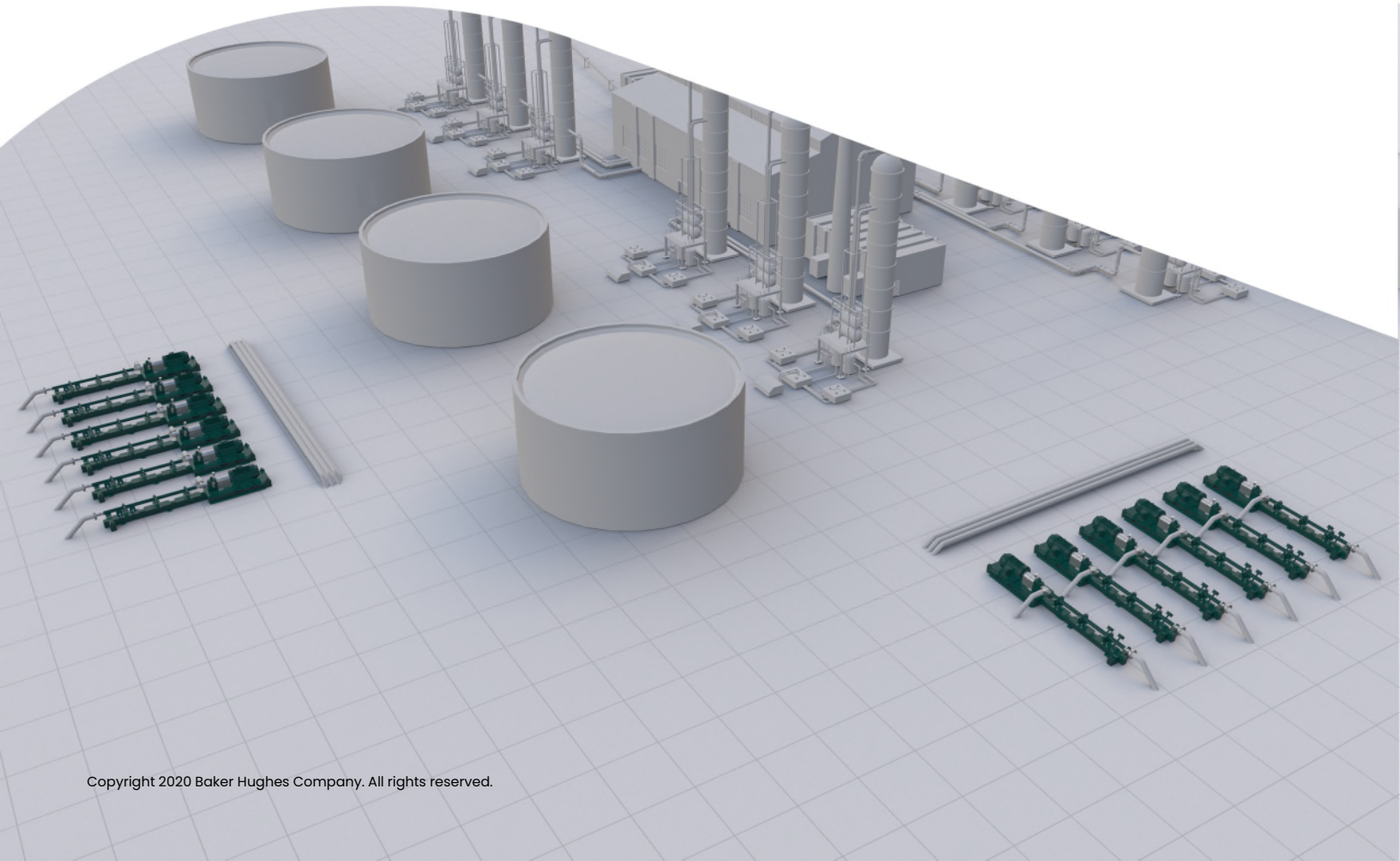
Baker Hughes

Artificial Lift Systems

HPump Surface pumping systems

User Instructions—Installation, Operation, and Maintenance

Rev 1_a



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HPump Surface pumping system user instructions, Installation, Operation, and Maintenance

1. Introduction

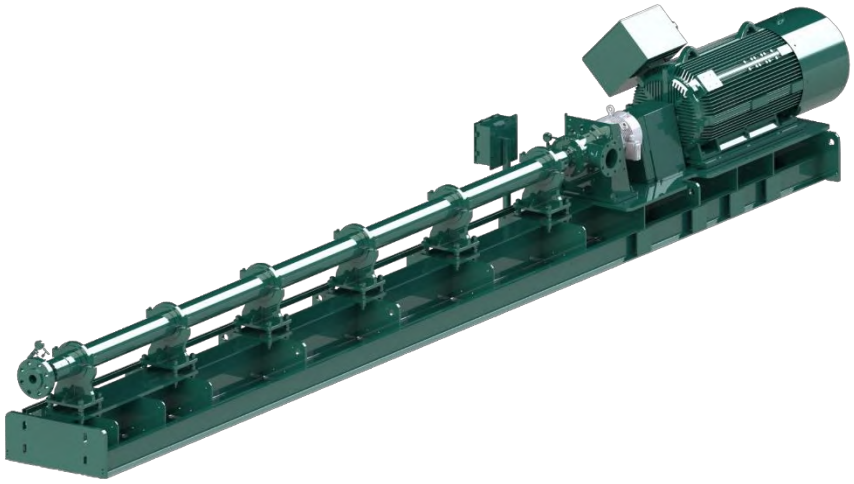
At Baker Hughes we are taking energy forward - making it safer, cleaner and more efficient for people and for the planet.

HPump systems (HPumps) are versatile, low maintenance, high-pressure pumping systems that provide an alternative to many multistage split-case centrifugal, positive displacement and vertical-turbine pump models. HPump systems feature a quiet, low vibration, environmentally friendly design adaptable for changing conditions. They can include an API 682 type mechanical seal and API 610 flush/quench options if required. Multiple units can be combined in tandem for higher capacities and flexible operation. This energy efficient pump is available with short delivery times and is well suited to many surface industrial and mining applications, as well as traditional oilfield applications such as water and CO^2 injection.

Baker Hughes HPump Systems are designed to conform to applicable regulatory standards based on the end use location including:

- Machinery Directive
- Pressure Equipment Directive
- Low Voltage Directive
- Electromagnetic Compatibility (EMC) Directive.

Important safety aspects referenced in the Essential Safety Requirements are outlined in the directives listed above. Where applicable, this document includes information relevant to these European Directives.



2. HPump™ general safety instructions

⚠ CAUTION

- Do not attempt to install, operate, commission, decommission, or maintain this equipment until you have been trained on specific activities (e.g., commissioning, maintenance, etc.) and have read and understood all of the product safety information and directions contained in this manual.
- During any type of preventive or corrective maintenance, the unit should be locked out for safety. Safety should always come first and is non-negotiable.

2.1 Safety alert symbols

The safety alert symbol indicates a potential personal injury exists. These are located where moving parts, pinch points and/or electricity could be a potential danger.

2.2 Signal words

Listed below are the signal words used throughout this manual, their descriptions and associated symbols.
When the words DANGER, WARNING, and CAUTION are used in this manual, they will be followed by important safety information to which all personnel must adhere.

⚠ DANGER

- The word **"DANGER"** preceded by the safety alert symbol indicates an imminently hazardous situation exists which, if not avoided, will result in death or serious injury to personnel.

⚠ WARNING

- The word **"WARNING"** proceeded by the safety alert symbol indicates a potentially hazardous situation exists which, if not avoided, could result in death or serious injury to personnel.
- The word "**CAUTION**" preceded by the safety alert symbol indicates a potentially hazardous situation exists, which if not avoided, may result in minor or moderate injury.

⚠ CAUTION

- The word **"CAUTION"** without the safety alert symbol indicates a potentially hazardous situation exists which, if not avoided, may result in equipment and or property damage.

Important Notice: There are several components that make up an HPump system. These components may vary by unit. The instructions contained in this manual are not intended to cover all details or variations in the equipment types, nor may it provide for every possible contingency concerning the installation, operation, or maintenance of this equipment. Please refer to the motor, drive, cooler, seal and seal support system manuals for further information and precautions concerning these components. Should additional information be required, please contact your Baker Hughes representative.

The contents of this manual should not become a part of, or modify, any prior or existing agreement, commitment, or relationship. The sales contract contains the entire obligation of Baker Hughes and its affiliates. The warranty contained in the contract between the parties is the sole warranty of Baker Hughes and any statements contained herein do not create new warranties or modify the existing warranty.

⚠ WARNING

- **Any electrical or mechanical modifications to this equipment without written consent of Baker Hughes will void all warranties and may void any safety certifications that were issued with this equipment. Unauthorized modifications may also result in a safety hazard, equipment damage and/or personal injury.**
- **Misuse of this equipment could result in injury and equipment damage. Under no circumstance will Baker Hughes be responsible or liable for either indirect or consequential damage or injury that may result from misuse of this equipment.**

3. Manual purpose and scope

This manual provides information on how to safely operate an HPump system. Refer to the motor, drive, seal and any other specific component manual for further information and precautions. This manual includes a section of general safety instructions that describes the warning labels and symbols used throughout the manual. Read the manual completely before installing, operating, or performing maintenance on this equipment. This manual and the accompanying drawings should be a permanent part of the equipment and should be readily available for reference and review.

Baker Hughes reserves the right, without prior notice, to update information, make product changes, or to discontinue any product or service identified in this publication. HPump™- Surface Pumping Systems is a trademark of Baker Hughes Inc. All other product or trade references in this manual are registered trademarks of their respective owners.

NOTE

Neither Baker Hughes Inc. nor any affiliate is liable for direct, indirect, special, or consequential damages resulting from the use of the information contained within this manual.

