Remanufactured Process for Pipeline and Centrifugal Pumps

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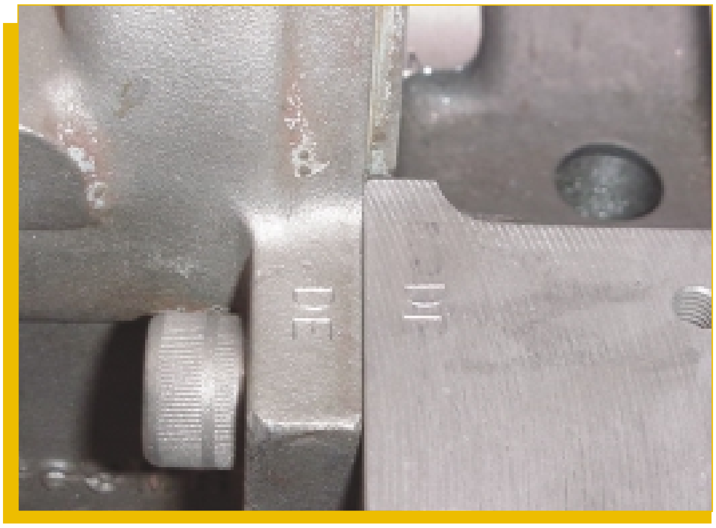
In today's competitive economy, it is more important than ever to get new pump installations up and producing as soon as possible. It doesn't matter if it's a 4 kW (5 hp) single stage unit or a 2250 kW (3000 hp) high-speed multistage unit, a remanufactured pump can help achieve a fast turnaround. Many people do not understand the meaning of remanufacturing. It is one of those "buzzwords" we hear today when people talk about repairing pumps. But, do not be confused; remanufacturing a pump is not the same as repairing a pump. To many people, a remanufactured pump is nothing more than a repaired, used piece of equipment with a new coat of paint. If you refer to the dictionary, the term "remanufacture" is defined as "to manufacture (as produced or used material) into a new product". The term "repair" is defined as "to restore by replacing a part or putting together what is torn or broken".



The parts shown have been carefully match marked during the disassembly process to ensure a mismatch does not occur during the final assembly of the pump.

During the inspection process some erosion was found near the suction nozzle. This case will be weld-repaired, stress-relieved and an NDE performed to test the integrity has been restored.

Within the remanufacturing process, repairs are commonly made to renew certain parts, but the overall process is very comprehensive and involves much more than just repair or replacing parts. The remanufacturing process addresses all aspects of the pump, including materials of construction, internal fits, internal running clearances, and mechanical and hydraulic design. The challenge in the remanufacturing process is to manufacture a pump from a used or surplus piece of equipment that will meet or exceed the mechanical, hydraulic and service life requirements of the end user.

Two major benefits from using remanufactured pumps are the utilization of existing pump resources no longer required in the original services and reduced lead-time. The purchasing, inspection, and machining of major pump castings can take 8 to 10 weeks or longer after an order is issued. A side benefit of the utilization of existing resources is the obvious contribution to the recycling effort.

This paper presents and discusses each step of the centrifugal pump remanufacturing process required to meet the challenging needs of industry today.

The process

Remanufacturing begins with a used or new surplus pump and an order to produce a pump to meet specific requirements. The pump may be a piece of equipment the purchaser currently owns or it may have been selected from a vendor's inventory. The intended service may be either a new or an existing service; the actual fluid to be pumped can range from cold water to a hot hydrocarbon.

The remanufacturing work scope is a function of the service requirements, existing pump construction, and existing condition of the pump. Some pumps, such as some new surplus pumps, may require only minor effort to restore to "as new" condition. Other pumps that have been in service for some time may have only major components such as the case that can be salvaged. Regardless of the initial condition of the pump selected for the new service, the objective of the remanufacturing process is to provide a reliable product that will meet or exceed the mechanical, hydraulic, metallurgical, construction and delivery requirements of the end user.

