CRYOGENIC INDUSTRIES
FROSTBYTE
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Application of FSI to Design and Analysis

Engineering simulation software packages continue to evolve, incorporating ever expanding feature sets and capabilities. These programs are used by design and analysis groups within engineering firms for everything from printed circuit board (PCB) cooling optimization to complex phenomena such as aircraft wing flutter. The latter is accomplished using a recent and highly useful capability of simulation software called "Fluid-Structure Interaction," or, FSI. This FSI capability allows engineers to model the effects of fluid and mechanical loads simultaneously, along with the coupled effects of one type of load upon the other.

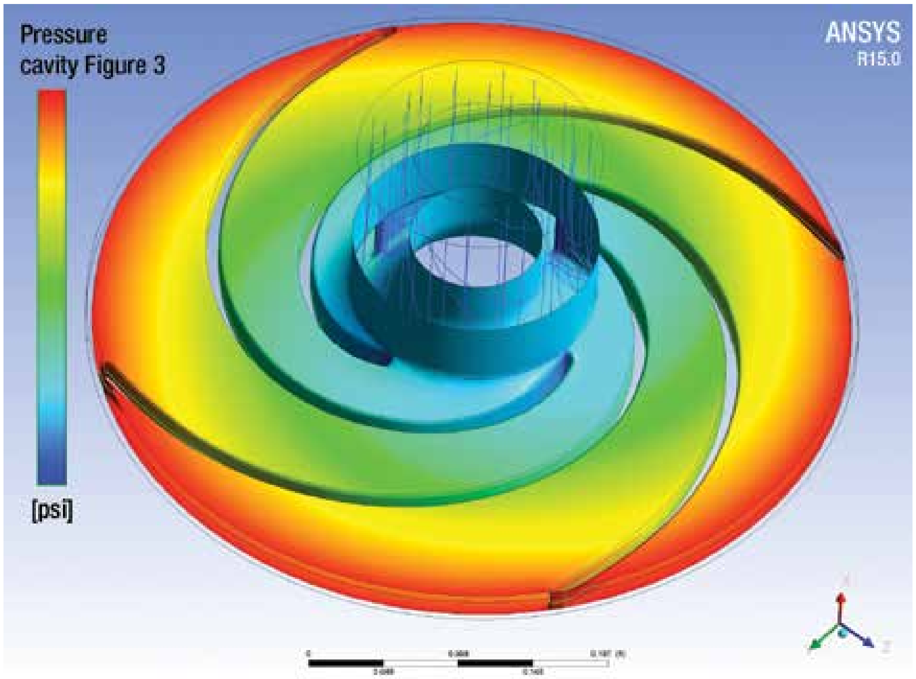

Figure 1: Impeller Internal Pressure Profile

In the wing flutter case, loads calculated by computational fluid dynamics (CFD) modeling of time-dependent pressures around a wing are applied to a mechanical model of the wing, and structural analysis is conducted for each time step of the CFD analysis to determine the stresses and deflections. This is called One-Way FSI. Deflections may also be fed back to CFD to modify the boundary walls in the fluid domain, allowing the mechanical model to influence the fluid flow. This is called Two-Way FSI. Two-Way FSI is typically only necessary when structural deflections are great enough to have a significant effect on the fluid flow.

ACD two years ago expanded its engineering analysis toolset with the introduction of ANSYS simulation software to its engineering workflow. A study using ANSYS FSI capabilities has recently been completed for an existing, legacy pump impeller design used in ACD's TC-50 and TC-30FC two-stage pumps. Stresses due only to centrifugal loading were calculated first, as a baseline case. A one-way FSI analysis was then run, applying CFD-calculated pressure loads (Figure 1) to the impeller mechanical model both within the impeller flow passages, and outside of the impeller in the pump cavity.