3.1 Special symbols

To identify special hazards, other symbols may appear in conjunction with **DANGER, WARNING**, and **CAUTION** signal words. These symbols indicate areas that require special and/or strict adherence to the procedures to prevent serious injury to personnel or death.

3.2 The electrical hazard symbol

Figure 1: Electrical Hazard is a symbol that indicates a hazard or injury from electrical shock or burn. It is comprised of an equilateral triangle enclosing a lightning bolt.

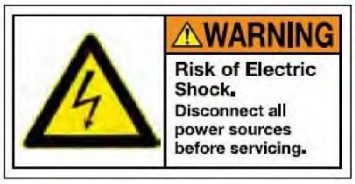


Figure 1: Electrical Hazard

3.3 Earth grounds

Figure 2: Earth grounds is an example of the symbols for grounding points.

Figure 2: Earth grounds

3.4 Equipment warning labels*

There are some components in the HPump such as the thrust chamber and/or motor that could be operating at temperatures above 70°C (158°F).

Even though some HPump systems are designed with "low noise" equipment (e.g., motor, oil coolers, seal systems, etc.) and their assembly and installation procedures include alignment tasks to reduce vibration and noise levels, there is still some level of noise associated with the normal operation of the system. Therefore, it is always recommended to use hearing protection while the system is running in order to minimize noise hazards.

*- ISO pictograms only displayed on CE systems

Important note: A Lockout tag must be completed prior to any service. Failure of the main control could allow and unexpected start under various scenarios including reenergize after power interruption. The use of Lockout tags and E-stops will eliminate the potential of the operations control system failing under service mode. E-stops as well as control system guidelines are provided according to what is included in the scope of supply of the HPump system. Site Risk assessments must be completed prior to operation.

Entanglement and trapping hazards are present at the motor coupling area. A protective coupling guard has been designed to prevent access to these dangerous moving parts while the HPump system is running. Do not remove the coupling guard until the lockout/tag-out procedures have been completed.

Do not attempt to install, operate, or perform maintenance to this equipment until you have read and understood all of the product labels and user directions contained in this manual. Labels attached to the equipment are there to provide useful information or to indicate an imminently hazardous situation that may result in serious injury, severe property and equipment damage, or death if the instructions are not followed.

4. Principles and Features

4.1 Principles of operation

HPump system uses adapted electrical submersible pumping (ESP) technology to deliver leak-free, low-noise fluid pumping. The multistage centrifugal pump is combined with a thrust chamber (TC) and an industrial foot-mounted electrical motor to provide a rugged, skid-mounted pumping system.

4.2 Exclusive features

4.2.1 Pump

Each pump is sized based on specific design requirements and operating parameters. The HPump pumping element is a multistage centrifugal pump consisting of multiple rotating impellers on a keyed shaft paired with stationary diffusers, additional impeller/diffuser sets can be added to enhance performance or adapt to changing conditions. Corrosion-resistant impellers and diffusers are cast from various materials. Baker Hughes has a variety of coatings available to offer additional resistance to corrosion and abrasives.

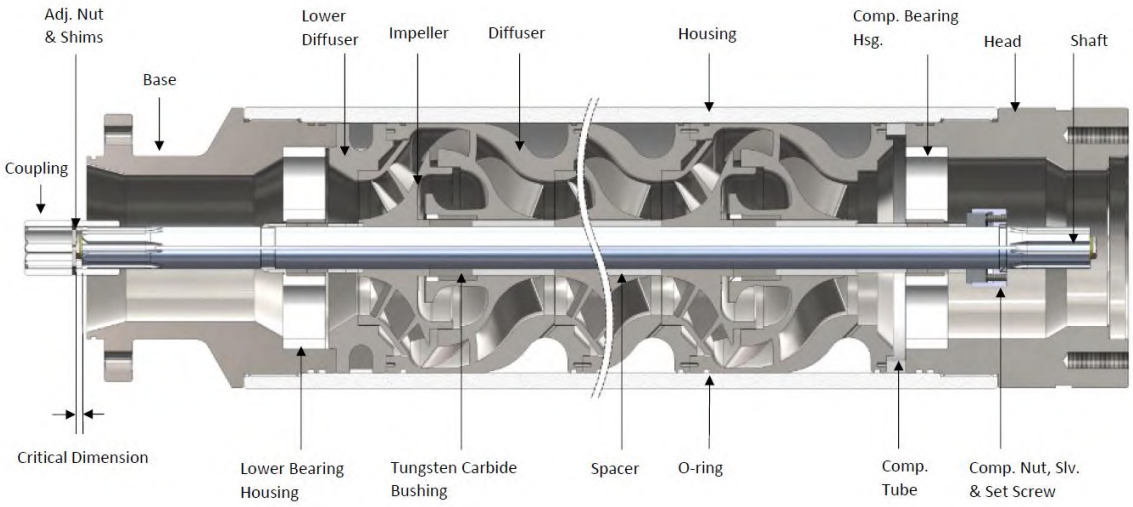


Figure 3: Pump Cutaway

4.2.2 Motor

Motors are selected based on customer's design specifications. Site conditions determine how the pump will be powered (e.g., electric drive—NEMA, electric drive—IEC, engine drive—gas, engine drive—diesel, etc.).

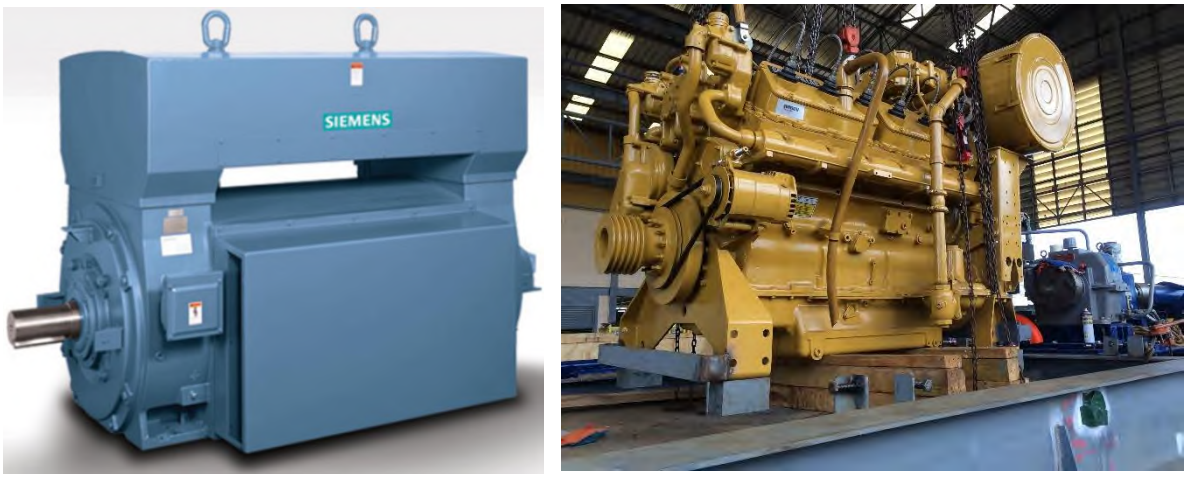


Figure 4: HPump Electric Motor and Engine Drive

4.2.3 Drives

The system's power requirements and customer preference determine what size and type of drive will be used such as a variable speed drive, soft start or switchboard motor controller.

Figure 5: Baker Hughes VSD

4.2.4 Seals/Seal support systems

The type of seal employed depends on design specifications, operating parameters and customer preference. Several different seals can be used such as component, single-balanced mechanical, cartridge, double-balanced mechanical, double cartridge, and tandem. The seal support system used depends on the design specifications and seal type used. There are varieties of API 682 seal flush plans available with or without a seal reservoir/pot.

4.2.5 Thrust chamber

The type of Thrust Chamber (TC) selected depends on the amount of thrust generated by the pump for the given application. Currently there are three TC options available: a Standard-Duty (SDTC), a Heavy-Duty (HDTC), and an Extreme-Duty (XDTC). Baker Hughes also has forced lubrication oil cooler systems for use with the HDTC and XDTC options. These are powered by a small total enclosed fan cooled (TEFC) motor.

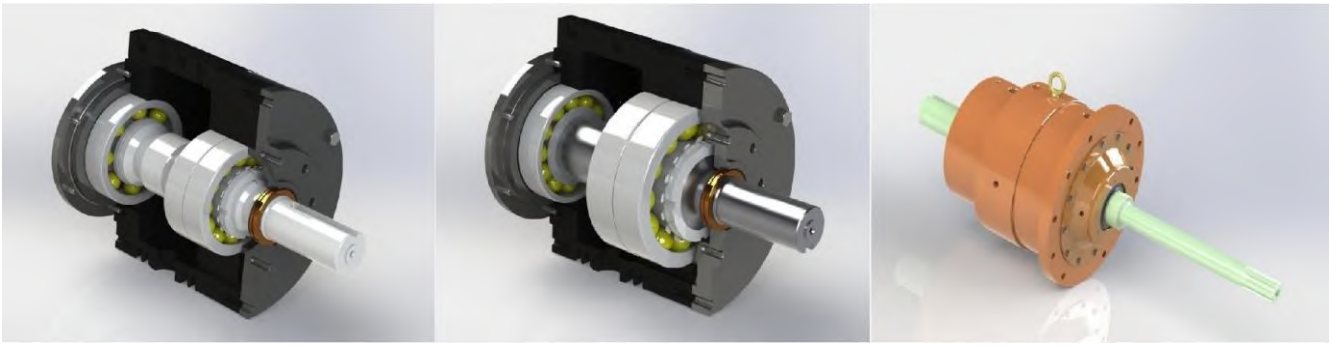


Figure 6: HPump Thrust Chambers (SDTC, HDTC, and XDTC)

4.2.6 HPump system frames

Baker Hughes HPump units incorporate the patented FM1000 Easily Modified Frames™, which are modular in construction and facilitate system modifications should operating conditions change. These frames feature a rigid base frame for low vibration and ease of installation. They incorporate integral lifting lugs throughout and a machined motor adapter plate in some configurations, which together with the frame motor plate are pre-drilled for virtually all available motor options. FM1000 frame features include:

- Motors: 75 hp to 1,000+ hp motors can be mounted to the FM 1000 design without having to cut or weld and without adjusting the pipe work.
- Each adapter plate has all possible motor mounting holes pre-drilled for the particular shaft height. The adapter plates have machined surfaces.
- If a replacement motor has a different shaft height the motor adapter plate can be swapped out. The pump centerline stays the same so suction and discharge levels do not change.
- Frame end plates facilitate the addition of future extension sections if required.
- EMF™ is a heavy-duty rigid design.

