacturing processes applied to these critical components are conducted in our facilities, by our trained employees, and in strict compliance with the rigorous quality controls that are designed into the product by our design and quality engineers. To that end, Cameron has put in place manufacturing cells (Singapore, Romania, etc) specifically dedicated to the production of our gate valves, assuring proper and sustained focus on manufacturing, assembly and inspection practices.

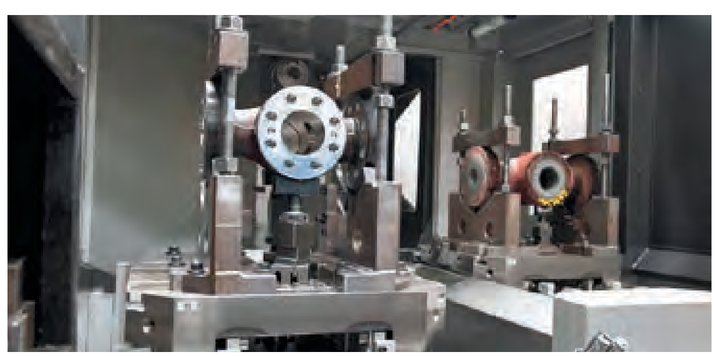
These design, procurement and manufacturing practices are what you would expect only of a world-class provider of quality, reliable gate valves. They are what you may expect of Cameron.

Hardness inspection being conducted on seat ring



Valve bodies in fixture for machining

Valve body in process in gate valve cell



Valve cavities going through finish machining process

CASE STUDY Frac Manifold

Background

With the combination of horizontal drilling and hydraulic fracturing technologies, shale play drilling and production has taken our industry by storm. The high cost of the frac crew and equipment, however, has a substantial impact on profitability. Failure to fully utilize the time this equipment is onsite is extremely costly.

The challenge

A major operator working in northeast British Columbia challenged Cameron to find a way to better utilize expensive stimulation resources and to increase the number of frac intervals conducted each day. Using the known conventional practices at the time they had been able to average 2 × 200 ton fracs per day.

Our solution

The frac manifold design allows for essentially continuous utilization of the frac crew. This is accomplished by pre-connecting manifold outlets to multiple frac tree goat heads and directing the output of the manifold to alternating wells as isolation plugs are set and new frac zones are perforated.

The daily frac completion rate has risen and transition time between frac stages has been minimized.

Results

The daily frac completion rate has risen up to ~ 4 × 200 ton fracs per day, and transition time between frac stages has been minimized.

The manifold design is highly modular, and can be easily adapted to virtually any well pad layout. Quick changeout of valves and components allows for off-line repairs. Manifolds are skid mounted complete with platforms and handrails for easy transport and improved safety.

Overall, the Cameron frac manifold has been an operational and an economic success. Equipment performance related to wear or erosion has been outstanding, with as many as 1,500 frac cycles conducted with only minimal wear.

Cameron frac manifolds allowed essentially continuous use of the frac crew on a project in Northeast British Columbia.

Manifolds quickly isolate wells that completed a frac cycle.

Manifolds ready to be deployed to an active field.

Frac Manifold Systems

slb.com/fracmanifolds

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A Schlumberger Company