Disassembly

Commonly, people consider the disassembly process as the simple task of taking a pump apart. In fact, it is a very important and critical step to the remanufacturing process. The disassembly process includes the collection of important information that will be used to ensure that the pump selected is correct for the intended service. During this process, rigorous procedures must be followed to avoid damage to components that may be used in the manufacture of the new pump. As required, mating parts are match-marked and gaskets, seals, and o-rings are collected for size identification during later steps. Initially the following list of items are checked and documented for selection verification:

- Pump Type
- Pump Size
- Pump Model
- Number of Stages
- Suction and Discharge Nozzle Sizes and Types
- Pump Rotation
- Basic Outline Dimensions
- Original Rated Condition
- PMI (Positive Material Identification) of Major Components

Pump type, size, model, number of stages, and nozzle configuration are compared with pump data records and order requirements. Pump rotation requirements are checked and, if incorrect for the new application, the need for a new shaft or other components is identified. Basic outline dimensions are used by Engineering to develop outline drawing(s). The original rated conditions, if available, are used by Engineering during the hydraulic design evaluation process. After the pump has been partially dismantled and the rotating element is exposed, a positive material identification (PMI) test is performed on the major components to confirm existing construction.

After the initial inspection, the pump is completely dismantled for cleaning. A variety of cleaning processes are used, such as sand blasting, bead blasting, high-pressure wash, and solvents. Extreme care must be taken to avoid damage to components that may be used in manufacturing the new pump.

Inspection

After disassembly and cleaning, the inspection process begins. Critical dimensions are inspected for size, concentricity, and overall condition and all information is documented in a "Disassembly Inspection Report". Critical areas for inspection are outlined below. Note that not all of the areas addressed are applicable to all pumps.

This case has been planed and bored and is in final inspection. Each volute throat area has been inspected and ground to match a template provided by engineering.

Case/Barrel

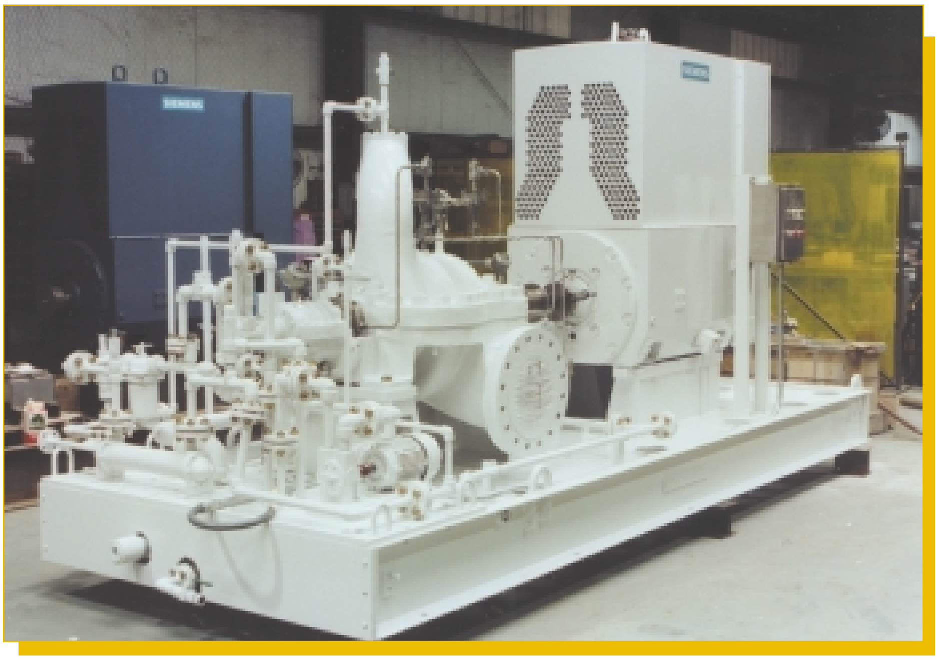
In general, all critical surfaces and pilot fits (bores and turns) are checked for signs of corrosion/erosion and other forms of damage. Critical component pilot bores, turns and faces are dimensionally inspected in both horizontal and vertical planes. Split-line surfaces, such as the mating surfaces on axially split case pumps are inspected for distortion and surface finish. Mounting holes and feet are checked for any damage that may have occurred during service or removal from service. Case volute cavities and cutwaters are visually inspected for signs of erosion and/or corrosion. Suction and discharge nozzle flange and sealing surfaces are inspected and any damage, no matter how minor, is documented. Threads in all tapped holes and ports are "chased", cleaned, and inspected, and any damage observed is documented for repair. Seal chambers (or stuffing boxes) are checked relative to mechanical seal (or packing) requirements; any modifications required to the existing case are documented.