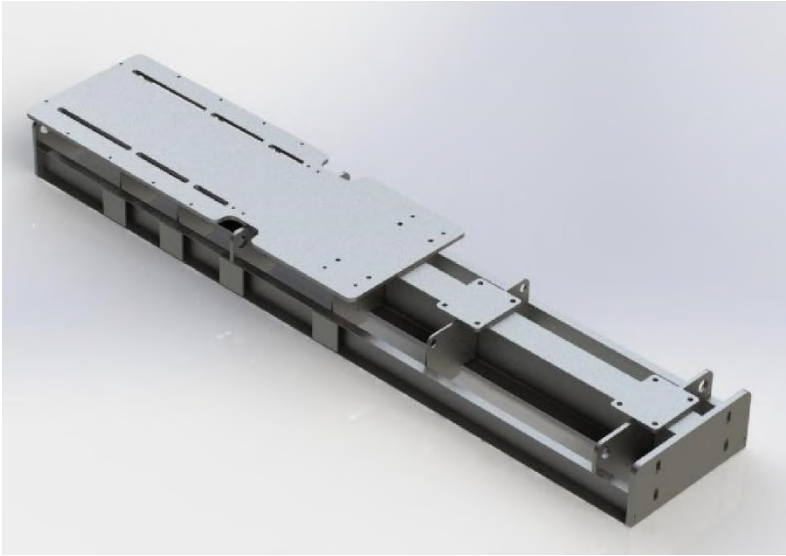


Figure 7: EMF™ style Frame

5. HPump unit handling and transport procedures

WARNING

Perform all necessary safety precautions before beginning any work on or around the HPump unit. Failure to follow all safety precautions can lead to damage to the equipment, personal injury or death.

NOTE

At Baker Hughes, safety is our first priority. Follow all safety procedures and precautions. Before working on or around an HPump pump, it is imperative to read and follow all warnings, cautions, notes, and instructions included in this document.

CAUTION

Important Notice: Lifting equipment must be sized appropriately for the equipment being lifted and inspected prior to use. A site Job Safety Analysis (JSA) should be performed to make sure the proper sized equipment is being used.

CAUTION

Check the load before lifting. Make sure the total weight of the load and its center of gravity is secure, especially when lifting separate components.

5.1 Lifting an HPump unit

There are two recommended methods to lift an HPump unit when loading or unloading for transport:

5.1.1 Lifting the HPump unit using a forklift

Make sure the forklift is rated for the given load at a distance from the mast. Since HPump units have the load located along the longitudinal axis of the frame, the centerline of the motor is the centerline of the load.
Each HPump unit has the approximate center of gravity (C.O.G.) marked on the unit. If there is packing material or other loose items on the frame, the center of gravity will change depending on the weight of the items. When lifting with a forklift the forks must straddle the center of gravity.

Figure 8: Lifting an HPump Unit with a Forklift

NOTE

A sticker (Figure 9: Center of Gravity Sticker, page 12) located on the HPump™ frame indicates the approximate center of gravity (C. O. G.). For units with a pump extension, the C. O. G. sticker is located in the same area on the extension frame

Figure 9: Center of Gravity Sticker

5.1.2 Lifting the HPump unit using a crane

Before lifting an HPump unit determine the center of gravity and locate lifting lugs. Take steps not to interfere with pump and motor alignment. Use recommended lifting locations.
A four-point spreader bar is recommended for lifting or moving the HPump equipment when using a crane refer to the general arrangement drawing of you unit for specific lifting points.

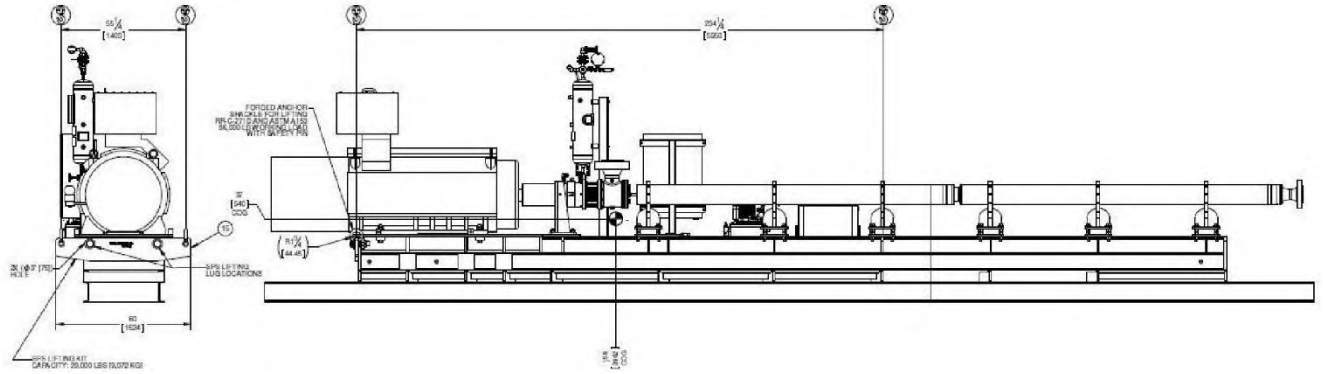


Figure 10: Lifting an HPump

5.2 Preparation of skid supports for transportation

The recommended spacing of supports is 4 to 8 feet and should not exceed 10 feet.

NOTE

Minimum acceptable supports are 3-in. x 4-in. landscape timbers or 3-in. x 3-in. lumber. Make sure the height of every support used is the same.

It is recommended the frame be supported under or near the center of gravity of the motor and the whole unit as well as the back end of the motor plate. This will help distribute the weight evenly.

CAUTION

Equipment must be secured to a flat surface when transporting or damage to the equipment may result.

- Do NOT prop or over hang equipment.
- Do NOT strap or chain on the pump body, supports, or brackets.
- Do NOT lift by the motor eyebolts or strap across the motor.
- Make sure straps and chains clear motors, junction boxes, and coolers.

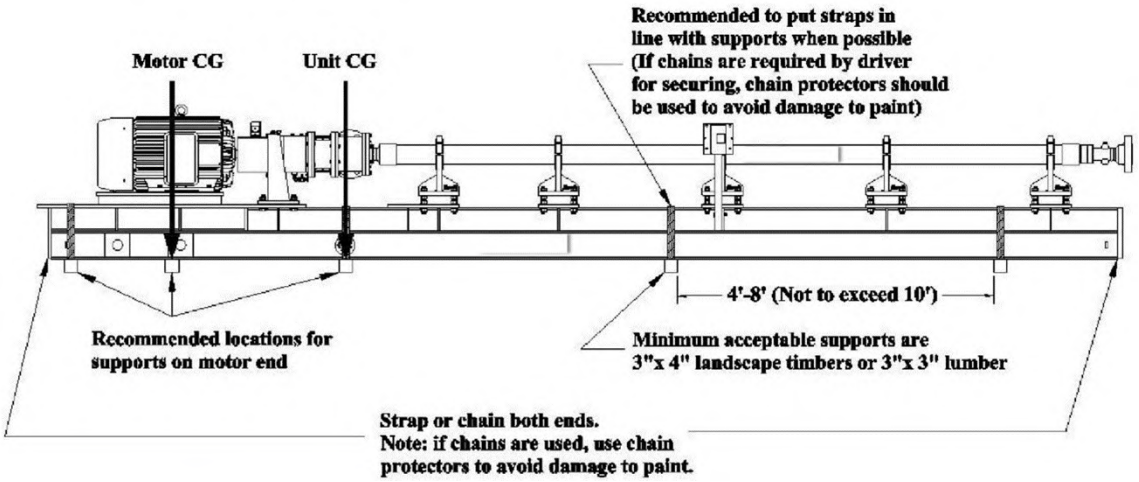


Figure 11: Recommended Strap/Support Locations

5.3 Securing the HPump unit

This instruction only applies to transporting HPump units.
After the HPump unit is loaded onto the supports, attention should be made to any significant gaps (1/8 in. or greater) between the unit and the supports. These gaps should be shimmed solidly. Secure the HPump unit directly in line with the supports or as close as possible. Straps should be routed over the top of the frame and under any tubing, if present, to avoid possible damage to the tubing. If it is not feasible to run straps under tubing, wood blocks can be used as shims under the tubing to prevent deflection. Check for loose supports after strapping. If there are any loose supports, unstrap the frame in that area, shim the frame solidly to the support and re-strap.
Do not run straps over the top of the pump, as this will cause deformation to the pump

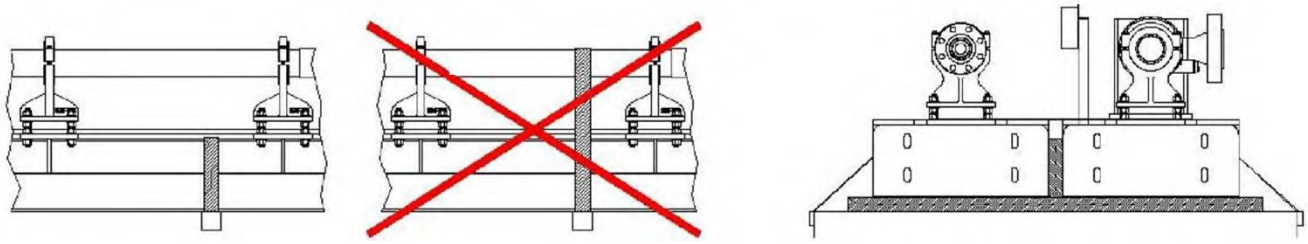


Figure 12: Correct Use of Straps

When securing multiple units side-by-side it is recommended to butt the units solidly with 3-in. x 3-in. blocks in between to prevent straps from coming loose in transit

Disclaimer: The purpose of this instruction is to provide guidelines for securing and transporting HPump units to avoid damage to the units. It is ultimately the driver's responsibility to make sure each unit is secured in a manner safe for transportation.