A 3D CAD model of the solid impeller was imported to ANSYS. The solid model itself was imported to the Mechanical solver for finite element analysis (FEA), and a fluid domain was generated from the impeller model with matched faces in order to accurately match pressure loads calculated in CFD to the solid model. Flow simulation was completed using ANSYS CFX with a simplified temperature and pressure-dependent fluid model of liquid argon based on National Institute of Standards & Technology (NIST) physical property data. This fluid model was sufficiently accurate for the pressure and temperature range expected in the simulation. Bounding flow conditions (maximum pressure) were applied to find the maximum

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expected stresses, and these were applied to a rotating domain turning at the maximum speed the impeller will spin in operation. Flow external to the impeller in the pump cavity was modeled as an axisymmetric wedge of the full 360 degree fluid space to allow rapid, accurate calculation of flow rate through the impeller labyrinth seals with a fine mesh that can correctly resolve the boundary layer (Figure 2). An accurate calculation of flow rate through the seals is required for the correct pressure profile to develop outside of the impeller.

Results from the FSI analysis (Figure 3) indicated that the pressure loading from the fluid flow is the dominant source of stress in the impeller. Additionally, the CFD simulation of the internal flow through the impeller captures the pressure differential between the suction and pressure surfaces of the blading (the blade loading), seen in Figure 4. This greatly improves the accuracy of stresses calculated at the blade roots. With FSI, this study showed that the maximum equivalent stresses in the impeller body are acceptably below the yield strength of the material, and consequently validated the original design of the impeller. Efficient use of computing resources with reasonable assumptions for the boundary conditions and optimized meshing allows the completion time for this type of study to be reduced below two weeks. FSI can then be more easily accommodated in the design workflow for future R&D.

For additional information go to www.acdllc.com.