A case may need to be replaned and rebored if:

- Any corrosion/erosion is found in the pilot bores
- Pilot bore dimensions are out of tolerance
- Excessive split line surface distortion is measured
- Split line surface corrosion/ erosion has occurred.

Impeller

The impeller outer diameter, wear ring diameter(s), and shaft bore(s) are dimensionally inspected and documented. Any damage in the impeller eye (inlet), vane passages, and on the hub faces or shroud walls will be noted for engineering review. The



River water transfer pump for Syrian installation. PumpWorks remanufactured Ingersoll-Rand 8PH-2 two-stage 316 SS pumps packaged with 600 hp motors, Sleeve/Kingsbury thrust bearings and force feed lube oil system. Unit remanufactured, tested and shipped in 14 weeks.

Crude service pump for a Romanian refinery. PumpWorks remanufactured Pacific API 610 4x15 pump with Lufkin speed increaser, Plan K cooling water piping, 6000V/3/50 European specification motor drive. Unit remanufactured, tested and shipped in 12 weeks.

number of vanes and pattern number, if present and legible, will also be documented in the report for use during the hydraulic design evaluation. An impeller may not be suitable for reuse for a number of reasons:

- Incorrect metallurgy
- Incorrect hydraulics
- Excessive corrosion/erosion damage that can not be repaired and will result in unacceptable performance
- Cracks that can not be repaired to restore original equipment integrity

Shaft

Run-out values over the entire length of the shaft and diameter measurements at each critical component location are documented. A shaft may not be reused for a number of reasons:

- Metallurgy is incorrect for the service
- Incorrect rotation
- Run-out is excessive and irreparable
- Any critical component pilot diameter is galled or scored beyond minor surface damage and is irreparable
- Corrosion and/or erosion is present that affects shaft integrity

Bearing housings

Bearing housing pilot bores are dimensionally inspected in both axial and vertical planes. Case mating surfaces, retainer cover mating surfaces, split line surfaces, and cooling chambers/tubes are all inspected and the condition documented. Threaded holes/ports are "chased", cleaned, and inspected to be sure the threads are not damaged. Oil Rings, deflectors, oil slingers, and any other items associated with the bearing housings are inspected and their condition noted.

A bearing housing may not be reused for a number of reasons:

- Incorrect metallurgy
- Incorrect housing design
- Irreparable damage

Bearings

Rolling element bearings are NOT reused; they are always replaced because internal damage is too difficult to determine. Sleeve journal bearings and hydrodynamic (tilting pad type) thrust bearings (sometimes referred to as "Kingsbury-type bearings" or KTBs), if present, are inspected and the condition documented. Most journal and tilting-pad thrust bearings are reparable, but they may be replaced if any of the following conditions exist:

- Journal bearing shell concentricity is out of tolerance
- Journal bearing shell is damaged and irreparable
- Thrust collar is damaged and irreparable
- Thrust pad carrier plates are damaged

Wear parts

All wear parts are dimensionally and visually inspected and the information documented for engineering review. A wear part may not be reused for a number of reasons, including the following:

- Erosion/corrosion on the critical surfaces
- Excessive wear on critical surfaces
- Incorrect metallurgy
- Incorrect hardness

When the inspection process is completed and all necessary information is documented in the "Disassembly Inspection Report", the report is submitted to Engineering for review. If the case requires planing

The impeller pictured here has cracks in the shroud that are irreparable. As a result this impeller will not be used in the remanufacturing process.

During the preliminary inspection of this bearing housing a piece of the support was found to be broken off requiring the housing to be replaced.

Single stage casing being reworked to match impeller for hydraulic rerate.

and boring, a "Case Planing & Boring Worksheet" is prepared and is used as a guide for the machinist that performs the actual work on the case. If the pump is to be equipped with a mechanical seal(s), a seal chamber drawing is prepared and issued to the seal vendor for use in selecting and sizing the seal.