5.4 Unloading equipment

Care should be taken when unloading the equipment. If the shipment is not delivered in good condition or according to the bill-of-lading, detailed notes about the condition of the shipment should be made on the receipt and freight bill. Promptly contact the transportation company and mention any claims regarding the shipment. Retain all documentation related to your claim.

Each HPump unit is shipped from the factory in a manner suitable for protection during short-term storage (0 to 90 days). If prolonged storage (over 90 days) of the equipment is required, please follow the long-term storage procedures found in Section 9: Storage Procedures, page 36 of this manual, or contact your nearest Baker Hughes field service representative for any questions regarding your unit.

6. Installation and commissioning

CAUTION

Important Notice: Lifting equipment must be sized appropriately for the equipment being lifted and inspected prior to use. A site Job Safety Analysis (JSA) should be performed to make sure the proper sized equipment is being used.

CAUTION

Check the load before lifting. Make sure the total weight of the load and its center of gravity is secure, especially when lifting separate components.

6.1 Unit location

WARNING

Perform all necessary safety precautions before beginning any work on or around the HPump unit. Failure to follow all safety precautions can lead to damage to the equipment, personal injury or death.

NOTE

For complete installation and commissioning instructions, refer to your Baker Hughes field service representative.

CAUTION

Important Notice: If any risk of fire or explosion applies to the operation of the HPump, recommendations and warnings will be included according to the specific ATEX Risk Analysis (if applicable).

6.1.1 Net Positive Suction Head (NPSH) optimization

To optimize the suction conditions the unit should be placed as close to the product supply source as possible to prevent friction loss. Each unit has certain NPSH requirements that need to be met in order to have adequate product supply for the pump upon start up and during operation, refer to the pump specifications for the detailed NPSHr value. This will reduce the likelihood of cavitation. A charge pump will be required if adequate NPSHr is not obtainable.

6.1.2 Unit clearances

Floor and headspace allocated to the equipment must be sufficient for inspection and maintenance. Allow for crane or hoist service as required, generally 3 ft around the unit should be open for maintenance activities.

6.1.3 Foundation recommendations

A flat level concrete slab is recommended for mounting the HPump unit. Do not use general dimensions for foundation design. Refer to your product drawings for specific foundation requirements. Please consult API RP 686 or a qualified foundation designer for detailed foundation design. The grouting of HPump frames is not recommended, and they are not factory acceptance tested as such. In fact, this unnecessary surface bonding has been linked to system resonance issues and thus is not recommended.

6.1.4 Foundation bolts

Foundation bolts are to be used, place them at cross member locations and take care not to distort the base when tightening, see Figure 13: Suggested Frame Clamp (FM 1000 Frame Example). The base must remain level to maintain pump alignment, refer to the suggested frame clamp down detail provided in the general arrangement drawing of your unit.

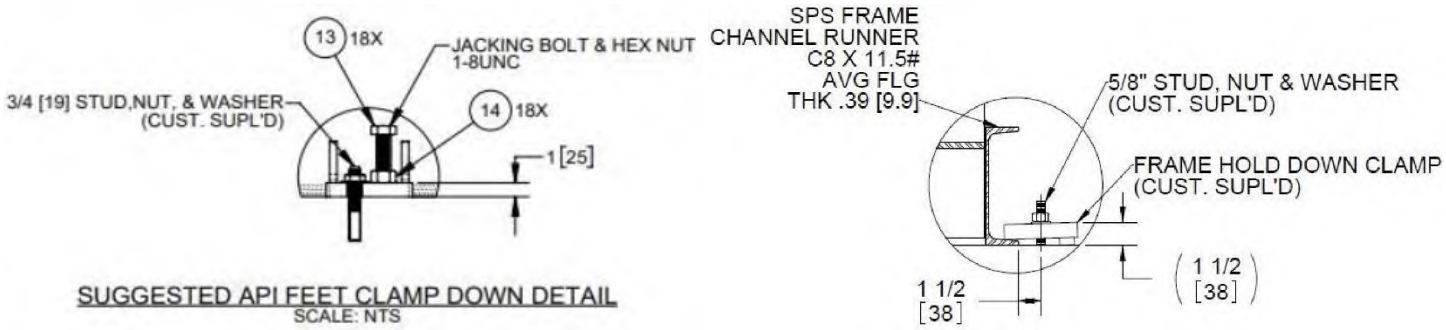


Figure 13: Suggested frame clamp (FM1000 frame example)

API and standard shown

6.2 Piping guidelines

6.2.1 Piping Installation Standards

Piping should be installed in accordance with NORSOK Standard L-CR-004 Rev 1 and API RP 686.

6.2.2 Pipe loads

Refer to API 610 Annex F for coordinate system, and table 1 below for maximum allowable nozzle loads in Ft-Lb for allowable piping loads.

Table 1-Maximum allowable nozzle loads in Ft-Lb*

Flange Size (Inches)	≤ 2-in.	3-in.	4-in.	6-in.	8-in.	10-in.	12-in.	14-in.
Each Top Nozzle								
FX	160	240	320	560	560	560	560	560
FY	130	200	260	460	460	460	460	460
FZ	200	300	400	700	700	700	700	700
Each Side Nozzle								
FX	160	240	320	560	560	560	560	560
FY	200	300	400	700	700	700	700	700
FZ	130	200	260	460	460	460	460	460
Each End Nozzle								
FX	200	300	400	700	700	700	700	700
FY	160	240	320	560	560	560	560	560
FZ	130	200	260	460	460	460	460	460
Each Nozzle								
MX	340	700	980	1700	1700	1700	1700	1700
MY	170	350	500	870	870	870	870	870
MZ	260	530	740	1300	1300	1300	1300	1300

**NOTE: Nozzle loads may be increased up to two times forces and moments shown in the table above only if they meet the criteria of API 610 Annex F and the results of Annex F have been reviewed and approved by GE Oil and Gas PS SPS Engineering. Nozzle Loads listed above are not valid at the suction*

nozzle when an expansion joint is utilized. Refer to expansion joint manufacturer's literature for allowable forces and moments.

6.2.3 Piping length

Use the minimum length of piping according to design specifications to keep friction loss to a minimum.

6.2.4 Piping clearances

Make sure piping is arranged to allow the proper clearance and accessibility for easy operation, inspection and maintenance.

6.2.5 Strainer specifications

Install an in-line strainer according to specified fluid conditions. After the strainer, allow a space equal to ten times the pipe diameter so the product/liquid can stabilize before entering the suction of the pump.

6.2.6 Piping layout

Provide a simple piping layout that is neat and economical and allows for easy support and adequate flexibility.

6.2.7 Connections to the HPump unit

Piping connected to equipment should be designed so any forces or moments caused by thermal expansion, dead and operating loads do not exceed the API or specified limits required by the manufacturer. Piping connections should not be forced together and are required to remain within the API standard nozzle loads or as specified by manufacturer.

6.2.8 Flexible suction connections

Flexible suction connections can be used to ease expansion and contraction of piping which could exert damaging forces on the unit’s suction chamber. Flexible connections should meet all design and pressure specifications.

6.2.9 Flexible discharge hose

A flexible discharge hose can be used, but it must be capable of handling both the duty point pressure and the pump’s dead head pressure at maximum temperature allowing for expansion without creating a misalignment force.

6.2.10 Suction-end isolation block

An isolating block should be installed before the suction-end of the pump so the process fluid can be shutoff from the pump for maintenance purposes. Refer to Figure 14: Valve/Piping Diagram.

6.2.11 Discharge-end isolation block

A block needs to be installed in the discharge line to isolate the pump from other units or downstream process equipment for maintenance purposes. Refer to Figure 14: Valve/Piping Diagram.

6.2.12 Discharge bypass valve

A bypass valve can be installed in the discharge line, which should be piped back to the suction tank and sized to bypass the minimum operating flow. This is for the protection of the pump in case a valve is closed or process change occurs during operation. Redirecting the fluid back to the holding tank will prevent the pump from operating with no flow. Refer to Figure 14: Valve/Piping Diagram.

6.2.13 Use of a choke

A choke should be installed in the discharge piping. A choke allows the pump to operate against pressure on startup until the line is fully charged. An automated choke is recommended as it prevents the pump from operating inefficiently. The choke should be located after the bypass valve in the discharge line. Refer to Figure 14: Valve/Piping Diagram.

6.2.14 Use of a discharge line check valve

A check valve should be installed in the discharge line for applications where back flow is likely to occur once the pump stops operating. This will prevent the equipment from back spinning, Refer to Figure 14: Valve/Piping Diagram.

- Failure to install a discharge line check valve may allow the equipment to backspin and cause damage to the pump and motor.
- Do not pipe a plant from these incomplete instructions. Failure to follow these guidelines will reduce pump efficiency and increase pump maintenance cost. Follow Norsok and API RP 686 piping standards as close as possible for best results.