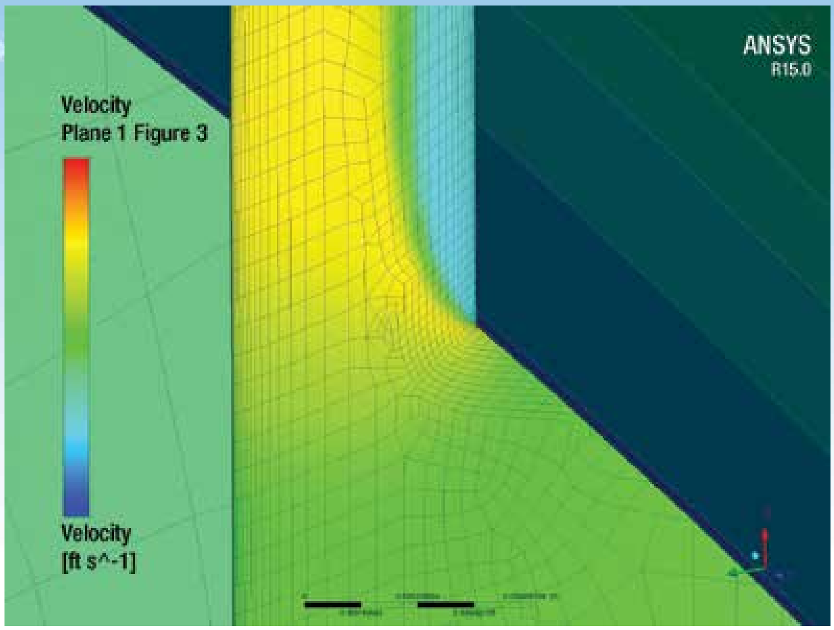


Figure 2: Boundary Layer at Impeller Laby Seal Entrance

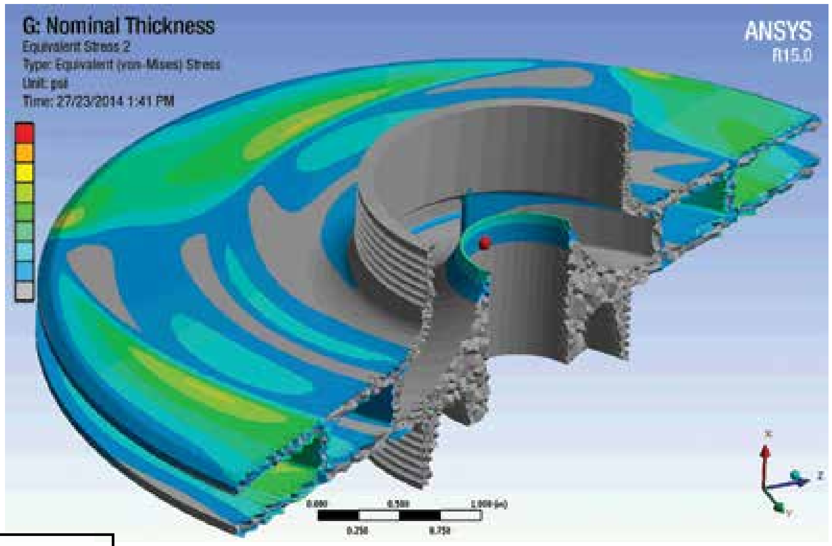


Figure 3: FSI Stresses - Combined Centrifugal and Pressure Load

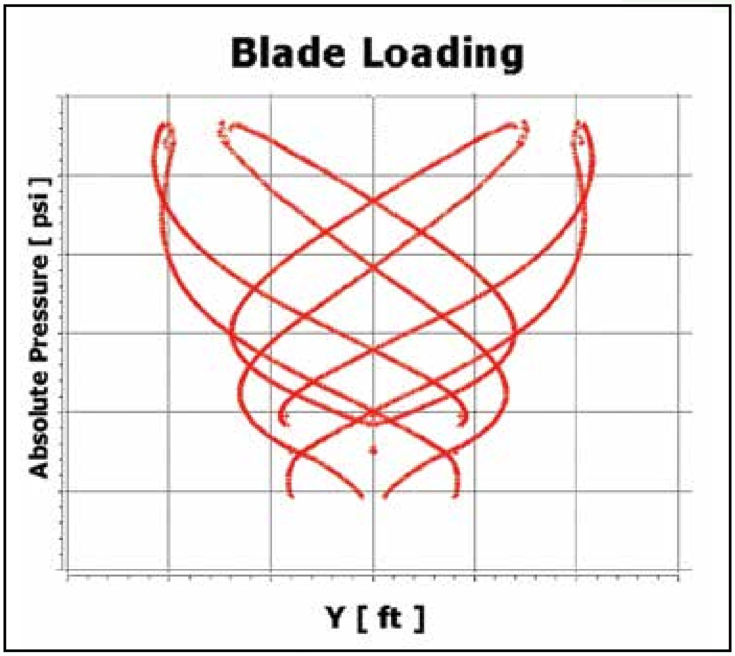


Figure 4: Blade Loading of Pump Impeller

“Fracking with Nitrogen”

What is nitrogen gas fracking?

Nitrogen gas fracking involves switching out the working fluid in the fracturing process. Some or all of the fluid used in hydro-fracking is replaced by nitrogen gas which can fracture rock at high pressures, much like water.

Three main types of nitrogen gas fracking can be identified based on the percentage and the state of nitrogen used in the fluid.