Engineering review

Upon completion of the inspection process, the remanufacturing process requires an engineering review. Engineering uses the disassembly report, case planing and boring worksheet, seal chamber (stuffing box space) drawing, and the order specifications to determine the pump remanufacturing requirements. A meeting is scheduled with Manufacturing to review the inspection results and to visually inspect each component that will be used to remanufacture the pump. During this meeting, necessary repairs are discussed, along with repair options. Parts that will require replacement are identified at this time and replacement orders are initiated. The critical areas of the engineering review are as follows:

Hydraulic design evaluation

The objective of the hydraulic design evaluation is to ensure the impeller and case volute designs are correct for the performance curve submitted in the quotation. Since the rated condition is guaranteed, it is imperative the hydraulics are correct. Although some of the pumps are equipped with nameplates that show the model number of the pump, there is no guarantee the original impellers are currently in the pump. Over time many pumps are reconfigured and rerated. The hydraulic evaluation is an important step in the process, especially for pumps that have no nameplate or history information.

To start the evaluation, preliminary impeller design calculations are performed and results are compared with the existing impeller geometry. If the impeller is found to be incorrect for the application, Engineering must evaluate modifications to the impeller geometry to meet the order performance requirements. If the existing impeller cannot be modified to meet the required performance, a new impeller of the correct hydraulic design will be specified. Note that all modifications made to the pump are documented for future interchangeability.

Next the case hydraulics are evaluated. Again, preliminary design calculations are made basis the quoted performance and required impeller design. Results are compared to the actual case dimensions ("throat" area and volute cutwater diameter in volute-type pumps). If the existing throat area is found to be too small, a cutwater trim may be specified to increase the area. If the existing throat area is found to be too large, the volute passage may be redesigned to reduce the area. Crossover and discharge systems are also critical to pump performance.

After the hydraulic design review and action plan have been established, an impeller trim analysis is performed to determine the present impeller diameter will develop the necessary head at the rated flow. An axial thrust analysis is also performed to determine if modifications may be necessary to minimize developed thrust load on the bearings.

If the pump is to be used in a high-speed application, requiring a driver and gearbox, lateral and torsional critical speed analyses will be performed. This will ensure that adequate margins exist between pump operating speeds and any critical speeds.

Pump construction

The disassembly report and the order specifications are used to review the materials of construction and internal clearances. A good reference for internal clearances is the American Petroleum Institute (API) Standard 610 "Centrifugal Pumps for Petroleum, Heavy Duty Chemical and Gas Industry Services." For pumps in boiler feed services, and pumps with wear components of non-galling materials, clearances less than those specified by the API 610 standard are typically used to improve efficiency. The internal clearances specified are a function of the fluid pumped, fluid temperature, and materials of construction. It is important to select clearances that will minimize the internal leakage, but at the same time consider contact between the stationary and rotating wear parts during start up and periods of transient (or unstable) operation.

The required materials of construction are normally determined during the inquiry stage. However, it is the responsibility of Engineering to make sure the materials are correct for the intended service. Materials certified to an industry standard, such as ASTM, should be used for all critical and pressure boundary components. For wear parts, non-galling materials are preferred. If mating wear surfaces are of hardenable materials, such as martensitic stainless steel, these surfaces should have a differential hardness of at least 50 BHN (Brinell hardness number) unless both surfaces have a hardness in excess of 400 BHN.

PumpWorks remanufactured Union MQE coke cutter pump, gearbox, lube system and 3000 hp, 6000 V, 50 Hz motor. Unit remanufactured and shipped in 10 weeks.

Manufacturing routing

After the hydraulic design has been verified, materials of construction have been selected and confirmed, and internal clearances specified, a manufacturing routing is prepared that outlines all aspects of the remanufacturing project including repair requirements, hydrostatic testing, rotating element balancing, and performance testing, if required.

PumpWorks remanufactured Bingham MSD 6X8X11D -10 stage for natural gas liquid, 0.49 spgr. Pipeline application. Unit complete with tandem seals, plan 52, lube oil system and 800 hp motor. Unit shipped in 12 weeks.