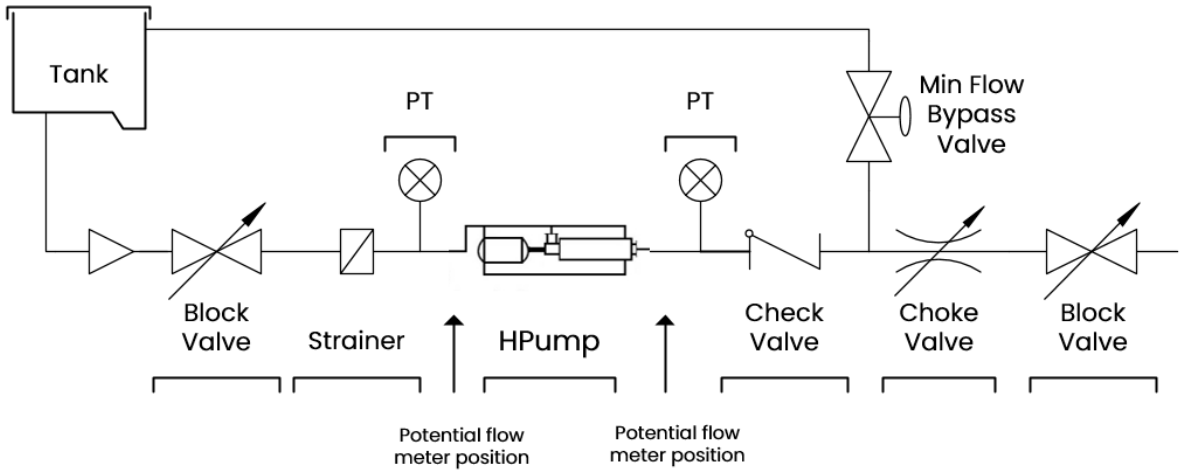


Figure 14: Valve/Piping Diagram

7. Operation and startup

⚠ WARNING

Perform all necessary safety precautions before beginning any work on or around the HPump unit. Failure to follow all safety precautions can lead to damage to the equipment, personal injury or death.

⚠ CAUTION

Coolant lines and thrust chamber can be hot after operation. Adhere to warning labels.

There are some components in the HPump such as the thrust chamber that could be operating at temperatures above 70˚C (158˚F). As a way to reduce the chance of touching the hot surface, warning labels are attached to the equipment, which remind the operators to wait until surfaces are cool before servicing the system.

Even though some HPump systems are designed with “low noise” equipment (e.g., motor, oil coolers, seal systems, etc.) and their assembly and installation procedures include alignment tasks to reduce vibration and noise levels, there is still some level of noise associated with the normal operation of the system. Therefore, it is always recommended to use hearing protection while the system is running in order to minimize noise hazards.

Important Note: Lockout/Tagout must be completed prior to any service. Failure of the main control could allow an unexpected start under scenarios including reenergize after power interruption. The use of Lockout/Tagout will eliminate the potential of the system energizing during service. Site Risk assessments must be completed prior to operations.

Entanglement and trapping hazards are present at the motor coupling area. A protective coupling guard has been designed to prevent access to these dangerous moving parts while the HPump system is running. Do not remove the coupling guard until the Lockout/Tagout procedures have been completed.

7.1 Critical installation/operating instructions

7.1.1 Duty conditions

HPumps are designed to for specific operating parameters, the reliability of an HPump depends upon the operator using the product in the intended manner, in accordance with safety guidelines of this manual. The operating range specified on the system data sheet must never be exceeded under any circumstance. If a user plans to change, or anticipates a change in the conditions of service (ex. fluid, temperature, duty, etc.) please consult with your Baker Hughes representative for recommendations prior to start up.

⚠ WARNING

This product must not be operated beyond designed application parameters and specified operating range. Operation beyond safe operating parameters can lead to equipment damage, personal injury, or death. If there is doubt as to the suitability of the product for the application intended, contact Baker Hughes for support.

7.1.2 Unauthorized alterations and spare parts

Modifications or alterations of the equipment supplied are only permitted after consultation with the manufacturer and to the extent permitted by the manufacturer. Use of original spare parts and accessories authorized by the manufacturer ensures safer operation. The use of other parts may create an unsafe condition and can invalidate any warranty or liability of the manufacturer.

7.1.3 Personnel qualification and training

The operator is responsible for ensuring all work be performed by authorized, qualified personnel who are thoroughly familiar with this manual and fully trained on the operation, maintenance, repair, inspection, and installation of HPump systems.

WARNING

Always coordinate repair activity with operations and health and safety personnel following all plant safety requirements, applicable safety and health laws, and regulations. Failure to follow all applicable requirements, regulations, and laws may lead to equipment injury, personal injury, or death.

7.1.4 Scope of compliance

Use equipment only in the classification zone for which it is designed. Always check all components of the equipment are suitably rated and/or certified for the classification of the area they are to be operated.

7.1.5 Pump performance and protection

This equipment has a specific performance window and operational limits. It is the end users responsibility to understand these limits and to make sure proper measures including instrumentation are installed to monitor key functions and to shut down the equipment in the event those limits are exceeded. In the event pumps are installed in parallel or in series, each pump must be operated within its own specific performance and operational limits.

7.1.6 Pump operating range

Multistage centrifugal pumps have an operating range specific to the model of pump: refer to the pump performance curve for your pump. Figure 15: Sample Pump Curve, is an example of a pump curve, it is imperative to ensure the pump is running within the allowable operating range at all times. Operation of the pump outside the allowable operating range can drastically reduce the life of the pump due to high thrust loads, increased vibration, cavitation and high pressure.

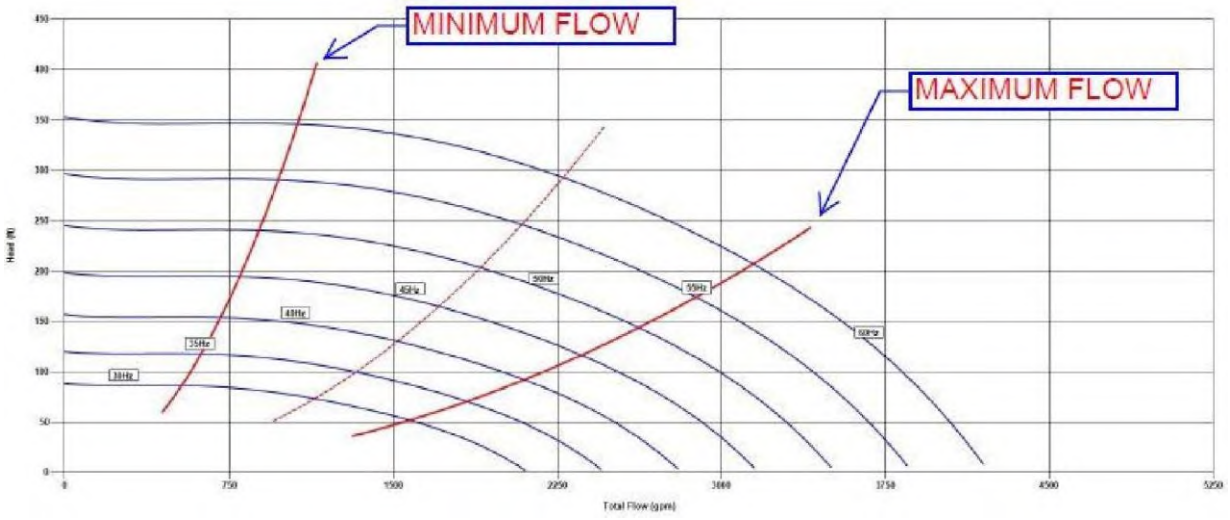


Figure 15: Sample Pump Curve

7.1.7 Low flow/No flow operation

When a pump operates near the shutoff with almost no flow, almost all the motor power is transformed into thermal energy, which is absorbed by the pumped fluid. In this condition, there is risk of the pump casing taking on high surface temperatures within a very short time, due to a rapid temperature buildup inside the pump. This causes excessive stresses on the pump and pumps materials and may result in premature pump failure, the pump seizing, or even bursting, which could lead to injury or death of persons standing in the immediate area and property damage.

Pump operation at shutoff or near shutoff conditions outside of the pump operational limits could lead to equipment damage, injury or death of persons in the immediate area.

Never exceed the maximum allowable working pressure (MAWP) limit at the stated design temperature marked on your equipment.

7.1.8 Maximum flow operation

When a pump operates with little resistance in the discharge line, the pump will operate at a condition of maximum flow or end of curve performance. Maximum horsepower is required to operate at this point.

Operating a pump with little resistance in the discharge line will cause motor overload and may result in equipment damage, personal injury, or death.

7.1.9 Net Positive Suction Head (NPSH)

To avoid cavitation conditions, the NPSHa must have additional margin to avoid cavitation and be greater than the net positive suction head required (NPSHr). Refer to the NPSHr curve for your particular pump.

Operating an HPump without the pump being fully flooded with fluid or with Inlet valves not fully open may cause the system to cavitate leading to equipment damage, injury, or death.

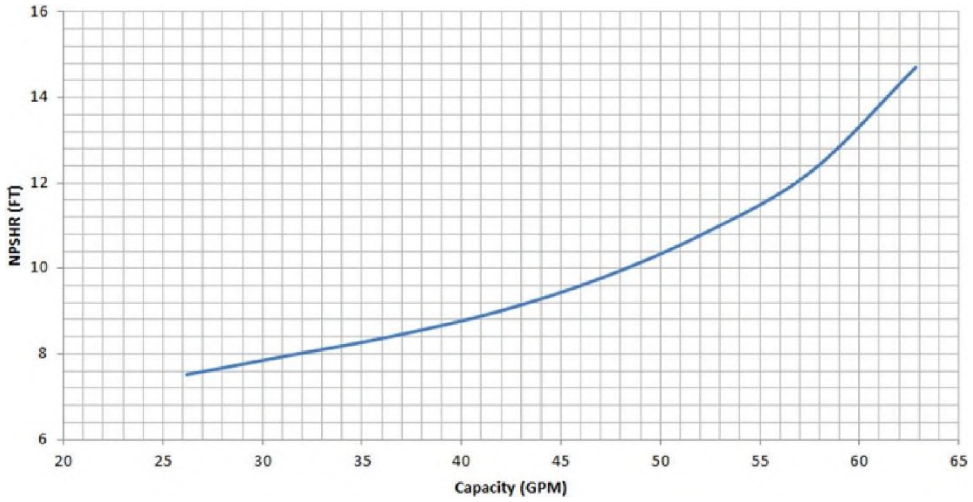


Figure 16: NPSH Curve

7.1.10 Piping loads

Piping should always be supported to restrict any forces, moments, piping weights, thermal expansions, etc., which could create pump/motor misalignment or deflections and overloading of pump flanges. There should not be any tensions, deformations, or misalignment of the piping when loosening the bolts holding the flanges together. Refer to Piping Guidelines in Section 6.2 for more information.