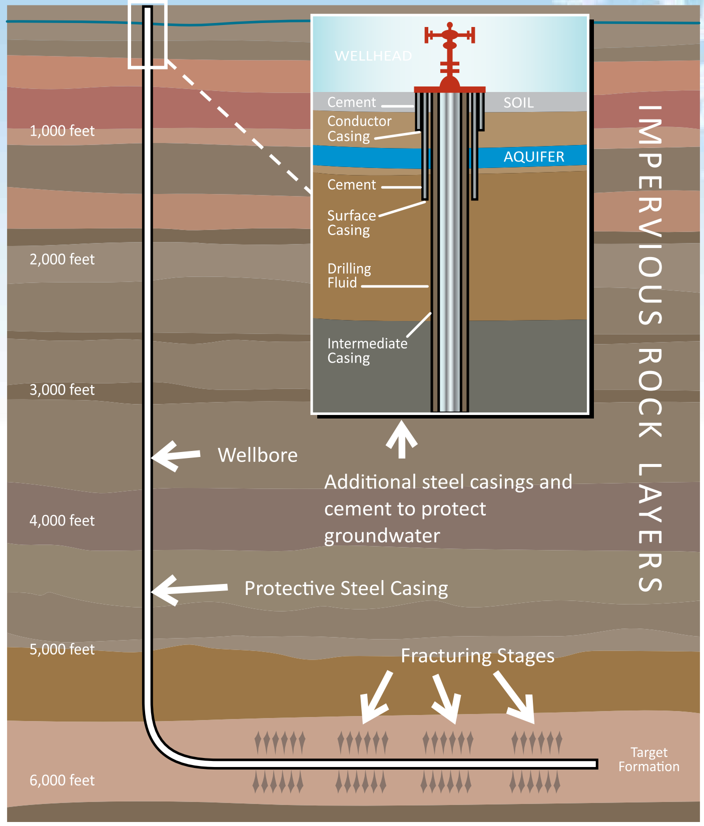
Types of nitrogen fracking

Pure Nitrogen Fracking:
Pure nitrogen fracking uses almost pure nitrogen with only a very small percentage of water. This type of fracturing is best suited for shallow water sensitive formations because it does not cause clay swelling like other processes that use water based frac mixtures. The low viscosity of nitrogen also makes it ideal for fracking shallow/brittle shale formations that have neutral fractures and stay self propped once pumping is complete.

Nitrogen Foam Fracking:
This process uses nitrogen that is mixed with water and other additives that are then cooled to form denser foam-like liquid. The mixture consists of somewhere between 50% - 95% nitrogen gas depending on the proppant and formation characteristics. The higher density and viscosity also make this a better proppant carrier which is capable of fracturing at greater depths than pure nitrogen fracking.

Nitrogen Energized Fracking:
The amount of nitrogen in this process is made up of less than 53% nitrogen, with the remaining fluid being made up of water and small amounts of chemical additives. The nitrogen is used to energize the liquid phase fluid, increasing flow back (less water remains trapped in the ground during fracturing of low pressure formations). Nitrogen energized fracking is also capable of being used at greater depths than either pure nitrogen fracking and foam fracking (about 8,000 ft.).

As Regulatory agencies discourage on hydraulic fracturing and the capabilities of horizontal drilling continue to advance, the demand to use nitrogen to fracture wells with less water is increasing. Although the cost of water is relatively inexpensive, the cost of properly handling and disposing the recovered frack fluid is not. By replacing the fluid volume with Nitrogen, the total volume of water needed is reduced. With Nitrogen being a component of the atmosphere, it has the perfect characteristics to be used for fracturing.



Frac Formation

These benefits include: Nitrogen is inert, non-flammable, environmentally friendly, creates an energized fluid through volume expansion, and can also be used for clean out and purging of the well. Because of these benefits, Nitrogen is seen as a clean substitute for traditional fracking methods.

For additional information go to www.cryoquip.com.

Frac Spread

Energent Tests 4 MW Two-Phase Turbine

In April 2014 Energent performed a test of a 4MW turbine for clients in China. The test was completed at the Santa Ana Test Facility in accordance with the API-617 requirements. The turbine will be used at an oil import terminal and refinery in China where Paraxylene (PX) is produced. The turbine runs inside of a Kalina waste heat recovery system. The Kalina system is an environmentally-friendly turbine since the power generated by the turbine is already available and free in the form of waste heat at the refinery. The working fluid is a mixture of ammonia and water vapor. The turbine is unique in that it is a two-phase turbine and will at times be running with very wet vapor in the ammonia/water mixture. Due to high vibrations, conventional axial flow and radial inflow turbines are not capable of running in such very wet gas flows, and eventually form damage on wetted surfaces impacted by the wet vapor droplets. The Energent turbine overcomes these wet vapor problems and has shown good reliability in previous wet vapor flow situations. The Energent turbine was manufactured by Energent in accordance with the specifications of API, ASME, IEC, and the Chinese Guobiao GB codes.