In the repair section, the work to be performed on each individual component is outlined along with welding requirements, machining requirements, and any special coating requirements. All raw materials specified are to be certified, with heat treatment. All welding is performed in accordance with a certified weld procedure specification (WPS) by a certified welder. Wear part diameters for each of the rotating and stationary parts are listed and the required internal clearances are noted. All special drilling, tapping, and machining, such as for mechanical seal flush injection ports, bearing and case thermocouples or RTD's, and vibration transducers are defined. In addition, any specified nondestructive examinations (NDE), such as dye penetrant or magnetic particle, are performed as required and results documented.

After the pump case and bearing housing(s) are complete, the case and bearing housing cooling chambers/ cartridges are hydrostatically tested to confirm the integrity of the castings and sealing surfaces. If the pump is a single stage unit, the hydrostatic test pressure will be based on the maximum allowable working pressure of the case. If the pump is a multistage unit, it is standard procedure to base the hydrostatic test pressure on the shut-off (closed discharge) head produced by the impellers at their rated trim diameter plus the maximum suction pressure times 1.5. Alternatively, if specified, the pump case may be hydrostatically tested at the design maximum working pressure times 1.5. However, this is

Examples of some of the more than 1000 used multistage pumps in PumpWorks' inventory.

not usually specified because the standard test is more than adequate to confirm casing and joint integrity and reduces the risk of distortion and damage. The bearing housing cooling chambers, cartridges and other cooling jackets normally are hydrostatically tested at a minimum pressure of 10 bar (150 psig). If a product-cooled system is required, high pressure cooling cartridges may be supplied and tested to the same hydrostatic pressure level as the case.

All major rotating elements are dynamically balanced. API Standard 610, 8th Edition requires dynamic balance to a residual unbalance level of 4W/N, approximately equivalent to ISO 1940 grade G1.0. This level of residual unbalance, although lower than that required by most pumps to ensure operation below the maximum allowable vibration levels of API or other standards, ensure a machine that will not vibrate in service because of rotor imbalance. For critical, usually high-speed applications, alternative balancing techniques are sometimes specified such as stack balancing and residual unbalance checks.

Assembly

The final step in the remanufacturing process is assembly of the pump. This is where all the work converges. Prior to assembly, all critical dimensions are checked and compared with the requirements outlined in the manufacturing routing. Shaft run-out is checked and, as each critical component is mounted on the shaft, run-outs are again checked and documented. After preliminary rotor assembly and balance, the rotor assembly is completed and installed in the case. Throughout the assembly process, critical dimensions are measured and documented in the "Assembly Inspection Report".

Performance testing

To ensure pump performance to predicted and guaranteed levels, a mechanical run test or a full hydraulic and mechanical performance test may be specified. This may also include an NPSH (net positive suction head) test to verify suction performance. The API 610 Standard as well as the Standards of the Hydraulic Institute are good sources for test standards.

A performance test normally consists of 5 or 6 flow points at which head and power data is taken and used to plot curves of total developed head, brake power and efficiency as a function of discharge flow. A mechanical run test is a basic test, typically using the complete unit including the baseplate, motor (assuming the power requirement on water does not exceed the rating of the motor), and coupling to be installed with the pump. During the mechanical run test, only the basic (usually rated) head and flow data is collected and plotted.

An NPSH test, if specified, is normally conducted only in conjunction with a full performance test. Data are usually taken at each flow point except shut-off (closed valve) and is based on a 3 percent drop in developed head (first stage head on multistage pumps) at each flow point. The resulting NPSH required curve is plotted on the pump performance curve as a function of flow rate.

Summary

A properly remanufactured centrifugal pump is not just a repaired pump with a new coat of paint. The result of the remanufacturing process is a precision pump, engineered and manufactured to provide the end user many years of dependable service. Since the remanufacturing process begins with an existing piece of equipment, the case casting and normally the impeller and bearing housing castings are available to avoid delays often associated with purchase, layout, machining, and testing of raw castings. Remanufactured pumps are reliable pieces of machinery that help users complete projects faster and get product flowing sooner. In today's competitive marketplace, this can mean the difference between winning and losing.

George J. Maddox is the Manager of Engineering for PumpWorks located in Tyler, Texas. Mr. Maddox has over 20 years experience in various engineering positions. His current responsibilities include the hydraulic and mechanical design and design evaluations of centrifugal pumps and pump units in the areas of remanufacturing, packaging, and repair.