7.2 Thrust chamber lubrication

CAUTION

Important Notice: Read the Material Safety Data Sheets (MSDS) of the Lubrication fluids before attempting to work with them.

For SDTC's, change the full synthetic ISO Grade 68 oil in the thrust chamber after the first hour of operation and every 2,200 hours of operation or once a year thereafter.

1. With the unit in a cold condition, oil should be filled to half way up the "Oil Level Zone" (approximately 46 to 48 ounces) on the site glass as shown in Figure 17: Oil Level Zone

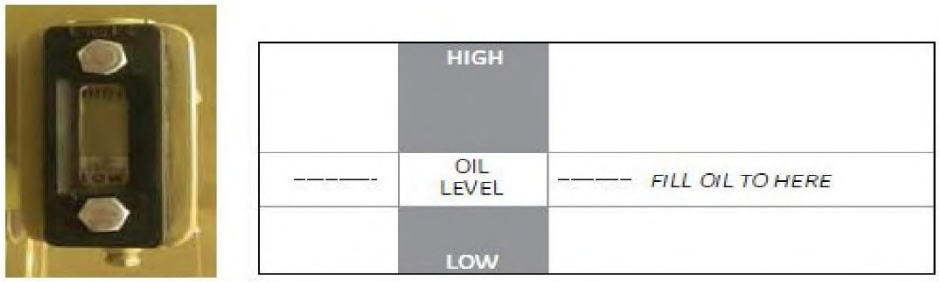


Figure 17: Oil Level Zone

2. Use approved full-synthetic ISO Grade 68 oil only, see Table 2: Recommended Oil Chart: Thrust Chamber
3. Check the oil level after the unit has been running for 30 minutes.
4. The oil level should have stabilized and should not exceed the high mark in the oil level zone in a stopped condition. When operating correctly, there should be a reasonable splashing of oil against the sight glass.

⚠ CAUTION

Under-filling or overfilling the thrust chamber oil will result in elevated run temperatures, which can lead to reduced service life. Under filling will also result in insufficient lubrication and reduced service life.

⚠ NOTE

- When the unit is running in a cold condition and the oil level is at the top of the zone line, the oil level will exceed the oil level zone line until normal operating temperatures are reached.
- Mineral oils of the same viscosity can be substituted under certain conditions, contact Baker Hughes Engineering Department for approval.

Table 2- Recommended oil chart: Thrust chamber

Manufacturer	Oil description
Shell	Morlina S4 B68 (manufacturer preferred)
Texaco	Code 2053 Pinnacle 68
Chevron	Hypr Syn (68)
Mobil/Exxon	Mobil SHC 626 (ISO 68)
Conoco	Syncon Synthetic R&O (ISO 68)

⚠ NOTE

The frequency of oil change for approved non-synthetic mineral oils is every 1,000 hours for SDTC's only. For HDTC's and XDTC's the oil change interval is noted in Table 5: Recommended Lubrication Intervals.

7.3 Motor to thrust chamber coupling

Important Note: Lockout/Tagout must be completed prior to any service. Failure of the main control could allow an unexpected start under scenarios including reenergize after power interruption. The use of Lockout/Tagout will eliminate the potential of the system energizing during service. Site Risk assessments must be completed prior to operations.

Entanglement and trapping hazards are present at the motor coupling area. A protective coupling guard has been designed to prevent access to these dangerous moving parts while the HPump system is running. Do not remove the coupling guard until the Lockout/Tagout procedures have been completed

Follow the coupling manufacturer's recommendations.

7.4 HPump Start-Up

⚠ WARNING

Before starting an HPump unit, consult the motor manufacturer's instructions and follow all their recommendations related to starting the motor. Failure to wear proper personal protection and follow motor manufacturer's directions may result in equipment damage, injury or death.

⚠ NOTE

- The motor startup procedure is only a summary of the commissioning manual. For the complete instructions for motor startup, refer to your HPump field service representative and manufactures manual.
- Generally, noise from HPump units is directly related to motor design and size. Noise levels are typically in the 80 dB to 95 dB range. When required, HPump units are designed for low noise emissions (below 85 dB). These quieter units employ low noise motors, low noise auxiliary systems (e.g., oil coolers, seal systems, etc.), and noise mitigation covers (i.e., sound enclosures).

⚠ CAUTION

Important Notice: If any risk of fire or explosion applies to the operation of the HPump, recommendations and warnings will be included according to the specific ATEX Risk Analysis (if applicable).

1. For a standard duty thrust chamber prior to motor startup:
   a. Before rotating the thrust chamber, remove the two oil ring stems.
   b. Before starting the motor, remove the sight glass on the thrust chamber and use a flashlight to make sure the oil rings are correctly located in their respective grooves on the TC shaft.
   c. Remove bottom section of oil ring stem and re-install threaded top portion.

Figure 18: Thrust Chamber with Oil Ring Stems

2. Open the suction line valve and bleed off all the air inside the lines by filling the pump with fluid and then opening the bleeder valve on top of the pump case at the discharge-end of the unit.
3. Close the valve as soon as the air flowing through the bleeder valve has stopped.
4. If the HPump unit is not equipped with a bleeder valve, a bleeder valve must be installed.
5. Set the discharge line valve open at 30% initially, and then adjust as necessary.
6. If applicable, unlock the power supply to motor and start the charge pump.

⚠ CAUTION

Important Notice: The HPump system is tested prior to delivery to the user to make sure the connections do not leak under pressure. In addition, the assembly and test procedures include specific torque ratings when installing flanges and hoses, and instructions for properly making up tube fitting connections. However, prior to startup it is recommended to perform pre-commissioning

and commissioning reviews in order to verify there are no leaks in the HPump system or customer piping and connections.

7. Jog the motor to check rotation. Correct rotation of the HPump pump is clockwise when standing behind the motor or at the Non-Drive End (NDE).

Do not run sleeve bearing equipped motors at slow speeds for more than 2 seconds; doing so will cause damage to the motor.

8. Correct the motor phase rotation if required.
9. Connect an ammeter to motor leads and start the unit to check motor amps for correct motor full load amps.
10. Check both suction and discharge pressure to confirm unit is operating properly.
11. Measure and record a full set of vibration readings using Baker Hughes Form F-486.
12. Monitor all instruments, including motor temperatures and thrust chamber temperature using a multimeter attached to a thermocouple. Record all parameters on Baker Hughes Forms F-481, F-482, F-483 and F-485 only after the temperature has stabilized.

HPump systems perform at or below the vibration amplitude of 0.156 in./sec (3.96 mm/sec) in 1x frequency as per API RP 11S8.

13. Inspect the pump carefully during the first hour of operation. Make sure to check for leaks at all connections and excessive vibration.
14. Complete and retain a copy of the commissioning report.

8. Maintenance

WARNING

Failure to perform all necessary safety precautions before beginning work may cause damage to equipment, personal injury, or death

Even though some HPump systems are designed with “low noise” equipment (e.g. motor, oil coolers, seal systems, etc.) and their assembly and installation procedures include alignment tasks to reduce vibration and noise levels, there is still some level of noise associated with the normal operation of the system. Therefore, it is always recommended to use hearing protection while the system is running in order to minimize noise hazards.

Important Note: A Lockout tag must be employed prior to any service. Failure of the main control could allow and unexpected start under various scenarios including reenergize after power interruption. The use of Lockout tags and E-stops will eliminate the potential of the operations control system failing under service mode. E-stops as well as control system guidelines are provided according to what is included in the scope of supply of the HPump system. Site Risk assessments must be completed prior to operation.

Entanglement and trapping hazards are present at the motor coupling area. A protective coupling guard has been designed to prevent access to these dangerous moving parts while the HPump system is running. Do not remove the coupling guard until the lockout/tag-out procedures have been accomplished.

CAUTION

Important Notice: When installing, servicing, or removing the HPump system it is possible operators may need to step on the skid. It is recommended to use caution when surfaces are wet because they can become slippery, especially when there are mixed fluids like grease, oil, and water.

Important Notice: Lifting equipment must be sized appropriately for the equipment being lifted and inspected prior to use. A site Job Safety Analysis (JSA) should be performed to make sure the proper sized equipment is being used.

8.1 Preventive and corrective maintenance

There are some components in the HPump such as the thrust chamber that could be operating at temperatures above 70˚C (158˚F). As a way to reduce the chance of touching the hot surface, certain units have warning labels attached to the equipment, which remind the operators to wait until surfaces are cool before servicing the system.

Important Notice: Make sure to read the MSDS of the fluids used for lubrication before attempting to work with them. Always consult with your supervisor if you have any questions.

Coolant lines and thrust chamber can be hot and cause burns.

Lubrication requirements for the motor, coupling, and thrust chamber are shown in Table 3: Recommended Lubrication Intervals, page 32.