Figure 2: The turbine in operation during the 4 hour customer witnessed endurance test at night. The plume of gas with vapor can be seen exiting the turbine while the turbine operated at 13 650 rpm.

Figure 1: Test arrangement of a 4MW turbine only at the Santa Ana facility of Energent.

The flow process conditions at the final refinery site could not be simulated during testing. Therefore, only a turbine mechanical spin test was performed in Santa Ana using compressed air to drive the turbine. The value of the mechanical spin test was to verify all the controls as well as the temperatures and vibrations were in the acceptable ranges, as measured by the instruments. The turbine speed was 13,000 rpm and an over speed trip test was performed at 13,650 rpm. Figure 1 shows the turbine arrangement. Figure 2 shows the turbine during the test with vapor leaving the turbine outlet.

Free waste heat at refineries is commonly available. Customer representatives have stated that they have many other locations available at refineries where waste heat recovery projects are being evaluated. Sizes up to 10 MW are being considered for future applications.

For more information, visit www.Energent.net.

Commitment To Service

After-sales support is an integral part of every Cryogenic Industries product. Through Cryogenic Industries Service Companies and affiliates we have designed a streamlined, efficient and quality approach to product support and service. By combining the expertise and resources of all our entities and locations, we are able to offer a worldwide spare parts and service network.

Think Globally – Act Locally

From our strategically-located global network of service centers, we are able to provide genuine OEM parts, best-in-class service, rapid and effective response, technical support and training, and long-term framework service agreements.

- Equipment exchange service
- Spare parts service
- Pump, motor and alternator repairs
- Test facilities
- Installation and Field repairs
- Geographic customization of standard systems
- Technical advisors (24/7)
- Technical seminars on equipment operation

Through Cryogenic Industries Service Companies, we have created a worldwide support network capable of providing 24 hour support. Service is provided through 18 facilities (including four third-party service providers) on six continents:

Cryogenic Industries Service
Santa Ana

Cryogenic Industries Service
Atlanta

Cryogenic Industries Service
Houston

Cryogenic Industries Service
Pittsburgh

CryoCanada
Toronto

CryoCanada
Red Deer

Cryogenic Industries
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CRYOGENIC PUMP TRAINING

Our no-charge, two-day pump training workshops are held twice a year at our service facilities.

Offered to managers, engineers and technicians, they are designed to provide the knowledge and experience needed to maximize product performance.

TRAINING SCHEDULE

2014

Sept. 9-10 – Atlanta, GA

Sept. 23-24 – Pittsburgh, PA

Oct. 7-8 – Houston, TX

Oct. 28-29 – CAL – Santa Ana, CA

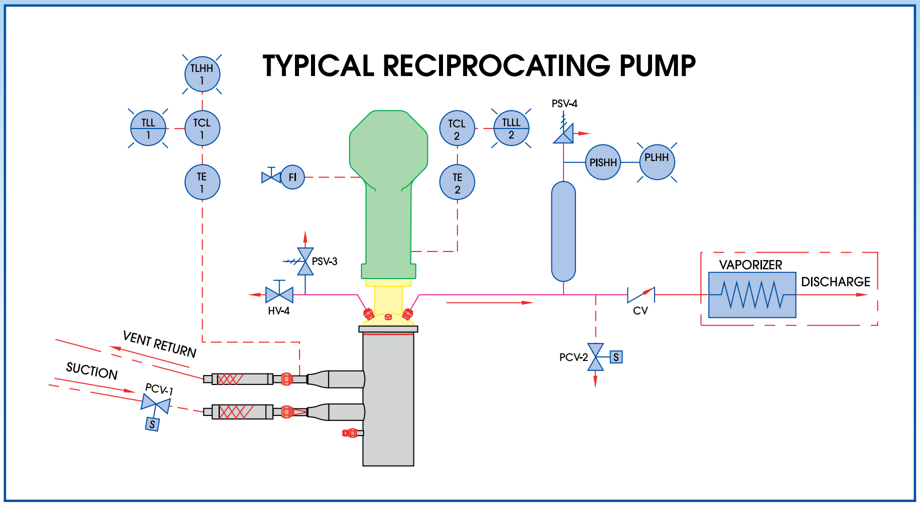
2015

TBD

Email Dwayne Ferraro at dferraro@cihouston.com for further information or to register to attend.

Avoid liquid pump installation problems

Reliable, trouble-free pump operation is the key to low-cost cryogenic liquid pumping. When installing either reciprocating or centrifugal cryogenic liquid pumps, careful up-front planning can mean the difference between long-term reliability or excessive maintenance and consequent downtime. Described below are the general principal issues to be addressed before and during installation of reciprocating and centrifugal pumps. Most topics apply to both types of installations. However, several additional considerations apply only to centrifugal pumps.



All Pumps

The mounting procedures and suction and discharge piping considerations described in the following paragraphs apply equally to reciprocating and centrifugal pumps.

Mounting to Pad

The flex lines connecting the piping to the suction and discharge fittings must be used to take up the stress or shrinkage when the system is cold. To ensure that the flex lines are adequate, the pump should be bolted to the pad after cooldown (not normal practice on reciprocating pumps) as this relieves any stress in the piping and allows the pump to be practically stress-free when in operation.

Therefore, the pump should be mounted in the following sequence:

1. Place pump on pad at desired location, but do not secure in place.
2. Connect suction and discharge piping.
3. Cool down pump.
4. Bolt pump to pad.

Suction Piping

Several suction piping issues should be addressed when planning either a reciprocating or centrifugal pump installation. In general, good piping practices improve the net positive suction head (NPSH) available to the pump. System performance is, therefore, enhanced by careful piping design.

When planning the installation, take into account the location of the pump with respect to the tank and the process so as to minimize piping runs. For the suction connection, the pump should be placed at a location that limits the piping run to less than 5 feet (1.5 meters) from the tank. All pipes in the system should have a pressure rating above system design pressure. Use as few elbows as possible to minimize liquid turbulence in the line and lessen pressure drop. The suction line should have a slight and continuously downward slope to aid in maintaining liquid flow into the suction fitting. At no point should the line rise and then drop (creating a gas trap).

A gate or ball valve, rather than a globe valve, should be used in the suction line. An inlet strainer is needed in suction piping except for most ACD reciprocating pumps, which have a strainer built into the suction fitting. A differential pressure gage should be used across the suction strainer.

Avoid the use of suction piping having a different diameter from the pump inlet fitting. If the diameter is too large product flows too slowly. This permits excessive heat leak into the fluid, which may cause the pump to cavitate. Conversely, small diameter piping increases pressure losses which reduces NPSH and thereby may also cause cavitation.

For reciprocating pumps, connect the suction fitting to a 6- to 8-inch long (15 to 20 cm) (maximum) flex line to compensate for expansion and contraction. Flex lines should not be used to compensate for misalignment or poor piping installations. Also, do not use full-length flex lines, as they add considerably to pressure drop and heat leak.

If the suction piping is relatively long, insulation should be considered. Vacuum-jacketed insulation is preferred because other conventional types of insulation may accumulate moisture, resulting in loss of insulation effectiveness and possibly causing cavitation due to heat leak. For operating cycles that are infrequent and of short duration, conventional insulation might be detrimental because the mass of insulation must be cooled down each time the pump is operated.

Whenever possible, pump suction piping should be separate from other liquid lines. If other pipes must be connected to the pump's suction pipe, a valve must be placed directly adjacent to the connection to prevent a dead-leg. A dead-leg is a void where liquid can vaporize, which adds heat to the fluid and could cause bubbles to flow into the pump and possibly cause cavitation.