Table 3- Recommended lubrication intervals

Part	Lubrication Intervals	Recommended oil
Main motor— Anti friction bearing	Replenish motor grease every 3 months or every 2,000 hours of operation or as recommended by the motor manufacturer's OEM	Refer to the motor or manufacture's recommended grease (usually found on name plate).
Main motor— Sleeve bearing	Replenish motor oil as recommended by the motor manufacturer's OEM.	Refer to the motor manufacture's recommended oil (usually found on name plate).
Lube oil motor— Anti-Friction bearing	Sealed bearing—no maintenance required	
Coupling—Grid type (lubricated)	Replenish coupling grease as needed or as required every 12 months or every 8,760 hours of operation if required. (Refer to coupling manual).	Requires Shell Alvania CG grease or Falk LTG grease
Coupling—Spacer type (Metal Flex)	No maintenance required	
Thrust chamber— Standard duty	Change every 3 months or every 2,200 hours of operation (slinger rings). Analysis every 3 months, replace at least once a year (oil injection)	Requires Shell Morlina S4 B68 synthetic oil or equivalent.
Thrust chamber— Heavy duty	Analysis every 3 months, replace at least once a year	Requires Shell Morlina S4 B68 synthetic oil or equivalent.
Thrust chamber— Extreme duty	Analysis every 3 months, replace at least once a year	Requires Shell Morlina S4 B68 synthetic oil or equivalent.
Thrust chamber cooler filter (if equipped)	Replace every 6 months	

8.2 Recommended maintenance schedules

HPump units are designed for years of trouble-free operation. There are no V-belts or packings to service. Routine maintenance consists of a quarterly lubricant change and component checks. To help keep your HPump unit operating properly, Table 4: Recommended/Minimum Maintenance Schedule, page 33 lists the 15 recommended maintenance tasks that should be performed regularly.

NOTE

- *The HPump unit should be running while performing tasks one through three.*
- *The HPump unit should be shut down and lock out/tag out procedures completed for the remaining tasks.*

Table 4- Recommended/Minimum maintenance schedule

Task	Task description	Daily	Monthly	Quarterly	Semiannual	Annually
1	While the HPump unit is operating, listen and feel for changes in sound and vibration level.			X		
2	Perform vibration and alignment checks.			X		
3	Verify the shutdown setting has not been changed and instruments are functioning.			X		
4	Inspect suction and discharge connections for leaks.			X		
5	Inspect the thrust chamber for leaks.			X		
6	Inspect the mechanical seal for leaks.			X		
7	If the HPump unit is equipped with a thrust chamber cooling system, inspect the cooling system for leaks and clean the radiator.			X		

Table 4- Recommended/Minimum maintenance schedule (continued)

Task	Task description	Daily	Monthly	Quarterly	Semiannual	Annually
8	If the HPump unit is equipped with a thrust chamber cooling system, replace the oil in the oil cooling system.					X
9	Standard duty thrust chamber (slinger rings)—Check the thrust chamber and thrust chamber cooling system oil levels.			X*		
10	Standard duty thrust chamber (oil injection)—Check the thrust chamber and thrust chamber cooling system oil levels and perform oil cooling system oil analysis.			X		
11	Heavy duty and extreme duty thrust chambers—Check the thrust chamber and thrust chamber cooling system oil levels and perform oil cooling system oil analysis.			X		
12	If the HPump unit is equipped with electric motor bearings lubricated with oil, change the oil.	Follow manufacturers recommendations.				
13	Inspect the frame for damage due to external forces.			X		
14	Inspect the HPump unit for cleanliness especially the electric motorfins, thrust chamber, and mechanical seal.			X		
15	If the electric motor bearings are lubricated with grease, lubricate the bearings in accordance to the specified motor manufacture recommendations.	Follow manufacturers recommendations.				

Table 4- Recommended/Minimum maintenance schedule (continued)

Task	Task description	Daily	Monthly	Quarterly	Semiannual	Annually
16	If the HPump unit runs on intermittent duty and the unit does not have a thrust chamber cooling system, change the thrust chamber oil.			X		
17	Change the thrust chamber oil regardless of accessories.				X	
18	If the HPump unit is equipped with a lubricated coupling, inspect the coupling for the grease leaks.			X		
*Or 2,200 hours, whichever occurs first.						

8.3 Recommissioning procedures

The following recommissioning procedures should be performed before any idle HPump unit is placed back into service.

1. Purge the system.
2. Re-plumb Heavy Duty Thrust Chamber (HDTC) and Standard (STD) INJ.
3. Reset thrust chamber oil levels. Refer to Section 6.2 Thrust Chamber Lubrication Thrust Chamber Lubrication, page 36 for more information.
4. If applicable, remove heater blankets.
5. Follow standard start up procedures. Refer to Section 6.4 HPump Start-up, page 39 for more information.

8.4 HPump installation and service report

A field service report should be started before any work is done on an HPump unit. This will help maintain a good service record and act as a reminder for commissioning and maintenance steps performed on the unit.

9. Storage procedures

9.1 New pump storage procedures

Failure to perform all necessary safety precautions before beginning work may cause damage to equipment, personal injury or death.

9.1.1 Short-term storage procedures (0 to 90 Days)

1. Partial fill with 75%/25% glycol/water mixture standard from factory.
2. Energize space heaters.
3. On units equipped with a standard thrust chamber (SDTC), remove the shipping stems and install short bolts and washers located in the junction box. Retain the shipping stems for future shipment.

Do not throw the shipping stems away. If the unit has to be transported to another location, these stems will have to be reinstalled before shipping. Shipping the unit without the shipping stems will damage the equipment.

4. Rotate the pump/motor monthly (10 revolutions) making sure the pump spins freely.
5. Make sure proper oil levels are maintained in the thrust chamber. Refer to Section 7.2 Thrust Chamber, page 26 for more information.
6. Follow motor manufacturer's requirements related to short-term storage.
7. Protect the system from freezing.

9.1.2 Long-term storage procedures (Over 90 days)

In addition to all short-term procedures, the following steps should be completed when storing an HPump unit for more than 90 days.

1. Fill thrust chamber with proper specified oil levels. Refer to Section 7.2 Thrust Chamber Lubrication, page 26 for more information.
   a. For standard-duty thrust chamber (SDTC):
      i. Fill oil level no lower than the middle of the ball bearings and no higher than the bottom of the inner race on the 7315 ball bearings.
      ii. Remove the sight glass and spray the inside of the thrust chamber with Morlina S4 B68 oil.
      iii. Replace sight glass taking care not to damage gasket.
      iv. Oil leaks may result if overfilled.
   b. For heavy-duty thrust chamber (HDTC) and Oil Injected SDTC:
      i. Remove oil return line from the bottom of the thrust chamber and plug (typically 1-1/4-in. NPT).
      ii. Fill oil level no lower than the middle of the ball bearings and no higher than the bottom of the inner race on the 7315 ball bearing. Refer to Section 7.2 Thrust Chamber Lubrication, page 26 for more information.
      iii. Remove the sight glass and spray the inside of the thrust chamber with Morlina S4 B68.
      iv. Replace sight glass taking care not to damage the gasket.
      v. Oil leaks may result if overfilled.

vi. If applicable to your installation, energize the immersion heater for thrust chamber reservoir. If an immersion heater is not available, install a heater blanket around the thrust chamber reservoir.

c. For extreme-duty thrust chamber (XDTC) maintain oil fill from factory.

i. Energize the immersion heater for thrust chamber reservoir. If an immersion heater is not available, install a heater blanket around the thrust chamber reservoir.

ii. Follow lube system manufacturer's requirements for long-term storage.

iii. Protect the system from freezing.

9.2 Commissioning

NOTE

The commissioning procedure is only a summary, for the complete instructions for commissioning refer to HPump Form F-480.

1. Purge the thrust chamber oil system.
2. Re-plumb the HDTC and SDTC spray mister system if equipped.
3. Reset thrust chamber oil levels. Refer to Section 6.2 Thrust Chamber Lubrication Thrust Chamber Lubrication, page 36 for more information.
4. If present, remove heater blankets.
5. Follow standard startup procedures. Refer to Section 6.4 HPump Start-Up, page 39 for more information.

9.3 Decommissioning

9.3.1 Short-term (0 to 14 Days)

1. Pump must remain flooded with glycol or rust inhibitor.
2. Do not allow air to enter the system.
3. Lock out power supply to motor.
4. Protect the system from freezing.

Important Note: A Lockout tag must be employed prior to any service. Failure of the main control could allow and unexpected start under various scenarios including reenergize after power interruption. The use of Lockout tags and E-stops will eliminate the potential of the operations control system failing under service mode. E-stops as well as control system guidelines are provided according to what is included in the scope of supply of the HPump system. Site Risk assessments must be completed prior to operation.

9.3.2 Long-term (14 to 90 Days)

1. Isolate pump from the process and purge the system.
2. Flush and fill with 75% glycol.
3. Rotate pump and motor weekly (10 revolutions) making sure pump spins freely.
4. Maintain the proper thrust chamber lube levels. Refer to Section 6.2 Thrust Chamber Lubrication Thrust Chamber Lubrication, page 36 for more information.
5. Lock out power supply to motor.
6. Follow manufacturer's recommended long-term storage procedures for the motor.
7. Protect the system from freezing.

Important Note: A Lockout tag must be employed prior to any service. Failure of the main control could allow and unexpected start under various scenarios including reenergize after power interruption. The use of Lockout tags and E-stops will eliminate the potential of the operations control system failing under service mode. E-stops as well as control system guidelines are provided according to what is included in the scope of supply of the HPump system. Site Risk assessments must be completed prior to operation.

9.3.3 Long-term (Over 90 days)

1. Follow all decommissioning procedures in Section 9.3.1 Short-Term (0 to 14 Days), page 39 and Section 9.3.2 Long-Term (14 to 90 Days, page 40.
2. Follow manufacturer's recommended long-term storage procedures for the motor.
3. Protect the system from freezing.