Gas Phase Return Piping

To eliminate trapping gas, the gas phase return line for a reciprocating pump should be continuously sloped gently upward toward the tank. Its diameter should match the fitting on the suction adapter, and either a gate valve or ball valve is required.

For centrifugal pumps, a gas phase recirculation line is needed on the discharge side for pump cooldown and startup. A globe valve should be installed in this line to allow throttling during startup. A discharge control valve, downstream of the recirculation valve, must be located as close as possible to the pump to control the flow to be on the "pump's curve." Allowing the pump to start against no restriction, or to fill a large volume before control is established, will cause severe cavitation and likely the inability to "catch prime."

A relief valve must be used to prevent over-pressure from vaporized trapped-liquid when the suction and gas-phase return valves are simultaneously closed. When a relief valve is installed in the gas phase return line, it is not necessary to install a second relief valve in the suction line.

Discharge Piping

Discharge piping should match the discharge fitting size and should be rated higher than the pressure required by the application. A check valve should be installed in the discharge line to prevent backflow. A pressure relief valve must be installed in the discharge piping. Centrifugal pumps must have a discharge control valve as noted above.

Relief Valves

Pressure relief valves must be used to prevent over-pressurization in all pump installations. Their use is even more critical for cryogenic fluids. Ambient heat leak will vaporize trapped liquid, which causes a large pressure increase if the fluid can not expand. Relief valves must be used at all potential trapped-liquid points. Particularly between a reciprocating pump's discharge and a downstream valve, between isolation valves, and between an isolation valve and an upstream check valve.

Centrifugal Pumps Supplied from a Trailer

The following additional issues should be considered when installing a centrifugal pump that is supplied from a trailer:

Minimize length of flex lines, as the trailer's flexible transfer hose adds even further to the overall piping length connected to the suction fitting. This is a heat leak and cavitation issue.

Provision should be made for supporting the trailer transfer hose in the middle of its length to prevent the hose weight from applying unnecessary stress on the suction fitting.

A "witch's hat" strainer should be used in the suction line. Be sure that the open surface area of the strainer is 1.5 times the diameter of the suction piping. A differential pressure gage should be used across the suction strainer.

Instrumentation and Controls

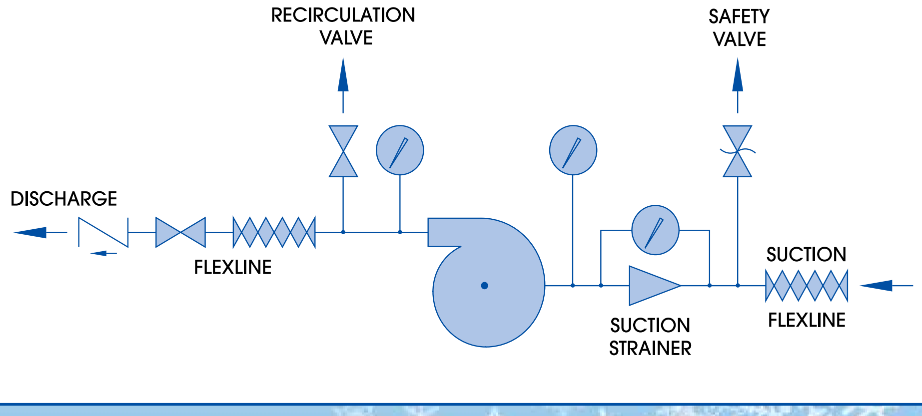
Pumps must be instrumented for proper control and maintenance. As a minimum, a discharge pressure gage must be used to control the operation within the pump's design limits.

For unattended operation, fully automated systems are available to control the operation and shut down the pump if a fault occurs, such as cavitation, seal leak, or over-pressurization.

The issues discussed provide general guidance for pump installations. However, each installation is unique. Always use sound engineering practices for a pump installation. If unsure of the proper criteria, contact ACD, or one of our authorized worldwide service centers (see page 5) to discuss your specific application and installation details.

For more information, visit www.acdllc.com.

TYPICAL CENTRIFUGAL PUMP



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