9.4 Recommissioning

1. Purge system.
2. Re-plumb thrust chamber and STD INJ, if applicable.
3. Set thrust chamber oil levels. Refer to Section 7.2 Thrust Chamber Lubrication, page 26 for more information.
4. If applicable to your installation, remove heater blankets.
5. Follow standard startup procedures. Refer to Section 7.4 HPump Start-Up, page 28 for more information.

10. Troubleshooting

Important Note: A Lockout tag must be employed prior to any service. Failure of the main control could allow and unexpected start under various scenarios including reenergize after power interruption. The use of Lockout tags and E-stops will eliminate the potential of the operations control system failing under service mode. E-stops as well as control system guidelines are provided according to what is included in the scope of supply of the HPump system. Site Risk assessments must be completed prior to operation.

Important Notice: Make sure to read the MSDS of the fluids used for lubrication before attempting to work with them. Always consult with your supervisor if you have any questions.

10.1 Basics of troubleshooting

10.1.1 General troubleshooting

Much of the work performed by technicians involves the maintenance and repair of equipment and systems. Technicians must have a good knowledge of what is commonly referred to as troubleshooting to make sure the equipment and systems operate at their peak performance.

Troubleshooting is the ability to determine the root cause of the problem and finding the solution to correct it. Troubleshooting covers a wide range of problems from the standard oil changes, finding a short circuit or tracing a defect in a complex HPump system. The same basic principles are used in all cases. Troubleshooting requires a technician with a thorough knowledge of electrical, hydraulic, and mechanical theory combined with a systematic and methodical approach to find and correct a problem.

10.1.2 Basics of Troubleshooting

The following general principles and tips will help with the troubleshooting process:

- Think before acting.
- Thoroughly study the symptoms of the problem and ask the following questions: – Were there warning signs preceding the trouble?

– Were there any previous repairs or maintenance performed?

– Is the unit or component still operational and is it safe to continue operation before further testing?

- Answers to these questions can be obtained by the following:

– Question the owner or operator of the equipment.

– Take the time to think the problem through.

– Look for additional symptoms.

– Consult troubleshooting tables in this section.

– Check the simple things first.

– Refer to the repair and maintenance records.

– Always use calibrated instruments.

10.1.3 Find and correct the problem

The source of a problem cannot always be traced back to a single component alone but to the relationship of that component and its interaction with other components of the system. Make sure all symptoms have been checked to prevent unnecessary work. There could be an easy solution to the problem that will prevent a major tear down.

Use the troubleshooting tables provided in this manual to help diagnose problems that may occur. Remember there are many variations and solutions that can occur. It is suggested a strict preventive and corrective maintenance schedule is followed and recorded to help with the diagnosis of possible problems.

After the symptoms of the problem have been thoroughly investigated, make sure to correct the cause of the problem to prevent repeated failures.

10.2 Troubleshooting: Symptoms, categorized by component

Table 5: Pump Symptoms, page 42 through Table 11: Motor Coupling Symptoms, page 44 outline possible symptoms to investigate. The possible causes are coded and listed in Table 11: Causes, Comments and Remedies, page 46.

Table 5: Pump symptoms

Pump symptoms	Possible causes
Vibration	C, PP, S, DD, GG, F, U
Noise	C, PP, DD
Change in performance (pressure, flow rate)	PP, C, DD, E, V, JJ, P
High housing temperature (too hot to touch)	D, DD
Locked rotor	L, HH, DD
Leak	CC, J, F, EE, Q

Table 6: Thrust chamber symptoms

Thrust chamber symptoms	Possible causes
Over temperature (measured by thrust chamber thermocouple, more than a 110° F rise over ambient temperature)	C, PP, S, DD, GG, F, U
Noise	C, PP, DD
Change in performance (pressure, flow rate)	PP, C, DD, E, V, JJ, P
High housing temperature (too hot to touch)	D, DD
Locked rotor	L, HH, DD
Leak	CC, J, F, EE, Q

Table 7: Motor symptoms

Motor symptoms	Possible causes
Vibration	OO, S, U, Q
Windings over temperature (if equipped with temperature detector), motor running above nameplate amperage	FF, DD, PP
Vibration	B, N, T

Table 8: Suction chamber/Intake symptoms

Suction chamber/Intake symptoms	Possible causes
Leak	R, CC, F
Noise	K, Also refer to pump section
Vibration	Refer to pump and thrust chamber sections

Table 9: Instrumentation symptoms

Instrumentation symptoms	Possible causes
Shutdown on high discharge pressure	E, LL, MM, K
Shutdown on low discharge pressure	E, M, V, O, P, QQ
Shutdown on high suction pressure	E, MM, LL
Shutdown on low suction pressure	E, O, V, M, P, QQ
Shutdown on high vibration	qq, Refer to motor, thrust chamber, and pump sections
NOTE: Also verify all settings on switches are correct.	

Table 10: Motor coupling symptoms

Motor coupling symptoms	Possible causes
Leak	CC, J, G, Q
Noise	S, Q, H, I

10.3 Troubleshooting: Causes, comments, and remedies

Table 11: Causes, comments and remedies

Code letter	Cause	Comment	Remedy
A	Bearing cages melted.	Typically black plastic particles will be found in the lubricant. Check also for items 1, 3, and 6 under thrust chamber section.	Replace thrust chamber.
B	Bearings are worn.	Refers to rolling element bearings in the motor and thrust chamber.	Replace thrust chamber or service motor (depending on where the problem is).
C	Cavitations.	Typically identified by noise near the pump base. Impeller vanes are processing a mixture of gas/liquid.	Increase suction pressure until the problem goes away.
D	Choke/discharge valve closed.	This can destroy a pump quickly.	Set the valve properly.
E	Choke/discharge valve not properly set.		Set the valve properly.
F	Corrosion.	This can occur in the pump head/base, the pump housing, the pump stages, and the intake parts.	Replace corroded components if possible.
G	Coupling grease plug missing.	Check for coupling wear	Install grease plug.
H	Coupling is worn.	Typically wear can be seen in the coupling gears and steel grid (if it is a flexible type coupling).	Replace coupling.
I	Coupling lacks grease.	Also check for wear.	Replace coupling if worn, otherwise re-grease coupling.
J	Flange gasket failure.	If it is a motor coupling leak, check also for coupling wear.	Replace gasket.
K	Foreign objects stuck in flow path.		Clear flow path
L	Frozen pump		Heat up the pump until it is able to turn

Table 11: Causes, comments and remedies (continued)

Code letter	Cause	Comment	Remedy
M	Insufficient discharge line back-pressure.		To be decided by customer, typically a valve can be adjusted.
N	Insufficient motor bearing grease.		Re-grease, if symptom still exists have motor serviced.
O	Insufficient suction line pressure.		Increase suction line pressure.
P	Leak in pipe work.		Fix leaks.
Q	Loose screws or bolts		Tighten applicable screws, bolts.
R	Mechanical seal failure.		Replace seal.
S	Misalignment.	Will see high (greater than 1X amplitude) 2X vibration, 2 critical points are between the pump base and intake, and between the motor and thrust chamber.	Check motor for soft foot condition, check alignment, make adjustments as necessary.
T	Motor bearing grease needs changing.		Re-grease, if symptom still exists have motor serviced.
U	Motor rotor unbalance.	Motor 1X vibration on the bearing housings in the radial direction more than 0.2 in./sec peak.	Have motor serviced
V	No flow to pump.	Check for pump vibration and for mechanical seal leaks after the problem is fixed.	Verify proper flow to pump.
W	Oil is emulsified.		Change oil.
X	Oil level too high.	Check for foreign particles in existing oil. Change thrust chamber if necessary.	Fill thrust chamber at proper oil level. Refer to Section 7.2 Thrust Chamber Lubrication, page 26 for more information.

Table 11: Causes, comments and remedies (continued)

Code letter	Cause	Comment	Remedy
Y	Oil level too low.	Check for noise and for foreign particles in existing oil. Change thrust chamber if necessary.	Fill thrust chamber at proper oil level. Refer to Section 7.2 Thrust Chamber Lubrication, page 26 for more information.
Z	Oil needs to be changed.		Fill thrust chamber at proper oil level. Refer to Section 7.2 Thrust Chamber Lubrication, page 26 for more information.
AA	Oil-ring stems not properly set.	Check for foreign particles in existing oil. Change thrust chamber if necessary.	Set stems properly.
BB	Oil seal failure.		Replace oil seal.
CC	O-ring failure.		Replace O-ring.
DD	Plugged pump.		Consult factory.
EE	Pump housing over pressure.	Pump discharge pressure equals housing pressure (see technical catalog for housing pressure limit).	Lower pump discharge pressure immediately, consult factory.
FF	Pump is not operating at proper point.		Make adjustments (speed, valve) to get the pump operating properly.
GG	Resonance.	Vibration will be maximum at a certain speed (can check, if equipped with variable speed drive).	Consult factory.
HH	Rusted pump.	Occurs when pump has been idle for more than several months.	Consult factory.
II	Sight glass not tight.	Also check oil level.	Tighten sight glass.
JJ	Speed change.	Applicable to units run on variable speed drives.	Determine why speed was changed.
KK	Thrust chamber ball valve not closed.		Close valve.

Table 11: Causes, comments and remedies (continued)

Code letter	Cause	Comment	Remedy
LL	Too much discharge line back-pressure.		See remedy for “m”.
MM	Too much suction line pressure.		See remedy for “m”.
NN	Too much thrust.		See “ff”.
OO	Unbalanced phase voltages.	Determine if the problem is in the supply line or in the motor.	Correcting a problem in the motor requires motor to be serviced.
PP	Worn pump.	Increasing vibration trend (primarily in 1X) with reduction in performance.	Consult factory.
QQ	Time delay relay on control panel not properly set.	Unit may not start due to low suction and discharge pressure, and high vibration at the start. Time delay relay is needed to bypass the switches at the startup.	Set time delay relay properly.